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BACKGROUND PAPER

Commercialization options for biomass energy technologies in ESCAP countries

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CONTENTS

COMMERCIALIZATION OPTIONS FOR BIOMASS ENERGY TECHNOLOGIES IN ESCAP COUNTRIES

I. INTRODUCTION

Biomass provides basic energy requirements for cooking and heating of rural households and for process in a variety of traditional industries in developing countries. Use of biomass fuels is well established in certain industries, e.g. pulp and paper, sugar mills, rice mills, palm oil mills etc. In general, biomass energy uses in such cases are characterized by low efficiency so that the biomass fuels used could potentially provide a much more extensive energy service than at present if these were used efficiently. For example, new stove designs can improve the efficiency of biomass use (and reduce biomass consumption) for cooking by a factor of 2 to 3 compared with traditional biomass fired stoves. Similarly, efficiency of biomass fuel use in certain industrial plants, for example, sugar mills, can also be improved substantially. Biomass fuels saved as a result of efficiency improvement of existing energy systems can serve as energy source for further applications.

Besides efficiency improvements of existing energy systems, putting huge quantities of biomass, mostly in the form of agricultural residues and wastes, which are currently disposed by burning or dumping, could potentially increase the energy supply from biomass substantially. Significant additional increase in biomass energy supplies should be possible through plantation of energy crops in degraded/marginal land.

As a result of growing worldwide concern regarding environmental impacts of utilizing fossil fuels, particularly climate change and nuclear risks, there is currently a great deal of interest in renewable energy in general and biomass energy in particular. Biomass provides a large share of world commercial energy consumption in sustainable energy scenarios developed by several international organizations. Thus, in biomass intensive scenario of Low CO_2-Emitting Energy Supply Systems generated by the Intergovernmental Panel on Climate Change, biomass energy accounts for about 32 per cent of global energy use in the year 2050.

The growing importance of biomass energy is also reflected in the intensification of related research and development efforts, as a result of which a number of biomass energy technologies (BETs) have matured in the recent years. These new BETs as well as the established modern BETs can potentially play a vital role in reducing greenhouse gas emissions and enhancing energy security in the near future in most countries, including the ESCAP counties.

Modern BETs can play a crucial role in providing energy services in rural and remote areas, e.g. lighting and clean cooking, and also contribute to employment and income generation.

However, the modern BETs face a wide range of barriers towards accelerated deployment. This paper presents a review of the state of the art of modern BETs, barriers to their commercialization in the ESCAP region and policy options to overcome these barriers.

II. BIOMASS ENERGY TECHNOLOGIES AND THEIR APPLICATION

A. Biomass Combustion

1. Technology

a) Domestic Biomass Combustion: Cookstoves

i) Traditional and Improved Cooking Stoves

In the developing countries, energy required for cooking often constitutes the biggest share of the total national energy demand and is normally met mostly by biomass. Traditional biomass fired cooking stoves have two major drawbacks, i.e., low efficiency (typically about 10 per cent) and indoor air pollution created by pollutants (which have been linked to different health problems) released inside the kitchen.

Basically an improved cookstove (ICS) attempts to overcome the drawbacks of traditional stoves; improvement in efficiency is achieved by improving heat transfer to the pot, while indoor air pollution reduction is achieved either by improving combustion so that less smoke is produced or releasing the smoke outside the kitchen by using a chimney or by both.

b) Commercial and Industrial-Scale Biomass Combustion

i) Commercial Biomass Combustion

In the developing countries, biomass fuels are used in a number of commercial applications, e.g. drying/curing/smoking, cooking, baking, pottery etc. There is a great deal of variation in the design of the combustion systems employed in different applications. Biomass energy use in these is often characterized by poor efficiency of heat utilization. However, the share of biomass fuel consumption in the commercial sector is normally low; thus, in the case of the Philippines about only 5.5 per cent of total biomass fuel consumption occurs in the commercial sector. Compared to cookstoves, relatively less efforts appear to have been spent for improving combustion systems in the commercial sector.

ii) Industrial Biomass Combustion

A number of technologies exist for large-scale combustion of biomass. These include the Dutch ovens, inclined-grate combustors, spreader-stoker systems, suspension burning systems, and fluidized bed combustors.

A Dutch oven is essentially a refractory lined combustion chamber. The fuel burns inside it in the form of a conical pile either on a grate or directly on the floor. Disadvantages of Dutch ovens include high capital cost, high refractory maintenance requirements, poor load-following capability, and manual ash removal.

In the inclined-grate system, fuel is fed to the top of the grate, where heating and drying occurs, with combustion taking place at the lower parts.

In a spreader-stoker system, fuel particles are fed into the firebox and flung, mechanically or pneumatically, across the grate, on which the fuel mostly burns.

Granular biomass, e.g. sawdust, rice husk, etc. is normally burned in fluidized beds or suspension type of combustors. In a suspension burning system, the fuel particles burn suspended in air. The most common suspension burning system is the Cyclonic burner.

In fluidized bed combustion, the fuel particles, normally below 1 cm in size, burn in a bubbling or circulating fluidized bed of small inert particles. In a bubbling fluidized bed (BFB) combustor, the particles remain suspended in the combustion air due to balance of downward gravity force and upward drag force exerted by gas flow. In a circulating fluidized bed (CFB) combustor, the solid particles at the exit of the main combustor column are separated from the gas stream by using cyclones and returned to the bottom of the combustor column. The first commercial CFB combustor was established in 1979. The important advantages of fluidized beds include low NO_x formation due to low operating temperature, high heat transfer coefficient in case of surfaces immersed in the bed so that boiler overall size is reduced, ability to burn multiple fuels and even low grade fuels with high efficiency.

2. Present and potential future applications

a) Improved cooking Stoves

The biggest improved cookstove (ICS) programs of the world are being undertaken in China where 177 million stoves have been installed so far covering 76 percent of rural households (Junfeng et al. 2000) and in India where about 30.9 million improved stoves were installed by 1999 covering 23 percent of rural households (MNES, 2000). In Sri Lanka, the percentage shares of fuelwood consumed in the three categories of stoves are 60 per cent in three-stone cookstoves, 28 per cent in semi-enclosed stoves and 12 per cent in improved cookstoves.

Although ICS programs appear to exist in other countries of the ESCAP region also, the actual dissemination of ICSs in most of these appears to be rather limited so far.

As indicated earlier, in developing countries, most biomass fuels are consumed for firing cookstoves. Thus, Bhattacharya et al. (1999) estimated that 90 percent the total biomass energy used in early 1990s in six selected Asian countries - China, India, Nepal, Pakistan, the Philippines and Sri Lanka - was consumed for domestic cooking. They also estimated that substitution of all traditional stoves by improved stoves could potentially save about 277 million tonnes of biomass per year (35.5 percent of the total consumption). Because of rising use of improved stoves in China and India the biomass fuel saving potential of improved cookstoves will be slightly lower at present. However, considering that a very large number of households in developing countries of the ESCAP region still use traditional stoves, the potential of improved cookstoves in terms of saving biomass fuels (and thus generating surplus biomass for providing further energy services) is, no doubt, very significant.

b) Boiler Steam Turbine Systems

Practically all electricity generation plants based on biomass combustion employ steam turbine systems at present. Such electricity generation is well established in situations where relatively cheap/waste biomass is available. For example, the installed capacity of electricity generation from biomass in the USA is around 7000 MW. The efficiency of these biomass power plants has been reported to be 20-25 per cent.

