Report to the Shell Foundation

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Using modern bioenergy to reduce rural poverty

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Executive Summary

The report considers village-scale biomass energy as a means of providing modern energy services to the billions who lack them, thus helping to reduce poverty. It concludes that there are large opportunities for meeting this goal effectively, affordably and sustainably. However, persistent world-wide efforts to develop and improve bioenergy systems will be needed to achieve this goal and to resolve some key problems associated with bioenergy.

Bioenergy has crucial advantages over other energy sources as a tool for poverty reduction in less developed countries (LDCs). Biomass resources are widely available in LDC rural areas, often in large volumes. They can meet energy needs at all times, without expensive storage devices such as batteries, in contrast to solar, wind and other intermittent renewable energy sources. They can deliver all the major forms of energy which people need (liquids, gases, heat and electricity). They can be CO_2 neutral or even act as carbon sinks; and they can help to restore unproductive degraded lands. Most value added from village-scale bioenergy systems is retained locally and helps to reduce poverty – in sharp contrast to fossil fuels and most other renewable energy systems.

These multiple advantages are offset by some generic difficulties. Bioenergy can be very land-intensive; for example, taking over 100 times more land than solar photo-voltaics to produce the same electricity output. Bioenergy supplies are very labour-intensive in most LDC conditions, owing to lack of capital for mechanisation. Most bioenergy projects therefore depend upon large pools of cheap labour. Both these characteristics carry substantial risks of failure as or if population and economic growth drive up land prices, create more profitable forms of land use, and reduce the availability of low-wage labour.

Bioenergy projects are also more complex to initiate and manage than simpler “packaged technologies” such as solar photo-voltaics and wind generators. Biofuels are produced within multi-purpose and competitive land-use and labour systems which form the bedrock of rural economies. These vary greatly from place to place. There are thus no “one size fits all” solutions: bioenergy projects must be tailored to the bio-physical and socio-economic circumstances of each location and must be supported by a great variety of stakeholders.

These problems bear strongly on the first stage of the bioenergy chain: the provision of sufficient, reliable, sustainable and affordable biomass supplies. Places with ample, low-cost “waste” biomass residues avoid most of these problems and are obvious first choices for bioenergy development (other factors equal). However, the larger challenge is to develop modern bioenergy for the majority of LDC locations, where potential biofuel supplies are less abundant and higher cost.

Several supply-side measures can help to meet this challenge. Comprehensive assessments at project and larger scales are needed to determine how much biomass might be available for energy purposes, as supply and market conditions alter. If availability is overestimated, projects could suffer serious supply shortfalls. Supply risk can be reduced by strengthening links between biofuel producers and consumers; increasing biofuel stockpiles; densifying biofuels to reduce transport costs and thus increase the economic supply area; designing conversion plants to accept a greater range of biofuels; and designing the entire bioenergy system to be resilient to rising fuel costs.

In the longer term, the most important issues of bioenergy supply centre on increasing the yield of energy crops (without large increases in fertiliser or water needs) especially on the huge areas of unproductive “marginal” lands in LDCs. Good yields are critical to the

production of low-cost biofuels; the use of marginal lands is critical to the growth of bioenergy into a major energy player.

The choice of the appropriate bioenergy conversion technology involves several techno-economic considerations, including cost, load factor, efficiency, feedstock, scale, and robustness. Despite high willingness-to-pay for energy services, initial cost is an especially important consideration for nearly all users, who routinely reject options that have the lowest life-cycle cost, because they have prohibitively high initial costs. Since low load factors considerably increase cost, energy systems can become much more cost-effective if they can secure a baseload source of demand, such as a local enterprise, irrigation pumping, or sales to the grid. Because efficiency determines the “effective” cost of the biomass resource, efficiency-improving capital expenditures can decrease overall cost of energy services. Scale strongly affects the cost, efficiency, and operating characteristics of a bioenergy system, so it is very important to size a system at the appropriate scale for its application. A final consideration is whether a bioenergy technology is sufficiently robust and mechanically simple to operate in a village setting. Building capacity to meet these needs at the village level can be challenging but is necessary. Mature, proven technologies are more likely to succeed, and attempts to disseminate widely emerging technologies should not be made until after a careful programme of field-testing and capacity building.

A broad consensus is emerging that an important ingredient to poverty reduction is improved access to energy services. These services can satisfy the basic needs of day-to-day family subsistence and also satisfy income generating demands: i.e. help a rural community undertake productive activities that generate wealth or assets. Energy services can relieve some of the unending drudgery that characterises the daily lives of poor families—gathering fuelwood, hauling water, milling grain, and other laborious tasks. Expanded energy services can dramatically improve the health conditions of the poor; for example, by providing potable ground water, replacing wood with cleaner cooking fuels, and providing lighting, refrigeration and other services for health clinics.

Many options for rural enterprises are viable only if there is access to a reliable modern energy source – such as mechanical power, electricity, process heat, or transport fuel. The poor are often able and willing to pay for them when they can invest this increased productive capacity in income-generating activities. For example, electric lighting can add productive hours to the day, process heat can enable farmers to process agricultural output, electric motors can enable people to carry out activities at a commercial scale that would otherwise be simply infeasible such as milling a large amount of grain or irrigating a field. Bioenergy projects can also generate income for rural farmers, many of whom would welcome the opportunity to sell residues or purpose-grown wood to long-term, steady consumers. Since the diffusion of energy-services and an increase in mechanisation do not always benefit rural development, bioenergy activities should be planned carefully to provide energy services that *increase* opportunities for productive activity, rather than *displace* them.

Rural energy practitioners increasingly appreciate that, in order to succeed, energy projects must intimately involve the local community from the very beginning, ensuring their input, interest, support, and investment. Participatory approaches should be adopted to ensure that bioenergy projects provide energy services that address the articulated needs of local people, rather than needs as perceived by well-meaning outsiders. They should take care not to neglect the heterogeneity of the community and its corresponding diversity of perspectives and needs. In particular, the participation of poor community members and women must often be deliberately sought.

In most countries, the private sector is likely to be an essential element of efforts to deploy bioenergy widely, particularly for manufacturing, marketing, financing, installing, operating, and maintaining systems. Commercial enterprises can accumulate experience and knowledge, innovate, obtain access to capital (either debt or equity), introduce an entrepreneurial energy, and operate efficiently. Despite these advantages, the private sector's capacity for delivering energy services to rural areas is severely limited if it responds only to demand that is backed by purchasing power. Public sector involvement might be needed, for example through the granting of energy concessions, public-private partnerships, subsidies, etc., to reach people that the private sector ignores.

Financing can be critically important because initial cost is frequently an overwhelming barrier. In many developing regions, financial markets are undeveloped and capital is chronically scarce, so financial choices are often made using extremely high effective discount rates. Many different financing models have been pioneered to address this problem, including supplier financing, third-party financing, leasing, and fee-for-service.

The broad policy environment can strongly affect the feasibility of a bioenergy activity. Regulatory measures that allow village-scale bioenergy systems to "export" electricity to the electrical grid can make them much more attractive economically. Energy sector subsidies strongly affect the attractiveness of bioenergy options. Too often, subsidies are distortionary, poorly targeted, and unsustainably expensive, creating a barrier to rational energy choices. Well-designed subsidies tend to be based on performance, provide flexibility, are suitably long-term but not permanent, encourage private sector entrepreneurship, and are carefully targeted at the intended beneficiaries. Energy markets can also become more efficient if they properly account for externalities – both positive and negative – such as environmental costs of fuel supply and use, and market-transforming impacts of technological learning.

Land tenure policies are at the core of sustainable agronomic practices, including bioenergy feedstock production. In many areas perverse land tenure and usufruct arrangements remove incentives for sustainable practices and discourages long-term investments. An emerging solution is to involve local communities in land management by radically expanding their rights with respect to the land. Bioenergy activities can take a similar approach by adopting equitable and secure land tenure arrangements.

Because bioenergy technologies are often more technically sophisticated and socio-economically complex than conventional alternatives, demands on local capacity are higher. A broad spectrum of capacities is needed to acquire the necessary information, conduct techno-economic analysis, design a biomass energy initiative, organise communities, and mobilise the necessary actors to design, manufacture, market, and finance the required technologies, provide quality control and service, and promote appropriate policies. Building this technological, entrepreneurial, and policy-making capacity is an extensive process, involving educational initiatives, public outreach, and training for prospective entrepreneurs and policy-makers.

With capacity building and assistance, development experts and rural communities could be empowered to design and implement bioenergy options in ways that provide energy services that contribute to income-generating activities and rural livelihoods. This will require careful attention to the organisational structures for supplying biomass feedstocks and for delivering energy services, so as to distribute poverty-reducing benefits equitably to the community.

1 Introduction

Biomass energy is remarkably heterogeneous. It encompasses industrial-scale plantations and hand-gathered weeds; long distance trucking of charcoal and headloading firewood bundles; 30 MW gas turbines and 3-stone cooking fires. This paper cuts through this diversity by focusing on smaller-scale systems for providing modern energy services to rural households, farms, and enterprises with the aim of increasing welfare and reducing poverty. While large-scale bioenergy systems can also improve rural livelihoods, their impact is usually indirect or limited to rural job creation. In contrast, smaller-scale systems – of up to say 500 kW capacity, enough to energise a village containing some small commercial or industrial enterprises – can meet the goal of poverty reduction directly and effectively[1].

Modern biomass energy is well-suited to this objective. World-wide interest in modern bioenergy is based on its major generic advantages compared to fossil fuels and other renewable energy sources. Some of these advantages are particularly relevant to the use of bioenergy as a tool for poverty reduction in less developed countries (LDCs):

- Biomass fuels are more widely available than fossil fuels and most other renewable energy sources. They are found wherever trees and food are grown and food and fibre are processed; i.e. in nearly all inhabited rural areas.
- Biomass fuels are stored energy which can be drawn on at any time to provide needed energy services. In this respect they are like fossil fuels but differs markedly from most other renewable energy sources such as solar, wind and hydropower, with their nightly, seasonal or sporadic supply shut-downs. Biofuels require no expensive storage devices, such as batteries.
- Bioenergy systems can provide all the major energy carriers (liquids, gases, heat, electricity). They can therefore meet the two main needs of rural energy users: replacing traditional biomass cooking fuels with clean, smokeless, efficient and easily-controlled liquid and gas alternatives, and delivering the modern fuels, heat and electricity which are needed to underpin rural modernisation and growth. Moreover, well-organised systems can provide these energy carriers whenever they are required, avoiding the hardship brought about by the severe and frequent disruptions to conventional electricity, bottled gas or kerosene supplies that afflict many rural areas of the developing world.
- Bioenergy systems have substantial economies of scale. They are therefore well-suited to village-scale supply (e.g. via mini-grids) and to system expansion.
- So long as biofuel supply does not "mine" biomass resources – a necessary condition for project sustainability – bioenergy is climate friendly because it is CO2 neutral. Well-designed energy crops can restore otherwise unproductive degraded lands (though normally at considerable cost).
- Most of the value added from village-scale bioenergy projects is retained locally and contributes to poverty reduction, in contrast to the use of fossil fuels and most renewable energy technologies.
- Finally, as with all renewable energy sources, bioenergy helps the national economy by reducing fossil fuel imports and their foreign exchange costs.