The world's largest stand-alone wood-fired power plant came online in June 1994 in Hurt, Virginia (http://www.westbioenergy.org/lessons/les13.htm). The independent power plant uses wood chips and wastes as fuel and has a capacity of 85.1 MW and efficiency of 24.0-25.1 per cent.

Boiler steam turbine systems are expected to find more applications for electricity generation in the future, particularly in situations where cheap biomass, e.g. agro-industrial residues, and waste wood, are available. On the technology side, efficiency of these systems is expected to improve through incorporation of biomass dryers, where applicable, and larger plant sizes as well as higher steam conditions**.**

c) Cogeneration

Cogeneration is the process of producing two useful forms of energy, normally electricity and heat, utilizing the same fuel source.

In an industrial plant where both heat/steam and electricity are needed, these requirements are normally met by using either 1) plant-made steam and purchased electricity, or 2) steam and electricity produced in the plant in a cogeneration system. The second option results in significantly less overall fuel requirement. Steam turbine based cogeneration is normally feasible if electricity requirement is above 500 kW.

Biomass based cogeneration is often employed for industrial and district heating applications; however, the district heating option would not be applicable in the tropical countries. A number of studies have been carried out on cogeneration in different agro-industries, particularly, sugar mills (Payne, 1990; Therdyothin et al, 1992; USAID, 1986; USAID, 1993), palm oil mills (Saran, 1986; Siemons, 1994; Wibulswas and Thavornkit, 1988) and rice mills (Winrock International, 1990). These show that biomass based cogeneration technology is well established in the pulp and paper industry, plywood industry as well as a number of agro-industries, for example, sugar mills and palm oil mills. Normally, there is substantial scope for efficiency improvements in such cases. For example, bagasse is burnt inefficiently in sugar mills in most developing countries because of a number of reasons, e.g., old and obsolete machinery, disposal problems created by surplus bagasse, lack of incentive for efficient operation etc. Improving the efficiency of biomass-based cogeneration can result in significant surplus power generation capacity in wood- and agro-processing industries; in turn, this can play an important role in meeting the growing electricity demand in developing countries.

India has launched an ambitious biomass based cogeneration programme. A surplus power generating capacity of 222 MW was already commissioned by the end of 1999, while a number of projects of total capacity 218 MW were under construction. The total potential of surplus power generation in the 430 sugar mills of the country has been estimated to be 3500 MW (MNES 2000)

d. Co-firing

Co-firing refers to the practice of introducing biomass as a supplementary energy source in coal-fired furnaces/boilers. Boiler technologies where co-firing has been practiced, tested, or evaluated, include pulverized coal (PC) boilers, coal-fired cyclone boilers, fluidized-bed boilers, and spreader stokers. Due to fuel flexibility of fluidized bed combustion technology, it is currently the dominant technology for co-firing biomass with coal in new plants (Mutanen, 1995). Co-firing can be done either by blending biomass with coal or by feeding coal and biomass separately and is a near term low-cost option for the efficient use of biomass.

Co-firing has been extensively demonstrated in several utility plants, particularly in USA and Europe. Experience so far shows that effective substitutions of biomass energy can be made up to about 15 per cent of the total energy input with little more than burner and feed intake system modifications to existing pulverized coal units (EPRI, 1997).

Cofiring represents a relatively easy option for introducing biomass energy in large energy systems. Besides low cost, the overall efficiency with which biomass is utilized in cofiring in large high pressure boilers is also high.

Current wood production systems in most countries are dispersed and normally can only support relatively small energy plants of capacity upto 5-20 MWe, although dedicated plantations can probably support much bigger plants in the future. Thus, biomass supply constraints also favour cofiring biomass with coal (with only a part of the total energy coming from biomass) in existing coa- fired plants in the short term (Hustad et al., 1995; Poulsen, 1996).

e) Whole Tree Energy (WTE) system:

The Whole Tree Energy (WTE) system is a special type of wood fired system, in which whole tree trunks, cut to about 25 ft long pieces, are utilized in the process of power generation in an innovative steam turbine technology that uses an integral fuel drying process. Flue gas is used to dry the wood stacked for about 30 days before it is conveyed to a boiler and burnt. Allowing the waste heat to dry the wet whole tree can result in improvement in furnace efficiency with net plant efficiency reaching comparable value of modern coal fired plants (van den Broek et al., 1995).

The first WTE power plant of the world is expected to start up in mid-2004 in Minnesota, USA.

f) Stirling Engine

A Stirling engine is an external combustion engine; working on the principle of the Stirling thermodynamic cycle, the engine converts external heat from any suitable source, e.g. solar energy or combustion of fuels (biomass, coal, natural gas etc.) into power. These engines may be used to produce power in the range from 100 watts to several hundred kilowatts. Stirling engines can also be used for cogeneration by utilizing the rejected heat for space or water heating, or absorption cooling.

A number of research institutes and manufacturers are currently engaged in developing biomass fired Stirling engine systems. For example, the Technical University of Denmark is developing medium and large Stirling engines fueled by biomass (Carlsen, 1996). For 36 kWe and 150 kWe systems, the overall efficiency is about 20 percent and 25 per cent respectively.

The design and product development target of a leading Stirling engine developer, Sunpower Inc. of USA, are reported to be as follows (Sunpower, 1999): fuel input = 5.6 kW; electrical output = 1.1 kW; thermal output = 3.8 kW; 1 kWe pre-production testing: year 2000; first 1 kWe product = year 2001.

B.GASIFICATION

1. Introduction

Gasification is the process of converting a solid fuel to a combustible gas by supplying a restricted amount of oxygen, either pure or from air. The major types of biomass gasifiers are i) fixed bed gasifiers, in which air passes though a packed bed of fuel blocks, and ii) fluidized bed gasifiers.

2. Biomass Gasification Technologies

a) Fixed Bed Gasifiers

Based on a study carried under UNDP/ World Bank Small-scale Biomass Gasifier Monitoring Programme (BGMP), Stassen (1993) concluded that only lump charcoal, dry wood blocks, dry coconut shells and rice husk can be considered acceptable for fixed bed gasification. He reported a matrix of acceptable fuels and gasifier types as shown in Table 1.

Charcoal gasification produces a gas, which has little moisture and practically no tar so that the gas cleaning system required is simple. Air gasification of charcoal has been claimed to be a relatively simple option for small energy systems.

Wood has been extensibly studied/utilized as a gasifier fuel. For gasification, wood has to be dried to a moisture content of about 20 per cent and reduced in size to small blocks.

Compared to wood, agricultural residues are more difficult to gasify. Except some residues, e.g. coconut shell, these have low bulk density and would present a problem of flow in conventional gasifiers having throat.

Also some important residues, for example, rice husk, have much higher ash content compared with wood; the higher ash content normally necessitates removal of ash from inside the gasifier continuously or at regular intervals. Rice husk is a difficult fuel to gasify because of its low bulk density, high ash content and tendency to form a bridge across the gasifier impairing flow under gravity.

Table 1. Gasification Systems and Gasifier Fuels

Biomass Fuel	Gasifier Type	Capacity Range	Application
	POWER GASIFIERS		
Wood Blocks	Fixed-bed/down-draft	< 500 kWe	Electricity/shaft Power
Charcoal	Fixed-bed/down-draft	< 50 kWe	Electricity/shaft Power
Rice husk	Fixed-bed/down-draft	< 200 kWe	Electricity/shaft Power
Coconut shell	Fixed-bed/down-draft	< 500 kWe	Electricity/shaft Power
	HEAT GASIFIERS		
Wood/charcoal	Fixed-bed/cross-draft	< 5 MW_{th}	Process heat
Coconut shells	Fixed-bed/up-draft		

b) Fluidized Bed Gasification

Fluidizeds bed gasifiers are flexible in terms of fuel requirements, i.e. these can operate on a wide range of fuels so long as these are sized suitably. However, because of complexity in terms of manufacturing, controls, fuel preparation and operation, these gasifiers can only be used for applications of larger capacities compared with fixed bed gasifiers, typically above 2.5 MW_{th}.

c) Biomass Integrated Gasification Combined Cycle (BIGCC)

A promising alternative to the steam-turbine cycle for biomass power generation is a set of biomass integrated gasifier/ gas turbine technologies. These technologies involve coupling combined power generating or co- generating cycles, which have already been developed for coal applications, to biomass gasifiers. The gas produced by the gasifier is used to fuel a gas turbine- generator unit; further energy can be recovered from the gas turbine exhaust.

In the integrated gasification combined cycle (IGCC), the exhaust from the gas turbine passes through a heat recovery steam generator (HRSG) to produce steam that in turn drives a steam turbine.

BIGCC systems may involve: i) atmospheric pressure direct gasification, ii) high pressure direct gasification or iii) indirect gasification. Direct gasification is basically conventional gasification in which the fuel and the gasifying medium are brought into contact directly inside the gasifier vessel. The product gas is cleaned before it is supplied to the burner of the gas turbine system; in case of atmospheric pressure gasification, the cleaned and cooled gas has to be compressed for supplying to the gas turbine cycle. In indirect gasification, biomass is pyrolysed and gasified by bringing it in contact with a hot inert medium such as sand and steam; sand is continuously circulated between the gasifier and a char combuster in which char carried with sand from the gasifier vessel burns.

3. Present and potential future applications

a) Fixed Bed Gasification

Fixed bed gasification technology is more than a century old and use of such gasifiers for operating engines was established by 1900. During World War II, more than one million gasifiers were in use for operating trucks, buses, taxis, boats, trains etc. in different parts of the world.

Currently, fixed bed gasification appears to be the most viable option for biomass based power generation for capacity upto 500 kW.

Although charcoal gasification presents no particular operational problem, the actual acceptance of the technology by potential users is rather insignificant at present, mostly because of low or no cost benefit that it offers. Also, producer gas is less convenient as an engine fuel compared with gasoline or diesel and the user has to have time and skill for maintaining the gasifier-engine system. However in situations of chronic scarcity of liquid fuels, charcoal gasifier-engine systems appear to be acceptable for generating power for vital applications. Thus, several gasoline-fueled passenger buses converted to operate with charcoal gasifier were reported to be in use in at least one province of Vietnam in early 1990s. As reported by Stassen (1993), a number of commercial charcoal gasifier-engine systems have been installed since early eighties in the South American countries.

Wood gasification for industrial heat applications, although not practiced widely, is normally economically viable if cheap wood/wood waste is available. On the other hand, wood gasifier-engine systems, if not designed properly, may face a wide range of technical problems and may not be commercially viable. Research and development efforts of recent years have been directed towards developing reliable gasifier-engine systems and the technology appears to be maturing fast. Although the demand for wood gasifiers is rather limited at present, a number of gasifier manufacturers appear to have products to offer in the international market.

Gasification of rice husk, which is generated in rice mills where a demand for mechanical/electrical power also exists, has attracted a great deal of interest in recent years.

The rice husk gasifier design that has found quite wide acceptance is the so-called Open Core design that originated in China; this is basically a constant diameter, (i.e. throatless) downdraft design with air entering from the top. The main components of the gasifier are an inner chamber over a rotating grate, a water-jacketed outer chamber and a water seal-cum ash-settling tank. Gasification takes place inside the inner chamber. The char removed by the grate from inside the gasifier settles at the bottom of the water tank.

At present, 120 to 150 rice husk gasifiers appear to be in operation in China. A third of the gasifiers are in Jiangsu Province; these include about thirty 160 kW systems and about ten 200 kW systems.

A number of rice husk gasifier systems have been shipped to other countries namely, Mali, Suriname, and Myanmar. Under a grant from FAO, a husk gasifier system of capacity 60 kW was developed in 1980s to use in smaller mills in the developing countries. This prototype was successfully used in a mill in China, although no other such unit appears to have been built or used.

Beside rice husk gasifiers, several other gasifier models have also been developed in China. Presently, more than 700 gasification plants are operating in China (Qingyu and Yuan Bin, 1997).

As a result of several promotional incentives and R&D support provided by the government, gasification technology has made significant progress in India in the recent years. Up to 1995-96 about 1750 gasifier systems (Khandelwal, 1996) of various models were installed in the different parts of India. The total installed capacity of biomass gasifier system in India by 1999 is estimated to be 34 MW (MNES, 2000). An interesting case of gasifier based power generation in a remote area is shown in Box 1. Besides generating electricity for the local community, it is estimated that the project has also benefited about 11,000 people directly or indirectly.

b) Biomass Integrated Gasification Combined Cycle (BIGCC)

BIGCC plants are currently at an early stage of commercialization. The first plant was established at Varnamo in Sweden in 1995. The plant has a total capacity of 15 MW and produces 6 MW of electricity and 9 MW of thermal energy from a total energy input of 18 MW (LHV).

At present, several BIGCC plants, of capacities up to 75 MW, are in different stages of construction for demonstration in the USA and Europe. Thus, an air blown circulating fluidized bed gasifier operating at atmospheric pressure will be used in ARBRE (Arable Biomass Renewable Energy) power plant in UK and will generate 10 MW of electricity using short rotation forestry. The main feedstock for the plant is wood chips. The plant was expected to be commissioned in late 2000.

C. Densification

1. Densification Technology

The process of compaction of residues into a product of higher bulk density than the original raw material is known as densification. Densification has aroused a great deal of interest in developing countries all over the world in recent years as a technique of beneficiation of residues for utilization as energy source.