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[1] Our focus on modern energy services and poverty reduction means that the huge problems and opportunities presented by the use of traditional biomass fuels for cooking and heating are beyond the scope of this report. They are mentioned but are not addressed in depth.

These multiple advantages are offset by some generic difficulties of most bioenergy systems. First, bioenergy is very land-intensive wherever dedicated energy crops are needed to provide adequate biofuel supplies. For example, a PV system covering one hectare of a reasonably sunny tropical site, can deliver around 2,400 MWh of electricity per year. With biomass one might reasonably expect an electrical output of about 20 MWh from each hectare committed to growing biomass for power generation – 120 times less than the PV system[2].

Second, most biomass supplies are very labour-intensive wherever capital is lacking for extensive mechanisation; i.e. in most LDC rural areas. It follows that bioenergy systems in LDCs typically depend on the availability of cheap labour. In many places, wages for commercial biomass production are as little as $US1-2 per day and labour productivities are as low as 1-3 GJ of biomass feedstock per workday (see Table 2).

While both these characteristics are often said to give a comparative advantage to LDCs for bioenergy development, they also carry substantial risks of failure as or if population and economic growth drive up land prices, create more profitable forms of land use, and reduce the availability of low-wage labour. High labour costs for wood-charcoal in 17th century England helped launch the Industrial Revolution as iron makers switched from charcoal to coal and coke with their lower labour costs (Rackham 1986).

Third, and most importantly, biomass energy is a uniquely complex renewable energy source. Biofuels must be produced as part of multi-purpose and competitive land-use and labour systems which form the bedrock of rural economies. These systems are often characterised by inequitable access to land, biomass and other productive assets. They also vary greatly from place to place. Although some places have plentiful biomass for all users, competition for biomass between alternative uses – from essential “survival needs” for household cooking to a large variety of non-fuel uses (especially animal fodder and construction materials) – is the norm and the appropriation of crucial biomass resources from vulnerable users is common.

This complexity and diversity have profound effects on the choice, design and management of bioenergy projects. There are no “one size fits all” solutions. Every project must be tailored to the bio-physical and socio-economic circumstances of its location. Furthermore, compared to other kinds of energy project, bioenergy projects need to involve a greater variety of stakeholders who must be consulted and integrated into the project – especially local farmers and other biomass producers. Packaged technologies such as solar photo-voltaics and wind generators are simplicity itself in comparison, a fact which may do much to explain why donors and private investors seem to prefer them.

All these difficulties can be eased or removed by good bioenergy system design; that is, by sound approaches (singly or together) to the four building blocks of any bioenergy systems: biofuel supply, biofuel-energy conversion technology, delivery of energy services to improve welfare or to energise income-earning enterprises, and the overarching institutional framework for the system, including ownership, organisation and financing. These building blocks provide the outline structure of the report.

In summary, these potential advantages and resolvable difficulties combine to make a powerful case for mounting intense world-wide efforts to develop and improve bioenergy systems, especially as an effective, affordable and sustainable approach to poverty reduction.

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[2] For PV the assumptions are 2,000 kWh of sunlight annually per square metre, the solar collectors cover 80% of the total site area, and 15% conversion efficiency to electricity. For biomass we assume annual production of 15 dry tonnes of biomass per hectare, 19.2 GJ per dry tonne (lower heat value) and conversion to electricity at 25% (the high end of small-scale power technologies).

2 Biomass Supplies

Bioenergy systems require sufficient, reliable, sustainable, and affordable biomass supplies. These supplies must be grown, harvested, gathered, and transported to the energy conversion plant. They must usually be stored and perhaps dried to avoid deterioration. In many cases the biomass must be chopped, pelletised or otherwise prepared for use as a biofuel.

These supply-side activities set bioenergy apart from other renewables, in which the primary solar, wind, wave or hydro energy resource is freely-provided. Bioenergy requires the additional steps of fuel production, collection and delivery to the energy conversion plant, such as a gasifier or biogas digester. While these steps can bring substantial benefits in the form of local employment and income (benefits which have, of course, to be paid for by energy users) they may also raise serious problems which do not apply to other energy resources. These may occur because biofuel supply and use is embedded in the production and use of all forms of biomass, which are in turn embedded in socio-political relations concerning the control of land, water, labour and other basic rural resources.

These underlying circumstances vary hugely from place to place and are usually complex, obscure, and dynamic, changing as political, economic and social conditions alter. They govern to a large extent how much and what kinds of bioenergy resource can be produced, the cost of production and associated benefits, vulnerability to supply failure, and risks of harming existing biomass-dependent social groups. They often impose constraints that render biomass supplies for energy much more limited than a straightforward technical biomass assessment might suggest. This section reviews these and other principal supply-side issues and ways in which inherent problems might be addressed by good biomass resource assessments, bioenergy project design and project management.

2.1 Low cost supplies

There are many kinds of biofuel, each with a large range of acquisition costs (see Table 1). At one extreme is the lowest-cost class of residues: the by-products of crop production or biomass-based industries which arise in concentrated form, close to the energy conversion plant, with dependable regularity. Examples include animal wastes from stalled livestock; harvested crop straws and stalks; and agro-industrial processing residues such as sugarcane bagasse, rice husks and coconut shells and husks. Wastes may be dry and suitable for direct combustion and thermal gasification (‘gasifiers’); or wet and suited to anaerobic fermentation (‘biogas’).

If these residues have no competing economic uses (see section 2.3) their financial cost as a bioenergy feedstock is usually very low – or even negative when disposal costs are avoided. Their economic cost can be even lower, if traditional disposal routes cause problems such as air pollution. (Some countries, including Egypt, Brazil, and China have moved to reduce residue burning because of the severe air pollution problems it can cause). These resources are the obvious first choice for national or regional bioenergy programmes and for private sector projects. They provide good opportunities, untroubled by biomass supply problems, for testing and demonstrating biomass conversion technologies and related institutional issues such as financing and management methods. Projects of this kind could do much to establish new technologies, build up manufacturing and distribution businesses, buy-down costs, and publicise modern bioenergy as an attractive alternative. There is a strong case for giving them a high priority in bioenergy programme development, at least for the short- to medium-term.

Looking to the longer-term future, the main challenge is to develop modern bioenergy for the majority of locations in the developing world, where potential biofuel supplies are less abundant and higher cost. These supplies include scattered residues which must be gathered and transported to the energy production site – such as weeds, crop residues which are normally left in the field, animal wastes from grazing livestock – and dedicated energy crops, especially trees and grasses. The remainder of this section focuses on these higher cost resources.

Table 1 Types of bioenergy supply

Residues	
1. Primary residues material from primary biomass production, especially forestry, agricultural crops, animal raising	
1a. residues arising in concentrated form [dung from stalled livestock; harvested cereal straws, stalks, husks]	costs: low or negative
1b. residues that must be gathered together [dung from grazing livestock; crop residues which are not normally harvested such as cotton and maize stalks]	costs: low to medium
2. Secondary residues material from processing wood, food and other organic materials, usually in concentrated form [sawmill bark, chips, sawdust; liquors in paper manufacture]	costs: low or negative (avoided disposal costs)
3. Tertiary residues wastes arising after the consumption of biomass [sewage, municipal solid wastes, landfill gas]	costs: low to medium
Natural Resources	
4. Biomass gathered from natural resources [fallen tree branches, woody weeds and shrubs]	costs: low to high
Energy crops	
5. Dedicated energy crops biofuels as sole or principal product [trees, grasses inc. sugarcane, sweet sorghum, starchy roots, oil crops]	costs: medium to high
5a. not replacing conventional crops e.g. on field boundaries, “waste” land	employment usually increased
5b. replacing conventional crops	employment usually reduced
6. Biofuel co-production pre-planned multi-output production including biofuels [sugarcane to produce sugar, ethanol, electricity; timber or tree-fruit production designed to deliver thinnings and harvest wastes as biofuels]	costs: low to medium

Note: broadly speaking, the potential size of biomass resources and risks associated with their production increase as one moves from the top to the bottom of the table

2.2 Labour and mechanisation

In many LDC rural areas biofuel resources are not abundant or their use involves very high opportubity costs. Considerable effort may be needed to collect them and additional biomass may have to be produced to run a bioenergy plant, usually from dedicated tree crops.

In nearly all such cases, capital scarcity and low wage rates mean that biofuel collection and production is based on manual labour with the help, at best, of a cart or chain saw. Table 2 illustrates the resulting very low energy/labour productivities, measured as GJ produced or collected per (direct) labour workday. Compared to 250-400 GJ/day for coal mining in the UK, productivities are as little as 1-2 GJ/day for many biomass energy supplies in LDCs. Note also the huge range of labour productivities for tree harvesting by hand tools and full mechanisation.

Table 2 Labour productivity for energy production, GJ per workday

	GJ / workday	*Source*
UK coal (1998): deep-mined / open cast	249 / 397	DTI 1998
Europe: highly-mechanised energy crops (trees, grasses)	73 – 216	Gielen et al. 1998
India, Korea, Nicaragua, Thailand: non-mechanised farm forestry. 10 cases: mean (range)	1.6 (0.6 – 5.1)	see note below table
Brazil ethanol + electricity: un-mechanised / partly mechanised farms [a]	1.2 / 3.8	Goldemberg et al. 1993
China: agricultural residue collection. 3 cases: range	0.7 - 11	Henderick & Williams 2000; Wang 2000
Tree harvesting only (small trees)		
LDCs, hand tools (1.5 – 5 days/tonne)	3 - 11	Perlack et al. 1997
LDCs, best chain saw operators (15 – 20 minutes/tonne)	400 – 500	Perlack et al. 1997
Europe & USA, short rotation coppice, fully mechanised	260- 5100	Perlack et al. 1997

Note: sources for farm forestry: FAO 1987; ILO 1998; Mathur et al. 1984; Reddy et al. 1999; van den Broek 2000.