Depending on the type of equipment used, densified biomass can be categorized into two main types: briquettes and pellets. Briquettes are of relatively large size (typically 5-6 cm in diameter and 30-40 cm in length) while pellets are small in size (about 1 cm in diameter and 2 cm in length). Because of small and uniform size, pellets are particularly suitable for automatic auger-fed combustion systems.

Box 1. Gosaba Biomass Based Power Plant

Summary of Data

Name and Address of the Plant:	Biomass Based Power Plant Gosaba Rural Energy Co-operative Society, Post office: - Gosaba District: - South 24 Parganas West Bengal, India
Capacity (kW)	500 kW
Raw Material	woody biomass
Type of Gasifier	Downdraft
Type of Prime Mover	Diesel engine
Diesel replacement	70%
Manufacturer of Gasifier	M/s Ankur Scientific Energy Technologies Pvt. Ltd., Ankur near Old Sama Jakat Naka, Baroda - 390008, India
Manufacturer of turbine or engine	M/s Greaves Limited, 25, Brabourne Road, Calcutta Pin - 700 001, India
Start up date	1st June 1997

Operation, Performance and Maintenance

The plant is looked after by Gosaba Rural Energy Cooperative under the overall supervision of West Bengal Renewable Energy Development Agency. The consumers are the members of the Co-operative. About 250 ha of land has been put under energy plantation program with plants like eucalyptus, acacia etc. Power generated from the plant is distributed through 11,000 V and 400 V distribution line. Total number of consumers at present is about 200 and is likely to go up to 600. There are three types of consumers viz. domestic, commercial and industrial.

Economics

The cost of generation works out to be about 6 UScent/kWh and average tariff is equivalent to about 10 US cent /kWh. Considering 10 years life of the machine, the plant appears to be techno-economically viable.

Conclusions

Vast rural areas of developing countries still do not have access to electricity. It is difficult to extend electric lines to these areas due to various reasons. Decentralized generation with people's participation in the program appears to be a good alternative for providing electricity to the unelectrified rural areas. Biomass based power plant is an ideal example of decentralized power generation. In addition, biomass plantation can generate employment avenues in rural areas. Energy plantation activities also protect the environment.

Source: West Bengal Renewable Energy Development Agency, India

Although BIGCC is one of the most important emerging biomass energy technologies, no plant based on this technology exists in Asia at present; a plant is, however, being planned in India.

2. Present and Potential Future Application

Densified biomass used in the developed countries appears to be mostly in the form of pellets. Use of biomass pellets for heat applications, particularly space heating, is well established in USA and Europe. In the developing countries of Asia, however, briquettes are mainly used.

In Bangladesh, briquetting technology has found remarkable acceptance over the last few years. At present, over 1000 briquetting machines appear to be operating in the country.

In Thailand, commercial briquetting is limited to two raw materials, e.g. ricehusk and sawdust. Ricehusk is briquetted without drying since it has a low moisture content when produced in rice mills. Drying is necessary for briquetting sawdust.

In mid-1988, there were nine briquetting plants in Thailand. Two of these produced briquettes from ricehusk involving a total of 9 machines while seven produced sawdust briquettes with a total of 44 machines. No significant change in the number of briquetting plants/machines appears to have taken place in the 1990s.

The technology of biomass densification by means of screw presses is mature in China, while piston press briquetting machines are also being developed presently. The capacity of screw press briquetting machines is about 100-120 kg/hr. The raw materials commonly used for briquetting are ricehusk, sawdust and agricultural residues. Currently, there are about 600 briquetting machines operating in China. About half of biomass briquettes produced is directly used as boiler fuel as substitute of coal, the other half being used to make charcoal.

In India, biomass briquetting appears to be gaining acceptance slowly but steadily. About 70 biomass briquetting machines were installed by 1995. Most of these were of piston-press type with capacity lying in the range 500-2000 kg/hr. The raw materials that are briquetted include sawdust, groundnut shell, cotton stalk, mustard stalk, coffee husk and tamarind husk. Heated-die screw press briquetting machines are also available commercially. One manufacturer offers preheated biomass briquetting systems.

In the Philippines, about 14 commercial biomass briquette producers were reported to be operating in mid-1990s. Sawdust and ricehusk are mainly used for briquetting (Elauria and Cabrera, 1996).

In Myanmar, biomass briquetting technology is in the initial stages of development. There is currently only one manufacturer who has developed a small (10 hp) screw press briquetting machine. By 1995, ten of his machines were sold in the country (Win, 1996).

In Sri Lanka, a commercial heated-die screw-press briquetting machine was adopted by the Ceylon Tobacco Company Limited (CTCL) for producing coir dust briquettes in early 1980s (Sepalage, 1985). Although technical feasibility of briquetting coir dust was demonstrated by CTCL and the coir dust briquettes could be used as fuel for curing of tobacco leaves, briquetted biomass was not found to be commercially viable. However, a renewed interest in briquetting technology appears to be emerging in recent years (Adhikarnayake, 1996).

D. Carbonization

Charcoal is commonly used in many developing countries for cooking. It has also a number of industrial applications. Normally charcoal is made from wood; a number of kiln designs exist for this purpose.

Considering that it is often difficult to have sufficient supplies of wood for charcoal making, agricultural and other residues appear to be interesting alternative raw materials. For this purpose, the raw material is normally first briquetted and the briquettes are next converted to charcoal. Briquetted charcoal is produced using this technique in a number of countries, e.g. Thailand, Malaysia, Korea, Taiwan provionve of China, Japan etc using the BC technique. Normally heated-die screw presses are used for producing the briquettes and carbonization of the briquettes is carried out in kilns similar to those used for charcoal making from wood.

A number of systems for carbonizing waste wood and residues exist. Some of these have proved commercially viable while the rest are at various stages of development, demonstration and commercialization. Charcoal produced from wastes/residues is in the form of powder, which must be briquetted using suitable binders (such as starch) for domestic use.

Charcoal is a popular fuel for house-hold cooking in many Asian countries. However, the charcoal making process is normally inefficient and polluting. There is an urgent need to develop/market clean and efficient charcoal making devices. Higher efficiency can be achieved by phasing out traditional kilns while pollution can be reduced by employing designs that flare the volatile matter evolved during charcoal making.

E. Biogas Production

Biogas produced from animal/human wastes can be used as a fuel for domestic cooking. The gas is basically a mixture of CH_4 (~ 65 per cent) and CO_2 (~ 35 percent). The process of biogas production essentially consists of anaerobic bacterial fermentation of biomass in a closed space. Two biogas digestor types are commonly used in the developing countries, e.g. fixed dome type (or Chinese design) and floating gas holder type (or the Indian design).

Biogas production is well established in China and India. In China, there were about 6.8 million household digesters and more than 1000 medium- and large-scale biogas plants for treatment of distillery and animal wastes by the end of 1997. Estimated biogas production by these plants is about 2 billion cubic meter amounting to about 5 per cent of the total gas energy production in China (Junfeng, 1999). Currently, the number of biogas plants in India is about 3.1 million (http://www.renewingindia.org/renart1.html).