[a] 7,000 to 2,200 agricultural + distillery direct jobs per Mt cane, producing 75 M litres ethanol at 21.2 MJ/l + 110 kWh electricity per tonne cane. 240 workdays/year assumed.

With energy crops the labour situation is more complex. Jobs are usually created when energy crops are *additional* to conventional field crops; for example, when trees are planted on field boundaries or village “waste” land. But employment often falls when energy crops *replace* other crops or land uses. In a review of un-mechanised production in the Indian state of Uttar Pradesh[3], Saxena and Srivastava (1995) concluded that the main field crops (rice, wheat and sugarcane) required 250-300 annual workdays per hectare compared to only 50-70 workdays for growing eucalyptus trees. Another study found that switching from groundnuts to eucalypts reduced labour needs from 112 to 45 workdays/ha/yr (Saxena 1989), with women losing most of the jobs. However, other studies have found that in some circumstances tree-growing on conventional crop land can increase jobs (ILO 1998).

These huge labour inputs mean that bioenergy projects can be an excellent way of creating employment and distributing money to the poor. However, they are feasible only because of very low wage rates, typically around US$ 1-2 per day (see sources for Table 2). Such employment opportunities, which might be attractive in regions where wages are low and unemployment is high, can contribute importantly to rural development. But this situation may not be sustainable as or if wages rise with hoped for national economic growth and, more pertinently in the present context, if bioenergy projects succeed in catalysing local enterprise and growth. New on- and off-farm enterprises, growing income, increasing capital for investment and greater demand for local goods and services, can generate a self-

[3] Many data in this chapter refer to India or other South Asian countries. This is a reflection only of the authors' professional experience and the large volume of available information for this region. Few of the points made do not apply also to other developing countries and regions.

reinforcing momentum which will inevitably push wages upwards. Consequently, increased mechanisation will probably be adopted to relieve the growing wage pressure and to keep bioenergy cost-competitive, as in Brazil where recent mechanisation in the national alcohol programme has cut agricultural jobs but also allowed substantial wage increases.

Bioenergy planners must be sensitive to the potential harm and deep conflicts of interests which can arise through wide-scale rural mechanisation. At the very least, wherever this process displaces jobs, attempts must be made to soften or offset the impacts. More generally, stakeholders in small-scale bioenergy systems need to be well-informed about the present and likely future options for employment, mechanisation, and resulting wage rates.

2.3 Competing uses

Biomass differs markedly from conventional fuels and other renewable energy resources by playing a huge range of roles and functions, extending far beyond energy-related uses. Biomass can serve a host of subsistence or commercial needs, including food, fodder, fibre, furniture, fencing, fertiliser and fuel. Land also has multiple uses, for human habitation, watershed protection and wildlife habitat as well as biomass production. All these alternative uses can compete to a greater or lesser extent with the production and use of biomass for energy purposes – especially in regions of significant or increasing scarcity of land or biomass resources. A bioenergy project must obviously be sensitive to these other local uses and be aware of likely future changes to them.

In many places, some types of biomass are simply less valuable as a source of energy than as a resource for fulfilling other needs. Over much of Asia, for example, sugarcane bagasse fetches a higher price as a fibre for paper-making than it does as a fuel. In Karnataka, India, a survey in one district of all biomass resources found that 79% were fully utilised as animal fodder (cereal straws) or highly valued as household cooking fuel or raw materials for coir manufacture. Only the remaining 21% – a substantial 55,000 tonnes per year of coconut residues – were “wastes” which could be used as biofuels (Radhakrishnan 1997).

In some cases, the market can sort out this competition, allocating the resource to the highest-bidder. Sometimes, however, this *laissez-faire* approach could seriously harm poor households that are dependent on low-value, low-cost biomass resources. Similar cautions apply to the appropriation of land for bioenergy crops. There is a long experience in South Asia of growing woodlots on village common lands, thereby depriving the poor of their traditional grazing and fodder resources. Great care must be taken to design bioenergy projects so as not to disrupt the local biomass economy. Project developers should fully understand existing biomass resource flows, identify appropriate biofuel resources, and make sure that existing biomass demands are not undermined.

Understanding is also required about possible future changes in competition for biomass or land as the economic or policy environment alters. One possibility is that bioenergy projects will create new markets which push up the price of their own biomass supplies. In Riberalta, Brazil, a 1 MW biomass-power plant was set up to use waste nut shells that were being dumped into a river. When neighbouring industries saw how successfully the shells could be used, they became competing buyers for them and pushed up their price (NRECA 2001). On a much larger scale, changes during the 1980s in the relative prices of agricultural crops, timber, pulpwood and fuelwood across much of NW India and Pakistan, led to massive booms and busts in farm forestry and the land areas devoted to tree crops grown for energy versus other purposes (Leach 1993, Saxena 1990).

However, resource competition need not be a brake on bioenergy development. Many kinds of bioenergy activity can also satisfy non-energy needs that might at first seem to conflict, usually by designing the activity to increase total biomass productivity or to increase the efficiency with which biomass is utilised. For example, animal dung retains its value as a fertiliser after it has produced energy in a biogas digester. Available biomass resources can be increased if a modern bioenergy system is integrated with the introduction of more efficient (resource-saving) traditional biomass end-uses, such as cookstoves and charcoal kilns.

More fundamentally, bioenergy activities can catalyse and be integrated with sustained increases in agricultural productivity; for example, by powering irrigation pumps. The modernisation of biomass energy systems and of biomass production for food could be pursued synergistically. Greater use of biomass-derived modern energy carriers (especially electricity), if used to catalyse on- and off-farm productive activities, could generate the income needed to pay for the capital investments and inputs required for modernising agriculture. In turn, higher yield agriculture would provide larger quantities of biomass residues that can be used for energy, or free up land for energy crops.

2.4 Biomass supply assessments

These observations underline the critical importance of assured and affordable biomass supplies for long-term project sustainability. In most places, neither of these characteristics can be guaranteed, simply because information about local biomass resources – such as biomass types, standing stocks, annual growth rates and human usage – is grossly inadequate. There is thus a crucial need for well-designed and comprehensive biomass resource assessments – certainly at the project level but also over the larger region surrounding each project.. Bioenergy systems must be designed and sized to match reasonably confident estimates of local agricultural crop yields and residue availability, or expected yields from tree-energy crops. If these are overestimated, serious supply shortfalls could result.

Strong community input and participation in these assessments is essential for reliable findings. The local stocks and flows of biomass resources are usually so complex and dynamic that the full involvement of the community is required to obtain authentic data which reflect local values, practices and perceptions of land/resource opportunities and constraints. These are usually obscured from "outside" observers by their own pre-conceptions (Chambers 1983).

In the longer term, when biomass markets are more mature, the need for thorough resource assessments could lessen. Regional biofuel trading, a proliferation of bioenergy systems which reduces the distance between supply and demand units, improved roads, and many other structural and institutional changes, could combine to smooth out local and temporal biofuel supply irregularities and associated problems.

2.5 Reducing supply risks

Bioenergy systems normally suffer from greater supply risk than do conventional energy activities. Biomass is more bulky than conventional (fossil) fuels, so costs for preparation, handling, and transport are proportionally greater. Transport costs, in particular, impose a spatial constraint in feedstock supply. This can result in a limited local pool both of resources and feedstock suppliers. Technical constraints on the type and quality of acceptable feedstocks can further limit potential resources and suppliers.

These constraints increase vulnerability to supply failure; for example, because of drought or because producers switch to more lucrative biomass markets. Watertight long-term procurement arrangements are usually needed to reduce these risks but have been notoriously difficult to arrange successfully. Reliance on many small-scale suppliers can help but may introduce significant transaction costs. Several technical and institutional measures can ease these problems and should be considered in the design and operation of bioenergy systems:

- Maintaining a large fuel stockpile provides short-term supply reliability. But as most biomass feedstocks are bulky, and perishable if damp, storage and drying costs can be considerable. Low-cost drying methods – e.g. using solar-heated air or cogenerated heat from power production – need to be developed and implemented. Costs can also be reduced if producers store and dry biofuels, using small-scale and generally cheaper methods.

- The supply base can be enlarged by densifying fuels (e.g. briquetting or pelletising crop residues) in order to reduce transport costs. This must be done close to the residue resources and on a substantial scale to be economic. Bioenergy projects that promote market demand for these materials as relatively clean and convenient cooking fuels could reap handsome dividends from cash earnings for the project, improved welfare for users of the new fuels, and general stimulation of modern bioenergy development in the region.

- Conversion plant can be designed or adapted to accept a greater variety of biomass feedstocks. This increases the size of the potential resource base and may increase supply reliability through fuel diversification.

- Bioenergy systems can be sized so that they avoid using a large fraction of the available resource, or avoid using free “waste” resources which might acquire a value.

- Systems can be designed to tolerate higher feedstock prices than initially appears necessary. This would help the project outbid competition for its feedstocks over the project lifetime. Paying attractive prices would also help to maintain the loyalty of feedstock suppliers and prevent them switching to other biomass markets.

- Other instruments can help to maintain the loyalty of biomass suppliers. For example, their loyalty can be bought by providing them with the modern energy services derived from their supplies. This is perhaps easier to arrange with cooperative systems of ownership and management than with more commercial, externally-controlled, management structures.

2.6 Energy crop yield and site quality

Where bioenergy projects rely on energy crops, the yield (productivity) of the latter has major implications for system costs and size. Feedstock prices are typically a major component of final energy prices; and energy crop yield is always a major component of the feedstock cost (and price). Many energy crop production costs – notably establishment, land, maintenance and overhead costs, as well as net returns – do not increase with greater yield. Only harvesting, transport and other post-harvest costs are yield-dependent. Consequently, unit production costs tend to fall steeply with increased yield. Yield also defines the area of energy crops and associated transport requirements that are needed to support a particular bioenergy facility; or if land is limited, the maximum feasible energy production of a facility.

Crop yield is highly dependent on many aspects of *site quality*, including solar radiation, temperature, rainfall, and soil depth and quality. This fact raises challenging questions about the choice of suitable sites for bioenergy crops. Biophysically-favoured sites may give the best yields but are also likely to have high land costs and/or be committed to high-value conventional cropping. Poor quality sites may be cheaper and more available, but require greater areas to deliver the same output and typically have higher production costs. They usually require greater technical expertise and more careful management to avoid soil erosion, soil nutrient depletion and other problems which can lead to major supply failures.

In the temperate industrialised countries, these factors generally balance out in favour of planting energy crops on good quality land (Perlack et al. 1997). Higher costs of good land are normally offset by better yields and lower costs for site preparation and planting. In LDCs increasing population and pressures on land and water for food and fibre production are likely to force energy crops increasingly onto degraded or marginal forest, crop or grazing lands, or even semi-arid "wastelands". These land types typically have many limitations such as poor and stony soils, low rainfall, steep slopes, or brush cover that must be cleared, resulting in low yields and high land preparation, harvesting and transport costs. On the other hand, the costs of the land (and of local labour) are also typically low.

The difficult trade-offs involved are basic to the siting and design of modern bioenergy systems. The dissemination of generalised methods for acquiring the relevant data and using them to develop optimal siting, design and related operating characteristics of bioenergy systems could form the basis of a most useful project.

Meanwhile, there are widespread expectations that continued R&D on high-yield crop species and improved management practices could greatly improve the yield of many bioenergy crops. This conjecture is based on the evidence of the wide ranges of yield found today for similar growing conditions. Fertilisation and irrigation also improve yields. The combined effect of these factors could be dramatic. Table 3 shows estimates of yields that might be obtained on degraded lands from short-rotation plantations with the application of genetic improvement, optimal fertilisation and optimal irrigation. For semi-arid lands all three factors combined could raise annual yields from the baseline 2-5 dry tons per hectare to 20-30 dt/ha. For sub-humid regions the equivalent increase is from 5-10 to 20-35 dt/ha/yr.

Table 3 Estimates of potential productivities of tropical tree plantations (dry tonnes per hectare per year)

Genetic improvement	Fertiliser	Irrigation	Semi-arid (500-1000 mm)	Sub-humid (1000-2000 mm)
no	no	no	2 – 5	5 – 10
yes	no	no	4 – 10	10 – 22
yes	yes	no	6 – 12	12 – 30
yes	no	yes	8 – 18	11 – 25
yes	yes	yes	20 – 30	20 – 35

Notes: Yields assume field-scale plantations on degraded forest and non-agricultural lands; 500-1000 mm and 1000-2000 mm indicate annual rainfall.
Source: Ravindranath & Hall (1996).

These huge potential productivity gains suggest two research priorities.

First, there is a need for authoritative guidelines on good-practice energy crop production on a wide range of site qualities. What yields and production costs can be expected on this or that particular site with various levels of management and technical input? What fertiliser, water, management and other inputs are required to improve on these yields (and are they sustainable?) What agricultural extension activities will help farmers attain such yields reliably? Guidelines and manuals of this kind are widely available for agricultural crops and conventional plantation forestry but little or nothing exists for tree or grass energy crops.

Second, a major research effort is needed on management practices for increasing yields, at reasonable cost, on saline, sodic, semi-arid and otherwise unproductive "marginal" lands. This research could build on the scattered studies of tree and shrub production on such lands as well as the larger global research base concerned with agricultural crops on dry lands.

3 Techno-economic Considerations and Technology Options

3.1 Techno-economic considerations

A first step in designing a bioenergy system is to identify the energy services for which there is a clear demand. After that, choice of the appropriate bioenergy conversion technology involves several techno-economic considerations. These can be broadly categorised as those pertaining to: cost, load factor, efficiency, feedstock, scale, and robustness.

<u>Cost</u>

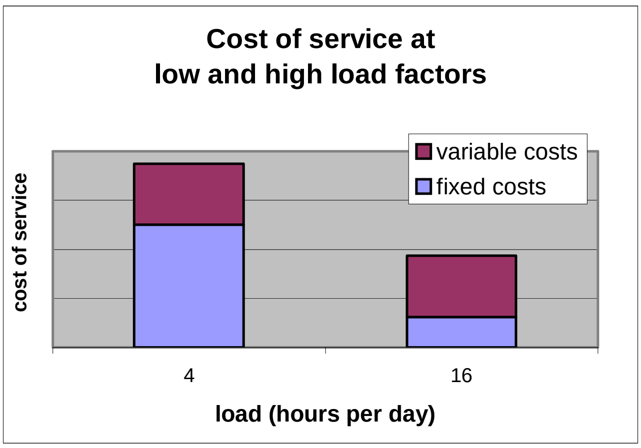
Energy users generally do not think in terms of intermediate products such as kilowatt hours or gigajoules of fuel. Rather, they think in terms of end-use services, taking into account reliability, convenience, safety, and other factors that can be hard to quantify. This is clear when one considers that electricity services can be attractive and worthwhile based on technologies such as PV panels or batteries, despite the fact that the per kilowatt price can be as much as *three orders of magnitude* more than grid-supplied electricity.

Still, cost is extremely important. Initial cost is an especially important consideration for nearly all users, both institutional and household. Users are routinely forced by capital constraints to reject technological options that have the lowest life-cycle cost, because they have prohibitively high initial costs. Financing options need to be considered in most rural energy applications (see section 5.4).

The capacity of users to pay for energy services will be greatly enhanced if they can apply the services toward income generating activities. This is a key element in the design of viable bioenergy systems and in their contribution to poverty reduction (see section 4.2).

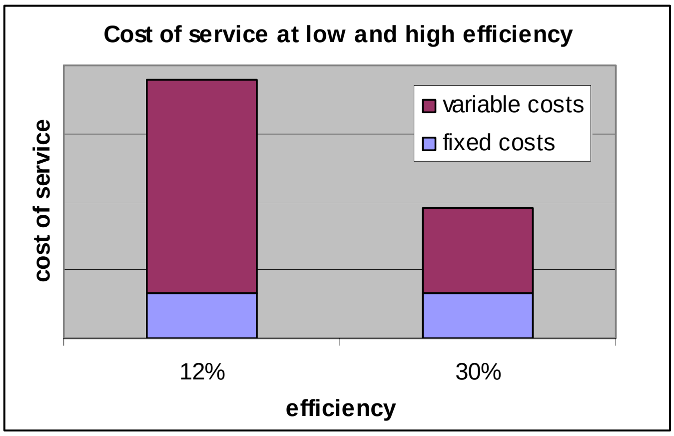
<u>Load Factor</u>

A main determinant of the cost of service is the load factor at which the bioenergy system is utilised. For capital-intensive options (which including most renewables including biomass), low load factors considerably increase cost. Since demand for electricity amongst poor households is driven by the need for lighting for a few hours in the evening, energy systems can become much more cost-effective if they can secure a baseload source of demand, such as a local enterprise, irrigation pumping, or sales to the grid. The chart below illustrates the impact on the total cost of delivered energy of increasing the load factor from four to sixteen hours per day (for a system in which fixed costs at four hours per day are about two-thirds total costs). The cost of service drops by more than half at the higher load factor.



Efficiency

Efficiency is also a critically important techno-economic parameter. It determines the "effective" cost of the biomass supply, since it is inversely proportional to the feedstock requirement. The chart below illustrates the impact on the cost of service of increasing the efficiency from 12% (a reasonable full-cycle efficiency for a gasifier/diesel engine system) to 30% (which might one day be achievable from a microturbine or fuel cell bioenergy system), all other things being equal. The cost would roughly half under these circumstances. The figure also suggests that one might accept a technology with nearly four times the capital cost of the low efficiency technology in order to achieve this efficiency gain, and achieve a similar cost of service. This might be attractive, for example, in situations where it is important to make the most of a constrained bioenergy supply.



Feedstock

While most bioenergy technologies are somewhat versatile in their choice of fuels, they do impose certain constraints. For instance, gasifiers operate most smoothly with biomass of a specified moisture content and density, anaerobic digesters require wet feedstocks such as dung, cookstoves function best with fuel of a specific size range, and biodiesel production requires an oily feedstock. Selecting a bioenergy technology for a certain site will obviously require a clear understanding of the expected type of biomass feedstock.

Scale/sizing

It can be difficult to estimate the scale at which a bioenergy system should be designed, especially if growth of energy demand is expected due to new enterprises or expanding household incomes. However, scale strongly affects the cost, efficiency, and operating characteristics of a bioenergy system, so it is generally very important to size a system at the appropriate scale for its application. Few technologies can be incrementally expanded to meet demand as needed, so it is important to make careful assessments of the anticipated end-uses and the available biomass resource in order to estimate as well as possible the required system scale.

Robustness and maintenance requirements

A major determinant of the viability of a bioenergy technology is whether it is sufficiently robust and mechanically simple to operate in a village setting, and whether any anticipated maintenance requirements can be met locally. Rural energy implementations have routinely failed because of inadequate training and follow-up service. Building capacity at the village level can be challenging but is necessary. It can also contribute significantly to rural development: skills learned in servicing energy systems can be valuable for a wide range of income generating employment. For periodic maintenance and infrequent servicing, capacity can also be built at a regional level – rather than village level – if there is enough dispersed demand to provide an economy of scale in providing service. If manufacturing standards are clearly defined and carefully adhered to, and if installation protocols are followed, it will be more likely that village energy systems operate properly. Mature, proven technologies are more likely to succeed, and attempts to disseminate emerging technologies widely should not be made without a careful programme of field-testing and capacity building.

3.2 Main technology options for village scale bioenergy activities

The following is a brief inventory of the main technological options for village applications of modern bioenergy. The intention is not to give comprehensive techno-economic descriptions of each technology, nor to relate lessons from ongoing bioenergy activities. It is merely to list the main technologies of interest for replicable village scale bioenergy activities, and to mention briefly their appropriate near-term applications and prospects for further development.

The list of options intentionally leaves aside large-scale electricity generation technologies such as steam turbine and gas turbine cycles, and large-scale fuel technologies such as ethanol distillation and synthetic fuel production. These are undoubtedly important technologies from the standpoint of deploying renewable biomass energy and potentially creating rural employment. However, as they are not directed at satisfying rural energy needs, they are not considered here. While mentioning energy demand for household cooking (see following section), this report focuses on *modernised* biomass energy.

3.2.1 Improved cook stoves, furnaces, kilns, etc.

Traditional stoves and cooking methods have evolved over generations through a process of trial and error that quite effectively optimised for local materials, fuels, and cooking needs. Improved cook stove programs were slow to produce stoves that were similarly adapted to local conditions and demands, but over time yielded sufficient improvements for them to be widely taken up. Critical to this eventual success was the input of crafts-people and end-users, especially women.

Lightweight portable stoves have now caught on in many parts of Africa, partly due to their low cost and their ease of fabrication, using materials as commonplace as used oil barrels and auto wheel rims. In Latin America and Asia the larger, non-portable (one to five pot) and generally more efficient “Lorena”-type cook stoves have been more widely adopted. Considerable advances have also been achieved in other biomass-fuelled heating applications, such as institutional stoves, dryers, curers, kilns, etc. These technologies are particularly important for providing energy services for income-generating activities in agro-processing, food establishments, and other rural enterprises. Urban consumers and enterprises have also benefited from advances in these technologies.