In Nepal, Fixed dome biogas digesters of capacity 4,6,8,10, 15 and 20 cubic meter are being promoted. A total of 49,275 biogas plants were installed in the country by the fiscal year 1997-98. Significant renewed efforts to introduce biogas digesters of improved design are being undertaken in some countries, notably in Bangladesh.

Although dissemination of biogas technology is quite impressive in certain countries, particularly China and India, there is substantial potential for further biogas production even in these countries. Thus, the number of biogas digesters installed so far in India is estimated to be only about 25 per cent of the total potential.

F. Other Biomass Energy Technologies

1. Ethanol Production

Ethanol can be produced from three main types of biomass raw materials: (a) sugar containing materials (such as sugarcane, molasses, sweet sorghum, etc.) which contain carbohydrates in sugar form; (b) starch containing materials (such as cassava, corn, potatoes, etc.), which contain carbohydrates in starch form; and (c) cellulosic materials (such as wood, agricultural residues, etc.) for which the carbohydrate molecular form is more complex. Production of ethanol from sugar containing materials by fermentation is an established technology. Production of ethanol from other materials involves first conversion of carbohydrates into water-soluble sugars and then fermentation of these sugars into ethanol. Production of ethanol from corn, a starch containing material, is well established in the USA. The first plant of the world, converting agricultural residues into ethanol will be established in the Louisiana state of USA. The plant, which will process 340,000 tons of sugar cane bagasse and rice hulls per year, is expected to be commissioned in February 2002.

Commercial ethanol contains about 5 per cent water, and is normally called hydrous ethanol. Anhydrous (i.e. water-free) ethanol is basically pure ethanol containing no water. Anhydrous ethanol can be blended (at about 23 per cent level) with gasoline for use in existing internal combustion engines, while hydrous ethanol is used in engines specifically designed for this purpose.

The biggest ethanol programme of the world was undertaken in Brazil. Box 2 presents some highlights of the Brazilian alcohol programme.

Roughly 60 per cent of world ethanol production is based on sugar, both cane and beet; the remainder mostly comes from grains, particularly corn. The world ethanol production in 1998 was 31.2 billion litres; the major producers of ethanol are Brazil and USA where production in 1998 was 13.5 and 6.4 billion litres respectively. Fuel ethanol accounts for about two-thirds of the total production (Berg, 1999; www.distill.com/berg/.)

In Thailand, more than 20 years ago, a process for making tapioca-derived ethanol was invented and the construction of four ethanol plants with a capacity of 600,000 liters a day was planned. However, the plan for the ethanol plants was later abandoned based on economic considerations. According to a recent newspaper report, the Thai government and Ford Motor Company will jointly work on a fuel ethanol project. The Indian government is setting up pilot projects in Maharashtra and Uttar Pradesh to study the use of ethanol as transport fuel. Initially a blend of five per cent alcohol derived from sugarcane molasses and 95 per cent gasoline will be tried.

2. Methanol Production

The production of methanol from cellulosic materials consists of the following steps: 1.gasification; 2. gas purification – the raw gas is purified to remove all but H_2 and CO; 3. shift conversion to produce a gas, called the synthesis gas, that contains a 2:1 ratio of H_2 to CO; and 4. conversion of the synthesis gas to methanol over a suitable catalyst.

A limited number of methanol passenger cars and buses are now commercially available. There are approximately 14,000 methanol passenger cars in use, and about 400 methanol buses in daily operation, mostly in California.

3. Biodiesel

Biodiesel is a substitute for diesel and can be used for running diesel engines. It is produced by modifying vegetable oils and can be produced from many crops, e.g. soybean, corn, cottonseed, sunflowerseed, peanuts and oil palm. Biodiesel can also be produced from recycled cooking oil. Generally biodiesel cannot compete with diesel at present because of high cost of vegetable oils. However, its use offers a number of advantages in comparison with conventional diesel; these include improved biodegradability, reduced carbon monoxide and sulfur dioxide emissions, reduced odour, and safer handling. Currently biodiesel is mostly blended with petroleum diesel at a 20-percent level (B20), although 100 per cent biodiesel can also be used.

Although use of biodiesel is not yet common, it has been extensively tested by government agencies, university researchers and private industry in the United States, Canada and Europe. Tests with biodiesel blends have logged more than 10 million road miles.

Use of biodiesel is in an early stage in Asia. A plant to make 200,000 gallons of biodiesel per year from used cooking oil has recently been built in Japan (http://www.biodiesel.com/release3.htm). Biodiesel from used cooking fuel has also been tested in vehicles in Hongkong. Research on using biodiesel for running engines is in progress in a number of other countries, e.g. Malaysia, India, Nepal etc. Biodiesel market in the region is expected to develop slowly in the form of blends, since these can reduce emissions from conventional diesel engines. Also, initial market development may be based on cheap oils.

III. CHARACTERISTICS OF BIOMASS PROJECTS

A. Environmental Aspects

When used in the renewable mode, (i.e. cutting/harvesting of trees is balanced by new plantations) CO_2 released to the atmosphere from combustion of biomass is reabsorbed during growth of new plants/trees. Thus, overall, biomass energy can be regarded as CO_2-neutral. However, certain other greenhouse gases (GHGs), namely CH_4 and N_2O, as well as other pollutants are also normally produced during biomass combustion; as a result, biomass use causes some net emission of GHGs as well as local air pollution.

Box 2. The Brazilian Ethanol Programme

Proalcool, the Brazillian alcohol programme is the world's largest commercial biomass energy program. The programme was launched in 1975 for substituting imported petroleum by a subsidized domestic energy source. The government and the automobile industry joined hand for promoting the program. Initially anhydrous alcohol was used as an additive to, gasoline to the extent of about 22 per cent. This mixture can be used in any type of car without modifications to the carburettor or engine.

Hydrous alcohol, on the other hand, is used alone in its pure state, in specially-designed engines. The Proalcool program promoted hydrous alcohol and as a result the production of hydrous alcohol rose from 323 million litres in 1975/76 to the all-time high of 10.768 billion in 1991/92.

The share of the new alcohol cars grew initially and reached a peak of about 80 per cent of all new vehicles in 1980s. However, since 1995, the fleet of alcohol based cars started to decrease; new alcohol vehicles now represent less than 1 per cent. Therefore use of anhydrous alcohol (as a gasoline additive) is growing while, use of hydrous alcohol is falling.

However, alcohol still remains an important energy source in Brazil as indicated by the fact that 58 per cent of total sugar cane production in 1999 was used for alcohol production.

Overall, the alcohol program has achieved several important results. In 2000, about one million people were working in the alcohol program including plantations, and industrial units. Ethanol productivity increased from 2400 l/ha in early years to about 5000 l/ha in recent years (Rosillo-Calle and Cortez, 1998). The program also resulted in development of anhydrous alcohol vehicles. The total investment of about US$ 11.3 billion in the program since 1976 is estimated to have saved the country about US$ 28.7 billion in foreign exchange.

Although alcohol program in Brazil currently appear to be passing through some uncertainty, mostly due to low oil price in the international and domestic market, climate change concerns may give it a new boost in the near future. Besides reducing greenhouse gas emission, the program may even become economically attractive if the price of oil increases in the near future.

Biomass fuels normally contain little or no sulfur. Emission of SO_2, an acid rain pre-cursor, from biomass energy systems is therefore very low. Also, biomass fuels normally have lower nitrogen content and lower flame temperature compared with coal; emission of nitrogen oxides from biomass combustion is therefore normally less compared with coal.

Besides the energy conversion process, certain GHGs and pollutants are also emitted from biomass cultivation, harvesting and transportation.

1. Small-scale systems

Poor combustion of biomass in stoves and other traditional combustion systems results in emission of products of incomplete combustion. Some of these are hazardous to health, while some others are direct or indirect greenhouse gases, thus contributing to climate change.

Reddy et al (1997) cautions, “because a large portion of the population is exposed, the total indoor air pollution exposure (from domestic biomass combustion) is likely to be greater for most important pollutants than from outdoor urban pollution in all the world’s cities combined”. Pollutants from biomass combustion are known to cause respiratory infections in children and chronic lung disease in women. Also, some of the pollutants, the polycyclic aromatic hydrocarbons (PAH) are known to carcinogenic.

It has been reported that the total mortality due to indoor air pollution exposure in India is in the range of 410,000-570,000 annually (Parikh, 1999); this indicates the severity of the problem in developing countries.

Based on review of international literature, Bhattacharya and Salam (2001) estimated greenhouse gas emission from cooking based on different fuels. Their results are summarized in Table 2. Among the different cooking options, producer gas stoves and biogas stoves emit the lowest total GHGs in terms of CO_2 equivalent per unit of useful energy for cooking, while kerosene stoves generate the highest total GHGs of 350 g CO_2-e/MJ. The GHG emission difference between an improved and a traditional wood-fired stove is about 68 g CO_2 equivalent per MJ of useful energy. Thus, modern biomass based cooking options such as improved biomass-fired cooking stoves, biogas-fired stoves, and producer gas-fired stoves can potentially play an important role in mitigating GHG emission from domestic cooking by providing an alternative to kerosene and gas based stoves.

2. Large-scale energy systems

Although small-scale biomass energy use causes some environmental problems as pointed out above, large scale use of biomass in modern energy systems can overcome most of the problems; biomass is therefore regarded as a potentially very important option for mitigating greenhouse gas emissions (Hulscher, 1998). Table 3 shows the reported GHG implications of woodfuel use in 16 Asian countries covered by the Regional Wood Energy Development Programme in Asia of FAO.

Faiij and Meuleman (1997) have estimated likely CO_2 emissions from electricity generation using biomass and coal based IGCC plants. CO_2 emission from the biomass fuel cycle, including fossil fuel use in production and transportation was estimated to be 24 g/kWh compared with 815 g/kWh in the case of coal.

Table 2. CO_2 equivalent emission from different cooking options

Cooking options	Efficiency (%)	CO_2 (kg/TJ)	CH_4 (kg/TJ)	N_2O (kg/TJ)	CO_2-e (kg/TJ)	CO_2-e (g/MJ)
Traditional stoves (wood)	11	-	519.6	3.74	12071.0	109.7
Traditional stoves (residues)	10.2	-	300	4	7540.0	73.9
Traditional stoves (charcoal)	19	-	253.6	1	5635.6	29.7
Traditional stoves (dung)	10.6	-	300	4	7540.0	71.1
Improved stoves (wood)	24	-	408	4.83	10065.3	41.9
Improved stoves (residues)	21	-	131.8	4	4007.8	19.1
Improved stoves (charcoal)	27	-	200	1	4510.0	16.7
Improved stoves (dung)	19	-	300	4	7540.0	39.7
Biogas stoves	55	-	20.65	1.84	1004.0	1.8
Gasifier stoves	27	-	-	1.48	458.8	1.7
Natural Gas	55	90402	20.65	1.84	91406.1	166.2
LPG	55	106900	21.11	1.88	107926.1	196.2
Kerosene	45	155500	28.05	4.18	157384.9	349.7

Source: Bhattacharya and Salam (2001)

Overall, biomass energy systems, except the traditional ones, are far more environment friendly compared with fossil fuel based systems. Figure 1 shows the environmental damage costs of a number of energy sources as estimated by Ottinger et al (1991). The high environmental cost of the fossil fuels, particularly coal, shows that current market price advantage of these with respect to biomass fuels would substantially diminish if the environmental costs are considered in pricing of fuels.

Table 3. GHG Implication of Woodfuel Use for 16 Developing Countries of Asia

Environmental Effect	1994	2010
Total CO2 emission due to energy Use	4,317,000	10,602,000
Avoided CO2 emission due to woodfuel use	278,000	349,000
Avoided CO2 costs due to woodfuel use	14,000 million US$	17,500 million US$

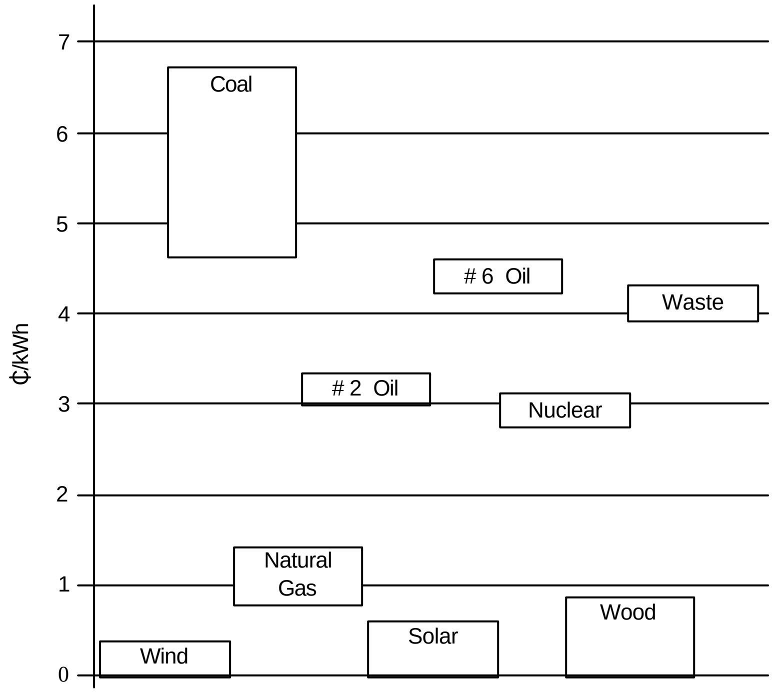
Source: Hulscher (1998).