With proper construction and operation, such stoves can measurably reduce fuelwood consumption and air pollution. Still, since overall efficiencies are still low, and air pollution is still dangerously high (with indoor cooking), significant further improvements are worth seeking. Such improvements are potentially attainable – and worth investigation – based on forced-draught designs and on wood-gas burning (and charcoal-producing) “next-generation” stove technologies.

3.2.2 Densification (briquetting, pelletising, etc.) for raw biomass

Biomass densification technologies are worth developing for several reasons. Densified biomass has better and more uniform thermal and physical qualities than raw biomass, including more complete combustion, greater efficiency, reduced emissions, and greater combustion control for residential or institutional applications. It is also easier to handle, transport and store.

While briquettes are produced commercially for specific industrial niche markets, only in a few cases do biomass briquettes or pellets compete successfully with fuelwood or other unrefined biomass resources (such as residues and dung) for household uses. A potentially valuable household application, however, might be in conjunction with advanced "next-generation" cook stoves (mentioned above), which may benefit from a uniform and denser fuel. Low-cost, mobile, feedstock-flexible densification technology would also benefit biomass gasifier applications, expanding the range of feedstocks that would be accessible and usable, and making gasifier operation easier.

3.2.3 Anaerobic digestion (biogas)

Small-scale biogas digesters have been widely deployed, particularly in China, India, Nepal, and elsewhere in Asia. Most biomass other than lignin (a major component of wood) can be converted to biogas (including animal and human wastes, crop residues, and landfill material) although high-moisture feedstocks are especially suitable and proven. Anaerobic digestion is an ambient temperature microbial process (as opposed to a high-temperature thermochemical process), and hence is relatively slow and inefficient but has the advantage of being an easily managed conversion technology. It is well-suited for integrated systems that combine livestock rearing, waste-water treatment, fish-farms, and agricultural crops.

Biogas is primarily used for cooking but can also be used in internal combustion engines. It has been fully proven in that application at small (village level) scales, where local dung resources have been sufficient to provide power for lighting and potable water pumping. A significant additional benefit of anaerobic digesters is the sludge that they produce, which can be dried to produce a fertiliser more valuable than the initial biomass feedstock.

3.2.4 Thermochemical gasification (producer gas or thermal gas)

Thermochemical gasification involves burning biomass without sufficient air for full combustion, but with enough air to convert the solid biomass into a gaseous fuel. Thermal gas is suitable for industrial process heat and is now being commercialised for such applications. It can also be used in household cooking applications, providing it is handled in a manner appropriate for a fuel gas with a high carbon monoxide content. There are some implementations (in China) of pipeline distribution of thermal gas for household cooking.

While charcoal-derived gas has long been used in internal combustion engines, recent technological advances in gasification and gas clean-up have proved that gas derived from raw biomass can also be a suitable engine fuel. This has led to the commercialisation of systems using biomass gasification and diesel engines as a village-scale source of electricity and shaft power. At sufficient scales and capacity factors, electricity from gasifier/engine systems can be competitive with other small-scale options, including diesel generators. The technology is currently at an initial stage of commercialisation and deployment.

3.2.5 Biodiesel

Biodiesel is the common term for a clean-burning diesel fuel substitute that can be produced from vegetable oils or animal fat. It can readily replace or be blended with diesel fuel or heating oil in standard diesel engines and boilers, but is used as a cooking fuel only in specially adapted cook stoves. It can be produced fairly inexpensively at the village level using simple technology. However, biodiesel feedstock is typically produced at much lower yields (per hectare) than woody or herbaceous biomass or agriculture residues. Nevertheless, on some sites sufficient oil can be produced to meet a meaningful fraction of local energy needs. Biodiesel derived from jatropha (physic nut) has been piloted at some such sites.

3.2.6 Emerging technologies for village-scale power generation

Various developers are exploring advanced technologies for producing electricity from biomass at small scales.

<u>Microturbines</u> have been powered primarily by natural gas or diesel fuel, but research is underway that is expected to produce microturbines that could use typical biomass-derived thermal gas or digester gas. It is expected that these might eventually be competitive with diesel engines for village-scale power applications, with relatively low maintenance costs, high reliability, long lifetime, and low capital costs.

<u>Stirling engines</u> have attracted interest because they can potentially tolerate a wide range of fuel sources with little fuel processing. Recent technical advances in “free-piston” Stirling designs may eventually yield commercial models with high reliability and engine efficiency, making them a particularly interesting power generating option at very small scales (1-3 kW).

<u>Fuel cells</u> might ultimately prove able to generate power at village scales from gasified biomass at efficiencies more than twice as high as the gasifier/diesel engine systems that are now being commercialised. If fuel cells and gas clean-up systems come to be mass produced for vehicle applications (as is likely), it may mean that rugged systems could be available at costs low enough to make village scale generation at the scale of ~100 kW roughly cost-competitive with today’s centralised power plants.

However, many technological and institutional hurdles remain before any of these technologies will be deployed in village applications. Their reliable operation must be demonstrated, particularly in remote areas, and large-scale commercial production will be needed to bring capital costs down. Availability of spare parts and trained technicians in the near term will also slow their acceptance for village applications.

4 Energy end-uses and income generating activities

A broad consensus is emerging that an important ingredient to poverty reduction is improved access to energy services. These services can, broadly speaking, fulfil two objectives. The first is to satisfy the basic needs of day-to-day family subsistence. The second is to satisfy income generating demands: i.e. services that help a rural communities to undertake productive activities that help to generate wealth or assets. If a rural energy activity is meant to reduce poverty, end-use activities must be thought of early in project design to determine how best to provide energy services so as to optimise the poverty reduction impact.

4.1 Household energy needs (basic needs and more)

Energy services can relieve some of the unending drudgery that characterises the daily lives of poor families—gathering fuelwood, hauling water, milling grain, and other laborious tasks. Currently, the poor must rely predominantly on their own labour (or on animal power) to meet these energy needs; much time and physical effort is invariably spent on these unrewarding subsistence activities. Water fetched manually can consume hours per household per day. With an electric pump the same amount can be obtained in negligible time for a cost of a fraction of a US cent. A similar amount of electricity could grind in a few minutes an amount of grain that it would take one- to two- hours to pound by hand.

Expanded energy services can dramatically improve the health conditions of the poor. Energy for pumping potable ground water reduces reliance on surface waters, which are frequently the source of disease. Replacing wood with cleaner cooking fuels and stoves improves indoor air quality and helps reduce the pandemic levels of respiratory disease in rural areas. Electric power for lighting and refrigeration can improve the quality and availability of medical services. Electricity can improve educational opportunities and access to information via radio, television, telephone and computers.

The *supply* of biomass fuel can provide many benefits for rural communities. Bioenergy feedstocks can be produced in conjunction with other necessities – food, fodder, fuelwood, construction materials, artisan materials, etc. They can help restore the environment on which the poor depend for their livelihoods – revegetating barren land, protecting watersheds and harvesting rainwater, providing habitat for local species, stabilising slopes or river banks, or reclaiming waterlogged and salinated soils. They can also provide an efficient use for agricultural residues, avoiding the pest, waste, and pollution problems of residue disposal.

4.2 Income Generation

Satisfying the basic needs of the poor will help to relieve the symptoms of poverty, but eliminating the root causes of poverty necessarily involves increasing the purchasing power of poor households. Rural energy projects, and bioenergy projects in particular, have great potential to create income opportunities. Many rural enterprises become viable only once there is access to a reliable modern energy source – such as mechanical power, electricity, process heat, transport fuel. The poor are often able and willing to pay for them when they can invest this increased productive capacity in income-generating activities.

Modern forms of energy can provide critical energy services for rural agriculture and non-farm enterprises in many ways. When household electric lighting replaces inferior light sources such as kerosene lamps, candles, or cooking fires, it adds productive hours to the day, since traditional light sources are barely adequate for fine work or reading, and can also be cheaper (Wamukosya & Davis 2001). Efficient sources of process heat enable farmers to process agricultural output, increasing their revenues by turning an agricultural product into a value-added, marketable good. Electric motors can dramatically reduce the amount of effort demanded by simple chores, enabling people to carry out activities at a commercial scale that would otherwise be simply infeasible – for example, milling a large amount of grain or irrigating an entire field. Increased availability of transport services provides better access to raw materials and markets. And increased access to information potentially enables rural producers to understand better the market conditions under which they are endeavouring to sell their output. The table below outlines a small subset of the wide variety of ways in which energy services can enable rural households and enterprises to undertake value-adding activities.

Energy services	**Income-generating value to rural households and enterprises**
Irrigation	Better yields, higher value crops, greater reliability, growing during periods when market prices are higher
Light	Reading, many types of manual production, etc. during evening hours
Grinding, milling, husking, etc.	Create value-added product from raw agricultural commodity
Drying, smoking, etc. (preserving with process heat)	Create value-added product. Preserve produce to enable selling to higher-value markets
Refrigeration, ice-making, etc. (preserving with electricity)	Preserve produce to enable selling to higher-value markets
Expelling	Produce refined oils from oil seeds, etc.
Transport	Reaching markets
TV, radio, computer, internet, etc.	Education, access to market news, coordination with suppliers and distributors, weather information, etc.
Battery charging	Wide range of services for end-user

Farming can also benefit greatly from improved energy services. A reliable supply of irrigation water is a main factor enabling farmers to plant more than one crop during the year. This increases both the amount of food produced and agricultural employment per hectare. On the large amount of land that cannot be irrigated by gravity-flow techniques, irrigation relies on the use of motorised pump sets, which can be powered by biomass-derived gas or electricity. Better access to energy services can also improve the efficiency with which food reaches consumers. Food losses are high in developing countries in part because the means of processing, storing, and transporting agricultural produce are inadequate.

Bioenergy project developers should also capitalise on opportunities for generating income through the bioenergy activity itself. Many farmers would welcome the opportunity to sell residues or purpose-grown wood to long-term, steady consumers or well developed spot market. Producing biomass can provide a new source of revenue and help farmers to diversify. Rural enterprises are also indirectly connected to the biomass feedstock production activity itself: providing and preparing agricultural inputs such as fertiliser, selling and servicing farm equipment, handling and processing agricultural products, and transporting and marketing finished goods. Employment is also generated in producing biomass and working at the bioenergy facility.