B. Cost

1. Cost of biomass fuels

Financial viability of biomass energy technologies largely depends on the cost of biomass fuels. However, the cost of biomass fuels strongly depends on the location/country as well as type. For example a residue like rice husk may have a cost

Figure 1: Environment Cost Summary
(Estimated Externality Cost in cent/kWh)



Source: Ottinger et al 19991

ranging from negative values in situations where it has to be disposed at a cost to 10-20 US$ per ton in places where it is used for energy, or upgraded by briquetting. Similarly, the cost of plantation grown biomass also varies quite widely (see Table 4). Thus, it is not possible to obtain any set of cost values of biomass fuels that would be globally applicable.

Table 4. Summary of the Costs and Productivity of Plantation-grown Fuel

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

Source: http://bioenergy.ornl.gov/reports/fuelwood/chap5.html

Table 5 shows the costs of a number of biomass and fossil fuels in the state of Iowa of USA (Brown et al., 2000). Although the cost values of Table 5 are not for the countries of the ESCAP region, the table provides an interesting comparison between various biomass and fossil fuels; also, the comparison is qualitatively valid in many situations, including the ESCAP region, at present. For example, for heat and power applications, plantation grown biomass cannot compete with coal, although agricultural residues (as represented by corn stalks in Table 5) can be delivered at a lower cost. Similarly, transportation fuels from biomass cannot currently compete with fuels derived from petroleum.

Table 5. Estimated Costs of Biomass Fuels in Iowa, USA

Fuel	**Cost, US$/GJ**
Transportation	
Diesel	4.84
Gasoline	5.31
Methanol from natural gas	15.30
Biodiesel	10.72-21.16
Ethanol from cellulose	18.21
Ethanol from corn	11.86-26.47
Methanol from Biomass	14.61-31.50
Heat and Power	
Corn stalks	0.47
Sub-bituminous coal	0.95
Natural gas	1.90-4.74
Hybrid poplar	2.28-2.85
Switchgrass	2.75-3.32
LPG	4.65-8.06

Source: Brown et al. (2001)

2. Cost of energy from biomass

Cost of energy from biomass energy systems depends on costs associated with the fuel, e.g. plantation, harvesting, transportation etc. and costs associated with the energy systems, e.g., capital and maintenance costs.

a) Small-scale energy systems

Cost of energy for traditional thermal applications, for example cooking, varies quite widely. In most cases in rural areas, people collect their own biomass fuel and build their own stoves. Energy from biomass in such cases is practically nil (if we neglect the value of the time for fuel collection and stove building).

However, in situations where biomass fuels are purchased and utilized with low efficiency (say, about 10 per cemt), the cost of useful energy delivered to the cooking pot may be substantial and even exceed cost of energy from LPG or kerosene, particularly if the fossil fuels are subsidized. Similar conclusions were drawn by Gupta and Ravindranath (1997), who assessed different cooking energy options for the case of India. The fuel considered were fuelwood, kerosene, biogas, liquefied petroleum gas (LPG), and electricity. They found that, for rural areas, an efficient/improved wood stove (Astra-stove) was the least cost option, and biogas was the most expensive option. The subsidized kerosene option was found to be cheaper than wood in the traditional stove. In the urban situation, the subsidy on kerosene makes it a low-cost fuel option, and fuelwood in the traditional stove is among the most expensive options. (Gupta and Ravindranath, 1997).

For small-scale electricity generation, biomass energy may be more cost-effective compared with fossil fuel based generation under some situations. Thus, a number of studies show that gasifier based power generation in remote locations can be cheaper compared with diesel based power generation. This is further borne out by the growing number of remote power gasifier units in India.

In general, biomass gasification based electricity is still more expensive than electricity from the grid. However, low fuel cost, low capital cost of gasifier and high plant load factor can result in low power generation cost, which may be competitive with electricity from the grid in some situations (http://www.devalt.org/newsletter/sep/of_4.htm).

b) Large-scale energy systems

Shukla (2000) estimated the cost of electricity generation for three sizes of biomass energy technologies - 100 kW, 1 MW, and 50 MW and compared with conventional coal based generation (500 MW), as shown in Figure 2. As can be seen from the figure, large-scale power generation is competitive with coal -based generation (or electricity from the grid) in situations of low biomass fuel cost. This explains why most of biomass fuelled power generation capacity in the USA is based on a cheap fuel, i.e. waste wood. Similarly, practically all the biomass energy plants installed by the EC-ASEAN COGEN Programme (an economic cooperation programme between the European Commission and the Association of South-East Asian Nations coordinated by the Asian Institute of Technology, Bangkok, Thailand) are also based on cheap fuels, residues and wastes.

Figure 2 suggests that biomass-based power generation is normally more expensive compared with electricity from the grid (as represented by coal based power in the figure). Similar conclusion was also arrived at by Faiij and Meuleman (1997); for the case of the Netherlands, they concluded that cost of electricity produced from short rotation crops (SRC), willow, would be roughly twice the cost of electricity produced from coal. One important reason why coal-based electricity generation appears to be significantly lower compared with biomass is that external costs of energy systems are not considered in calculating generating costs. Faiij and Meuleman (2000) concluded that, if external damage costs are taken into account, the costs of electricity based on SRC and coal would be comparable.

C. Employment Generation

One important advantage of biomass energy is job creation, particularly in rural areas. Faaij and Meuleman (1997) estimated employment generation for SRC Willow based power production in comparison with coal based power generation in the Netherlands. The biomass plant is a 30 MW BIGCC plant while the coal plant is of capacity 600 MW. A summary of their results is shown in Table 6. The employment generation for biomass based power generation can be seen to be more than two times that for coal based power generation. Although the employment generation values are assessed for