Certain bioenergy feedstock production and supply chains, if appropriately designed, can offer multiple avenues for income generation. One strategy is the co-production of value-added product along with the biomass feedstock. A bioenergy project in Hosahalli, India, provides an especially good model. In this village, a small-scale biomass gasifier and diesel generator provides electric power for household lighting, a village flourmill, and pumping of potable water and irrigation water. The irrigated cropland includes a plot on which the villagers grow mulberry, which produces enough woody stalks as a residue to fuel the gasifier. The primary crop is mulberry leaves, which are fed to silkworms, yielding silk cocoons that are then sold. This covers the cost of the bioenergy system and generates a profit for the villagers.

Of course, income generating opportunities will not be spurred automatically with the mere arrival of modern energy. Bioenergy projects will need explicitly to facilitate income opportunities, by helping to create the enabling conditions that make rural enterprises viable. Rural entrepreneurs typically identify the lack of credit and capital as their greatest impediment (see section 5.4). In many cases, however, a further key obstacle facing rural enterprise is inadequate upstream and downstream linkages. Remote enterprises can find it difficult to procure raw materials at reasonable prices on a reliable basis, or to reach prospective sources of demand for their products. This often results from inadequate physical infrastructure but no less important is social infrastructure – healthy workers with productive skills, management expertise, access to market information, and the resources to negotiate fair terms of trade.

Bioenergy planners must bear in mind that a diffusion of energy-services and an increase in mechanisation do not always benefit rural development. In some situations, labour scarcity is indeed a problem and labour-saving innovations are welcome—for example, at key points in the seasonal agricultural cycle when lack of labour constrains agricultural productivity. But in *most* rural areas at most times of the year, severe unemployment or underemployment prevails. Energy services will support development only to the extent that they expand employment opportunities. In many economies, overvalued exchange rates, direct capital incentives, and subsidised credit have introduced market distortions that induce excessive substitution of capital for labour. Bioenergy planners should be aware that such external economic factors might increase the possibility that a bioenergy project will displace labourers.

If they are to avoid such impacts, bioenergy projects must target energy services in ways that *increase* opportunities for productive activity, not *displace* them. Bioenergy planners should try to anticipate where workers might be displaced, design projects to minimise this possibility, monitor to see whether this is happening, and if so, implement steps to soften or offset the impacts. Such steps include, for example, temporary material assistance, alternative employment opportunities, and the training and resources that will enable displaced workers to take advantage of those opportunities. Particular attention should be directed toward women and girls: they are especially likely to be displaced, their displacement is more likely to go unredressed, and their access to alternative employment is more likely to be constrained.

Growing incomes, expanding enterprises, and improving agriculture in rural areas generates a self-reinforcing momentum. As incomes increase, capital for investment becomes more available and demand for locally produced goods and services grows – fuelling further opportunities for income-generating activities. Increasing the purchasing power of lower-income households is the most effective means of stimulating this self-reinforcing phenomenon. Households with higher incomes tend to spend more of their earnings on goods from the urban manufacturing sector or on imports, whereas poorer households tend to purchase services and goods generated within the local rural enterprise sector (FAO, 1998; Liedholm, 1998). The development goals of bioenergy projects will benefit from targeting efforts at poorer households, helping them to meet their basic needs, accumulate productive assets, and become a source of demand in the incipient local economies.

5 Institutional factors

Institutional factors are those that determine the broad context in which bioenergy projects are designed and implemented. They range from local institutional arrangements to macro-level policy issues and largely determine the viability of a bioenergy activity.

Each bioenergy project can determine some of these contextual features; others might be beyond its influence. Larger bioenergy programmes, with public sector collaboration, might be able to review policy and propose changes in the macro-level context. Where large-scale replication is the ultimate goal of a project proponent, institutional issues will probably be an important part of the broader dissemination strategy. For this reason, it is advisable for a project proponent to review carefully and understand fully the relevant institutional factors.

5.1 Participation

Rural energy practitioners are gradually coming to appreciate that, in order to succeed, energy projects must intimately involve the local community from the very beginning, ensuring their input, interest, support, and investment. The lack of this participation has been a main reason for the failure of past energy activities.

Participatory approaches help to ensure that bioenergy projects provide energy services that address the articulated needs of local people, rather than needs as perceived by well-meaning outsiders. The rural poor rarely express their needs in terms of energy *per se*, but rather as concrete concerns in their unique contexts, such as the endemic prevalence of diarrhoea among infants, the prohibitively high cost of kerosene, and the lack of paid work. Participatory approaches should underlie every stage of the project: background assessments, project design, implementation, operation, and ongoing evaluation. Community workers, NGOs, and academics have pioneered and promoted participatory methods which are now being adopted by the broader development community (UNDP 1998; World Bank 1995).

Local participation is important even for large-scale projects that supply power to the grid or produce fuel for the transport sector, as opposed to satisfying a local demand for energy services. Participatory approaches can also help to ensure that the supply side of bioenergy projects benefits the local community while providing a cost-competitive biomass feedstock.

"Participatory" must be defined appropriately. In the past, some projects have attempted to be participatory but neglected the heterogeneity of the community and its corresponding diversity of perspectives and needs. To involve community members successfully, the project must either identify a small, coherent social unit (e.g. the individual household), or establish an institutional arrangement (e.g. a village committee, a stakeholder forum) that can mobilise a larger disparate group, by designating roles, resolving differences, and brokering agreements. The participation of poor community members and women must often be deliberately sought. A forum will be more successful in eliciting their participation if it targets the poor, is unthreatening, and perhaps comes with a minor incentives such as a meal (Kanetkar & Varalakshmi 1994; FAO 1999). In many cases, women can effectively voice their opinions and discuss their concerns only in separate women-only fora.

5.2 Organisations for local involvement

5.2.1 Local organisations

An effective way to ensure local participation is through a local organisation that is granted certain rights and responsibilities with respect to the bioenergy project. The function of the local organisation will be context dependent. It will include consultation during the project design phase at a minimum, and probably continued involvement through project implementation and ongoing management of the project. In some cases, it might be appropriate to vest ownership of the project itself in the local organisation. The "Village Development Society" formed to manage the community biogas digesters in Karnataka, India, is an example of an organisation that made contributions to local empowerment beyond its direct role as the project-managing authority.

Such local organisations can fill a number of roles:

- They can serve as the primary forum for local community participation, providing a well-defined point of contact and constancy over time.
- They can be given the responsibility and authority to manage the project or contract its management to a private actor. This can endow the community with a sense of equity in the project and accountability for its success. Experience has demonstrated this to be a necessary ingredient for project success.
- They can provide a transparent decision-making process and open access to information, helping to minimise abuses of office or corruption.
- They can coordinate or mobilise the community, providing a forum and process for articulating local needs and concerns, for building political consensus, and for resolving disputes among community members.
- They can be given official legal authority over common resources in cases where the bioenergy feedstock relies on them. It can also provide a forum for managing the benefits of a bioenergy project, such as energy services, irrigation water, fertiliser (from a biodigester) and the funds intended for or arising from bioenergy projects.

In some cases, existing local administrative bodies such as village councils can effectively manage bioenergy matters (Chaturvedi 1997). But in many cases, specially constituted bodies might be more effective, flexible, and democratic (Agarwal & Narain 1990).

5.2.2 Organisations in the context of larger-scale bioenergy activities

In the case of large bioenergy facilities such as multi-MW power plants or industrial-scale fuel processing plants, a village organisation such as that described above might not be relevant. Large-scale facilities are unlikely to interact closely with local communities in providing services, as they will primarily be serving urban demand centres. However, they are likely to have close interactions with local farmers providing biomass feedstock, and/or local wage labourers either growing biomass or staffing the conversion facilities. In order to benefit from these income opportunities, farmers need to be able to negotiate fair terms of trade, and farm or plant workers need to have basic protections as wage labourers. Farmers' cooperatives and workers' organisations can help secure these rights.

Farmers' cooperatives can exploit the economies of scale that are otherwise available only to larger farmers. They can inform small farmers about market conditions and technical advances. They enable larger investments of capital and labour than would be feasible for individual farmers. They can spread project risk and, perhaps most importantly, endow small farmers with greater bargaining power. Where there is only a single buyer, as in a contract-farming situation, cooperatives can make the difference between a profitable, low-risk undertaking and debt-ridden foreclosure.

For rural labourers, a job's attractiveness depends on a variety of factors: wage rates, seasonal variability, job security, length of workday, job safety, availability of medical care, ability to air grievances, etc. Sometimes laws exist to ensure minimum job standards, but these are much more likely to be effective when labourers are allowed to organise and bargain collectively. Labourers are then better equipped to identify, articulate, negotiate, and secure acceptable labour conditions. Employment within large-scale bioenergy facilities can better contribute to rural development if worker organisations are involved.

NGOs and others groups that are interested in seeing large-scale bioenergy activities benefit local communities, can assist farmer cooperatives and worker organisations in several ways, including: providing legal, strategic, and technical advice; facilitating contact with other farmer and worker organisations; monitoring local exchange and employment conditions; initiating and mediating dialogues between employers/buyers and workers/farmers; introducing a recognition of gender issues; advocating on behalf of farmers and workers in legal and bureaucratic fora; and publicising issues and attracting outside support.

5.3 Private sector involvement

In most countries, the private sector is likely to be an essential element of any effort to deploy renewables widely for rural energy. A community-based organisation or local NGO is generally less motivated than a commercial company in seeing a venture expand and spread to other sites. Large or small commercial enterprises can facilitate replication by applying accumulated experience and knowledge to new projects. They can obtain capital (either debt or equity) to which few community-based organisations or NGOs have access, and they can introduce an entrepreneurial energy. With appropriate public sector oversight, private sector firms can help achieve social objectives such as provision of rural energy services. And, in an appropriately competitive environment, they can do so efficiently. The private sector can play especially important roles in the manufacturing, marketing, installation, operation, and maintenance of technology. In addition, private companies are often the source of technology improvements, either via their own applied research and development or in collaboration with research institutes or other companies (e.g. joint ventures between local and foreign companies).

Private companies can also serve important roles as energy service companies (ESCOs), sparing their customers – whether communities or individual households – the difficulties and complexities of owning and operating an energy system. ESCOs can handle all the hassles associated with designing, financing, installing, and operating an energy system and simply provide their customers with the amenities associated with energy (heat, light, water, etc.). This is much more attractive to many customers, especially where high initial costs are prohibitive, and where installing and operating requires special technical capacities. ESCOs first emerged in a substantial way in the 1980s in urban areas of industrialised countries, where their activities focused on energy efficiency improvements. More recently, ESCOs are also found in rural areas of developing countries (Shivakumar, Rajan & Reddy1998).

Despite these advantages, the private sector’s role in delivering energy services to rural areas is severely limited in that it responds only to effective demand; that is, demand that is backed by purchasing power. Some of the unmet demand for energy services in LDC rural areas comes from potential customers who have sufficient resources to pay for energy services. However, much of the unmet demand comes from rural residents who do not have sufficient resources to pay for energy services, even if there were an active market.

Three approaches can be used, individually or in combination, to meet this demand. The first involves relying on public sector support, either directly or through fiscal, regulatory, or other incentives to the private sector. The second involves using cross-subsidies within community-level projects, whereby revenues from the wealthier households help fund services for poorer households. The third – and most sustainable – option involves coupling bioenergy activities with income generating activities – a multi-disciplinary undertaking that will require close coordination with rural development organisations.

5.3.1 Energy Concessions for the Private Sector

A promising approach to encouraging private sector involvement in the widespread replication of bioenergy systems is to grant concessions similar to those granted for oil and gas exploration and production (Shivakumar, Rajan & Reddy 1998). The key steps in developing a resource using a concession approach include (1) conducting a regional survey to identify prospective areas to be developed, (2) delineating the resource area into concession areas, (3) soliciting bidders under published terms and conditions, and (4) evaluating and licensing successful bidders under a free and fair competition. In the present context, the key objectives are to encourage the development of a large number of applications and to enable successful bidders to take advantage of cost reductions arising from multiple implementations in their concession area (e.g. equipment, learning, administrative, and overhead cost reductions).

A concession approach might work well for installing and operating village-scale, biomass-based electricity-generating systems in a region. In countries where construction of new electricity-generating capacity is not keeping pace with growing demand (which is the case in many countries), governments might find it effective to grant biopower concession areas. While a single biopower unit would contribute relatively little, a large number of units in aggregate would have generating capacity equivalent to (large) conventional generating units in the utility system. The concessionaire would benefit from the opportunity to reduce transaction costs and other overhead costs associated with contract negotiations, marketing, manufacturing, installation, operation, maintenance, etc. It would also have exclusive access to biomass resources that are allocated to energy, and certain rights and responsibilities regarding exploiting a local market for energy services. Innovative pilot programs are being initiated in Argentina, Bolivia, Peru, and the Philippines for issuing concessions to private companies for the provision of energy services, especially electricity services, to dispersed rural populations.

5.4 Financing

Initial cost is all too frequently an overwhelming barrier for decision makers at all levels, from energy authorities to households. In many developing regions, financial markets are undeveloped and capital is chronically scarce, so financial choices are often made using extremely high effective discount rates. For the poor in particular, deeper structural problems contribute further to this problem: they are exposed to many sources of risk, chronic insecurity of assets, and pressing immediate subsistence needs, all of which militate against long-term investments.

Importantly, although energy users are often incapable of making large initial outlays, they have a very high willingness to pay for energy services. Village energy surveys have found that households already pay rates that are exorbitant from the perspective of, say, the typical electricity consumer from an industrialised country who is accustomed to paying approximately one US cent for several hours of high quality illumination.

Several innovative microfinance initiatives have been developed in recent years to address this problem. The well-known Grameen Bank in Bangladesh, for example, has conclusively shown that poor families are creditworthy and that they make investments that are highly remunerative—indeed life-transforming. The Bank Rakyat Indonesia has demonstrated furthermore that local microfinance can be a self-sustaining, unsubsidised, commercial undertaking, without levying the exorbitant rates that characterise the informal credit market.

Energy activities could serve as an effective platform for expanding these approaches, bringing together enterprise-enabling energy services with access to investment capital. Financing for energy services at the household or community scale could take several forms:

Supplier financing: Financing is provided directly to the end-user by the supplier. This gives the supplier a strong incentive to provide a quality product and regular maintenance, in order to secure regular payments. But, as the supplier assumes the risk of default, it could also lead to demand for a high initial payment and/or payment rates, and to the exclusion of low-income customers who might appear less credit-worthy.

Third-party financing: Financing is provided by a third-party institution that operates a loan fund. This approach allows the supplier and the creditor each to focus on his area of specialisation. Service agreement with the supplier can help reduce the risk to the creditor of default due to technical failure or inadequate maintenance.

Leasing: Financing is provided through a lease agreement, whereby the supplier retains ownership of the energy system until its full cost is repaid. The supplier has a strong incentive to maintain the system during the lease period. This type of financing is already in place in many rural areas for agricultural machinery and rural micro-enterprise assets.

Fee-for-service: The three models outlined above are most appropriate for bioenergy systems that are small enough for single household ownership (e.g. cookstoves, household biogas digesters). Fee-for-service is more appropriate for systems that involve a larger community of end-users who are financially unconnected to each other (e.g. community mini-grids). The entity that owns and maintains the system (in essence, an ESCO) is responsible for providing the energy service – such as electricity for lighting, biogas for cooking, or pumped water, refrigeration, or milling services. Fees for these services allow the owner to recover investment costs and earn a return in his investment.

There are a several examples of financing arrangements for energy products. One is the international program FINESSE – *Financing Energy Services for Small Scale End-users*, established by the World Bank, the UN Development Programme, and the US and Dutch Governments. A major FINESSE objective is to use the financial resources of multilateral lending institutions to make "wholesale" loans to intermediary organisations such as commercial banks, utilities or NGOs, who on-lend them to small-scale energy users at market rates. A second example is the Grameen Shakti loan programme (a non-profit affiliate of the Grameen Bank) which by 2000 had financed 800 small PV electric systems ranging in cost from $300 to $800, provided with a two year, 8% loan (UNDP 2000). An example of a fee-for-service arrangement is the village biogas model demonstrated at Pura village and its eight successor implementations, where households make monthly payments for an electrical connection and water tap. In this case, villagers have a further level of involvement, in that they are participants in the cooperative-style management of the system.

5.5 Policy Environment

The feasibility and costs of a bioenergy project can depend importantly on macro-economic and national policy conditions. These include the extent and level of energy subsidies, taxes and credits designed to internalise the environmental costs of energy production and use, financial incentives for establishing new enterprises, tariffs on imported goods (e.g. parts of a bioenergy installation), and regulations and taxes on the disposal of biomass wastes. A review of these factors is far beyond the scope of this paper, but some central policy conditions will be mentioned here.

5.5.1 Access to the electrical grid through power purchase agreements

Bioenergy projects will generally be more attractive economically if they are able to "export" electricity to the electrical grid as well as serve local demand. In rural areas, local demand for electricity is often too low and sporadic to utilise a power system fully, especially in the initial years of a project. Sales to the utility grid can ensure fuller utilisation, increasing the system load factor and thereby reducing the costs of electricity production. The grid can carry electricity to urban demand centres until the size and diversity of local power demands grow to the extent that larger amounts of power can be consumed locally.

Even in cases where grid extension has been deemed uneconomical for electrification of a particular rural area, it may nevertheless be economical if the electricity were transmitted *from* – rather than *to* – the rural area. Transmission costs are strongly dependent on the total capacity of the transmission line and the capacity factor with which it is utilised. For the export of baseload electricity to urban demand centres from rural areas, lines would be utilised at a high capacity factor, and therefore transmission would be much more cost-effective. (Indeed, this is the configuration under which many remote hydroelectric installations and mine-mouth coal power plants currently power urban centres.) Moreover, generating power at remote arms of a grid system can help to provide grid reliability and enable power balancing.

Regulatory measures are generally required to induce electric utilities to purchase power from independent generators. Currently, electric sector restructuring is being explored or undertaken in many countries. As this occurs, policy-makers should consider carefully what roles distributed biomass-based generation can play, and create an electric sector policy framework that is hospitable to independent generators. A secure regulatory and legal environment, with standard long-term power purchase contracts that are pre-approved by the appropriate regulatory agencies, is necessary if the private sector is to invest in independent power production. Meanwhile, electric sectors world-wide are starting to recognise the significant gains to be had from distributed generation. Regulators in Brazil are considering mandating that utilities buy biomass-generated electricity at an attractive price to sellers: bagasse-based electricity generation is expected to grow significantly as a result. For several years, India has had a fixed purchase price for biomass-generated electricity that has encouraged expansion of biomass-generating capacity, with 3000 MW of cane-based generation now planned. Mauritius recently commissioned a bagasse cogeneration facility that helped to establish a model power purchase agreement based on avoided-cost pricing, which should streamline the commissioning of subsequent facilities. Such arrangements can considerably benefit small-scale bioenergy projects.

5.5.2 Energy subsidies

Many governments, in both developing and industrialised countries, have put in place subsidies intending to make energy services and energy-intensive products more affordable. Three general rationales are typically use to justify such subsidies. First, they are rationalised on social welfare grounds. Many energy services – such as heat for food preparation – are indispensable basic goods, and poor households typically spend a high fraction of their income on them. Poor households tend to use less efficient end-use appliances and lower quality fuels, purchase energy sources in smaller quantities, have worse access to energy markets, and have poorer terms of trade with energy providers. Second, the energy sector is seen as a strategic sector responsible for catalysing economic growth, which is sometimes seen as a rationale for broad, permanent subsidies for the sector. Third, energy subsidies are sometimes targeted to support specific government objectives. For instance, subsidies to ethanol in the United States serve as an agricultural support, subsidies to industrial charcoal in Brazil have helped preserve foreign exchange, and subsidies for wind turbines in many countries support national environmental objectives (Barnes & Halpern 2000). In some cases, subsidies achieve their objective, but often they do not or do so at an unacceptable cost.

The main problems with poorly designed subsidies are the following:

- *Distortionary:* Subsidies for electricity and fuels can make it more difficult for energy efficiency and alternative energy sources to compete. For example, fuelwood subsidies in the form of free access for commercial woodcutters to state-controlled woodlands frequently results in unsustainable harvesting, while under-priced fuelwood reduces incentives for wood-conserving cookstoves and charcoal kilns or for wood-energy plantations.

- *Poorly targeted:* Subsidies that are justified on grounds of welfare are often diverted from their intended beneficiaries, with the poor receiving a small fraction of the total outlays for such subsidies.

- *Expensive:* subsidies can impose considerable demands on public sector resources and become fiscally unsustainable. Globally, conventional energy subsidies were estimated at $250-300 billion per year in the mid-1990s (UNDP 1997). In some countries, support for expensive subsidy programs has left public energy authorities with too little capital to make the investments needed to maintain or extend service.

Effective subsidies for commercialising bioenergy technologies: Subsidies can be justified for technologies that are not yet competitive under existing market conditions, but still have good long-term prospects and/or provide other environmental and social benefits. Such subsidies are generally most effective when they have the following characteristics:

- They are based on performance, rather than capital investment alone. In the past, poorly designed subsidies and incentives have resulted in the construction of facilities with no incentive to operate them.

- They provide flexibility for the investor and/or consumer to choose from among a range of technological and institutional options, so as not to predetermine a winning option.

- They are suitably long-term and predictable to provide the intended incentive, but with a sunset clause that encourages developers to continue to advance the technology until it is cost-competitive with conventional alternatives with no subsidies.

- They do not impose a fiscal obligation that will compromise the financial stability of the responsible agency. Cross-subsidy from one consumer sector to another (for example, urban to remote consumers) may be viable, *providing* there is sufficient purchasing power in the sector that is absorbing the cost. Cross-subsidy from the future to the present may also be viable, when subsidies for the early phases (while consumer demand is growing) can be recovered in the subsequent phases once economies of scale have been realised.

- Subsidies should encourage, not undermine, private sector entrepreneurship. If the aim is to reach poor households that the private sector cannot reach, this should be done in a manner that allows the market to continue to respond to effective demand.

- Welfare-based subsidies should be more carefully targeted at delivering services to poor households. An example is the so-called *lifeline rate* – whereby a subsidised rate is offered to households for a “subsistence” level of consumption, e.g. up to 30 kWh per month. A second strategy is to focus on initial *access* as opposed to long-run prices – subsidising the cost of establishing the connection, or energy-using appliances.

5.5.3 Environmental externalities

Energy markets are distorted not only because of explicit subsidies, but also because they do not account for "externalities", i.e. adverse impacts that are not felt as financial costs to the producer or user. Externalised costs include environmental costs from fuel extraction (e.g. strip mining of coal or unsustainable harvesting of wood from forests), treatment (e.g. effluents from refining), and consumption (e.g. pollutant emissions from combustion).

In most cases, the externalised costs of fossil fuel cycles are higher than those of renewable energy cycles, so markets are generally distorted in favour of conventional fossil fuels. But the case for bioenergy is more complex. These environmental impacts are likely to be wider-reaching for bioenergy than for most energy sources, given the intricate chain of activities from feedstock production to final consumption that bind bioenergy systems so tightly with the environment. Many proponents of bioenergy have asserted that biomass feedstock production can be done in ways that advances other environmental goals, such as wasteland restoration, watershed protection, or the disposal of wastes that would otherwise pose a pollution hazard. (i.e. air pollution from burning agricultural residues, fresh water pollution from dumping sewage). However, negative externalities of biomass production can be considerable. Some commercial-scale feedstock supply systems rely on unsustainable practices such as harvesting at rates that degrade the underlying resource base or creating plantations of questionable environmental soundness.

Although it is difficult to quantify the externalised damage and to assess a precise monetary value for it, policies that cover a range of externalities are widely implemented and can be economically efficient and fairly straightforward to implement. Approaches have ranged from mechanisms that are market-based (such as pollution taxes, "cap and trade" regimes, and renewable portfolio standards) to those that are largely "command and control" (such as efficiency standards, technology requirements for end-of-pipe cleanup, and fuel content standards).

Some of these measures are intended to address not only the negative externalities associated with conventional energy, but to acknowledge that there can be positive externalities associated with disseminating new technologies, such as market transformation benefits that arise from ushering novel technologies into the marketplace. These include public benefits that are not exclusively appropriated by the investor, such as technological advancement, cost reduction from learning-by-doing, consumer awareness, and economies of scale in ancillary services such as maintenance. These mechanisms are an accepted rational for supporting pre-commercial technologies. The Global Environment Facility, for example, has adopted as one of its Operational Programmes a portfolio of projects aimed at demonstrating emerging technologies and bringing down their long-term costs. Biomass-based electricity and biomass-based fuels are explicitly targeted under this GEF effort.

Waste disposal often entails environmental costs that bioenergy systems can help to avoid. Several examples exist where restrictions on dumping, land-filling, open burning, and river disposal have created new bioenergy resources from what formerly were waste streams. Even where official regulations are not in place (or not enforced), bioenergy implementers can involve communities in identifying water pollution, air quality problems, and other locally felt costs of current waste practices. Doing so can help identify potentially useful bioenergy resources and build a constituency for addressing local problems through bioenergy activities.

5.5.4 Trade Policy

With the exception of household-level technologies such as cookstoves or mature technologies, the manufacture of bioenergy conversion technologies is largely restricted to industrialised countries and larger developing countries. Smaller developing countries often rely on imported equipment and turnkey plants, which may face import tariffs that impose a significant barrier to investment. Some countries have enacted legislation to encourage the use of domestic and/or renewable energy sources by eliminating or reducing such tariffs on related equipment. Especially in countries that are dependent on imported oil, tariff exceptions such as these can ultimately result in decreased foreign exchange expenditures. Creating capacity for local manufacture and installation can help reduce imported parts and decrease costs.

5.5.5 Land tenure

In planning any bioenergy activity, it is of fundamental importance to understand how land can and cannot be used by different people in a community. Presently, a principal impediment to the environmentally sound and economically productive management of land is the perversity of many land tenure and usufruct arrangements. Many rural families do not have secure land tenure over the land on which they rely for livelihoods: it is owned by large (often absentee) landholders or by the state. Insecure land tenure removes incentives for sustainable practices, and discourages long-term investments. Farm labourers and farmers without secure land tenure are less likely to be vigilant about the long-term productivity, or even the short-term productivity if they do not reap the marginal product of their labours. In the case of forestry, commercial wood cutters usually have no incentive to restrict themselves to sustainable harvesting levels or practices; nor do local communities have an incentive to protect or restore the resource if they lack secure usufruct.

A solution, gaining currency over the past decade, is to involve local communities in land management by radically expanding their rights with respect to the land. Devolving control over land, from a centralised forest authority to the village or even the household, can establish the correct incentives for economically viable and environmentally sound management practices. In some cases, the state simply grants ownership titles over land parcels to rural families, perhaps as limited-term renewable leases. In other cases, the state retains ownership, but grants certain limited management and usufruct rights: for example, the right to plant crops between rows of state-owned trees, in return for tending and protection of the trees. In other cases, the state fully restores (or officially sanctions) traditional land-tenure and usufruct arrangements.

Bioenergy activities can support the adoption of equitable and secure land tenure arrangements as one aim in the establishment of sustainable biomass feedstock production systems. They can also increase the likelihood that such arrangements can be viable by providing technical assistance and material resources for restoring degraded land, improving agricultural productivity, and ensuring a stable source of demand for the produced biomass.

5.6 Capacity Building

A broad spectrum of capacities is needed to acquire the necessary information, conduct techno-economic analysis, design a biomass energy initiative, organise communities, and mobilise the necessary actors to design, manufacture, and market the required technologies, and provide quality control and service. Building this technological and entrepreneurial capacity is an extensive process, involving educational initiatives, public outreach, and training for prospective entrepreneurs. Capacity to finance is also needed – from the side of the entrepreneurs, who might need to set up a workshop or purchase materials, and of the end-users, who might otherwise be daunted by the high initial costs. Capacity building activities will often require sustained efforts over a period of several years, with a well-designed exit strategy that leaves behind a viable institutional and entrepreneurial capacity.

Because bioenergy technologies are often more technically sophisticated than conventional alternatives, demands on local capacity are higher at all phases of design, manufacture, and especially operation. Poor maintenance is regularly cited as the reason for failed performance, especially in remote areas where outside expertise is difficult to access. The widespread dissemination of sophisticated small-scale systems, such as biomass gasifiers, might be particularly susceptible to the scarcity of skilled labour at remote sites.

There must also be the capacity to implement policies effectively. This is especially challenging with policies that impose new burdens on some sectors, such as fiscal policies that remove subsidies or impose new taxes.

Conclusions

While energy services are critical to the support of income-generating activities for poverty reduction, rarely are they the only ingredient. Several other factors are at least as important: credit, access to markets, skill development, etc. This suggests that the challenge of implementing viable bioenergy systems will often expand to the much larger and eternal issue of spurring income-generating activities and thereby promoting rural development.

For modern biomass to contribute to rural development, it would be helpful to rally the existing bioenergy expertise, create more such expertise, and bring this expertise to bear on the (much more complex) rural development activities of experienced, effective, well-organised development organisations. Given some capacity building and assistance relating to technical bioenergy issues, development experts and rural communities could analyse the ways in which the available bioenergy options could provide energy services that contributed to income-generating activities and rural livelihoods. Although rural development is widely recognised to be a complex multi-disciplinary challenge, relatively little of this sort of integration of bioenergy expertise with rural development experience has occurred.

Ownership and organisational structures are absolutely central to the poverty reduction impact of a project. Creating an organisational structure that can survive even with extensive informal nurturing from outside is challenging; identifying structures that can thrive and be replicated without such outside assistance is even more so. It is important to develop organisation models through which poor households can pay for and manage their own modern bioenergy systems, or alternatively, can participate in community or cooperative ventures. This is more than a straight financing issue, as with household PVs, because bioenergy systems are more complex and require much more management.

Equally important is the organisation structure for supplying the biomass feedstock in a way that equitably distributes poverty-reducing benefits. While there will be many opportunities for “easy supply” projects at sawmills, coconut processing facilities, etc., it is important to investigate other options for producing biomass that can provide income for small-holders and landless families. It might be especially important to consider marginal or degraded land, where the best long-term potential may lie for providing environmental and social benefits. For the equitable use of common land and other common resources, institutional decision-making arrangements will need to be developed. Existing traditional woodfuel supply chains are mature markets that provide large number of rural livelihoods. In cases where these are sustainable, they could provide an adaptable model for modern biomass supply system.

Since the delivery of energy services to poor people will not be very lucrative in most cases, it is likely that purely private sector activities will not reach the poor. In such cases, a government role may be necessary, and dissemination models might be most effective if the paying “customer” is not only the end-user, but also the government. In many cases, governments acknowledge their responsibility to provide services (e.g. water, education, health care, electricity) to rural communities, but are unable to do so because of capital and human capacity constraints. Public-private partnerships can provide a mechanism whereby the private sector provides the capital, entrepreneurship and connections with technology developers, etc., while the government provides some infrastructural support and a fee in the form of payment per household served. The payment could be commensurate with the funds provided to urban households, in terms of a per kilowatt subsidy, a deferred grid connection cost, or other expenses that the public sector routinely incurs in delivering services to urban households.

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