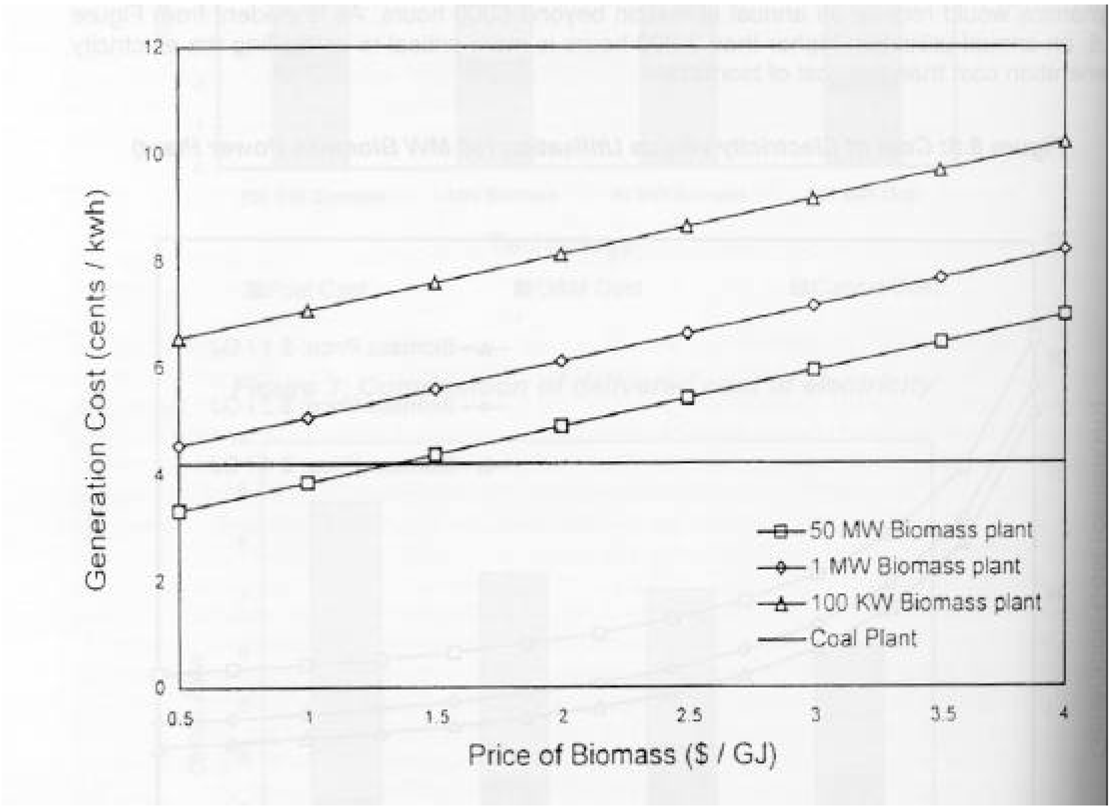


Figure 2. Costs of Power generation from biomass and coal (Shukla, 2000)

the Netherlands, these can be taken as indicative for other countries as well. However, in developing countries, where plantation is more labour intensive, the employment generation for biomass based power generation is expected to be even higher in comparison with coal.

Table 6. Estimated Employment Generation from Biomass and Coal Based Power Production

Employment generated	Biomass Based Power Generation			Coal Based Power Generation		
	Direct	Indirect	Total	Direct	Indirect	Total
Man-year per GWh	0.37	0.07-0.16	0.44-0.53	0.11	0.07-0.09	0.18-0.20

Source: Faaij and Meuleman (1997)

Table 7 shows a comparison of employment by fuel type based on a World Bank/ESMAP study of 1991 as quoted by RWEDP (1997). Considering transporting and retailing of biomass fuels, RWEDP suggested that the employment figure for woodfuels in many situations should be significantly higher than shown in the table.

Also, investment cost per job created in the biomass energy industry is relatively low; it is estimated that for the biomass energy industries, this lies between US$15,000 and US$100,000 per job (FAO, 2001) The sugarcane- ethanol industry requires only about US$ 11,000; this may be compared with US$ 220,000 in the oil sector, US$ 91,000 in the automobile sector and 419,000 in the metallurgical sector (Rosillo-Calle and Cortez, 1998)

Table 7. Estimated Employment by Fuel Type

Fuel type	Amount of fuel per TeraJoule (TJ)	Estimated Employment per TJ consumed in person days
Kerosene	29 kilolitre	10
LPG	22 tons	10-20
Coal	43 tons	20-40
Electrrcity	228 MWh	80-110
Fuelwood	62 tons	110-170
Charcoal	33 tons	200-350

Source: World Bank/ESMAP (1991) as quoted in RWEDP (1997)

The workers in the sugarcane- ethanol industry of Brazil enjoy good job security and wages with a low seasonality index; they receive higher wages on average than 80 cent of the agricultural sector, 50cent of the service sector and 40 per cent of those in industry (FAO, 2001)

The tree plantation industry is much less labour intensive; approximately 12 per cent of these jobs are needed for research and administration. For short rotation crop (SRC) based power generation, jobs are created for direct as well as indirect employment. Direct employment is needed for fuel production, harvesting, transport processing etc. as well as for construction and operation of the power plants. Indirect employment is generated in other sectors of the economy due to implementation of the power project.

D. Stakeholders and Management

A biomass energy system may involve a wide range of stakeholders, e.g. growers/producers, environmentalists, industry, consultants, financial institutions, researchers, regulators, state and local officials etc. Biomass energy systems, which may involve multiple stakeholders, multiple fuels, complex fuel acquisition, handling, preparation and storage, diversity of conversion technologies as well as coproducts are often more complex than other renewable energy or fossil fuel based systems.

The simplest projects are those involving only one predominant stakeholder, for example energy systems based on wood- or agro-processing residues implemented by the residue generating facility, which also consumes the energy generated. Such projects are also normally economically attractive, particularly if the residue has to be disposed otherwise. This explains why most of the earliest biomass energy projects were established for captive energy generation in certain industries, e.g. sugar mills, pulp and paper mils etc. Similarly, of the thirteen full-scale demonstration projects that have been implemented so far under EC-ASEAN COGEN Programme, twelve serve to meet demand of the host facility.

Complexity of a biomass energy project in terms of implementation and management increases with increasing number of stakeholders. A common external stakeholder is a local utility, to which surplus power is to be sold. Often, protracted negotiations and government interventions may be necessary to lay down rules acceptable to all the parties concerned regarding important issues, for example, buy-back rate. Considering the advantage that renewable energy based power generation offers, such regulations have already been established in some Asian countries, e.g. India and Thailand.

An example of complexity introduced by external stakeholders is case of energy systems based on residues, such as rice husk or saw dust, obtained from the local market is rise in the price of the residue once a biomass energy project utilizing the residue established. A number of rice husk briquetting plants established in Nepal in late 1980s were later closed because of low profitability, one main reason being an increase in the local cost of husk. Long-term supply contracts with the residue generators (i.e. rice- and saw-mills) may be a satisfactory approach to avoid this type of risk in such cases.

Biomass energy systems based on energy plantations appear to be more complex, particularly if the plantation is owned by external stakeholders. Such plants need more careful planning, are difficult to coordinate/manage, may face opposition from local communities and environmental groups, and need long time to implement. In the extreme case, a bimass energy project may fail if it cannot secure effective participation of all key stakeholders. Thus, one important reason behind the failure of the dendropower program of the Philippines in the 1980s was involvement of a large number of stakeholders and lack of coordination among them, particularly the power plant owners and the tree planters.

IV. POLICY OPTIONS FOR PROMOTING BETs

A. Barriers

Although biomass has been in use for energy since time immemorial in traditional energy systems, modern BETs have not yet found wide acceptance. In fact, some of these are still in early stages of demonstration and commercialization. Modern BETs face a wide range of barriers, which must be removed for these to play a significant role in the energy scene.

1. Technical barriers

Some of the BETs, for example Stirling engines, clean carbonization systems, biomass pyrolysis for producing liquid fuels, alcohol from cellulosic materials etc, still need further research and development efforts. Even the operational feasibility of the relatively mature BETs - for example gasifiers, efficient cogeneration systems, biogas digesters etc. - have not yet been proven in many Asian countries through adequate demonstration. Also certain BETs - for example, briquetting machines in rice mills, and cogeneration systems in saw mills - are often regarded as rather complex by the potential users. In view of the above and poor performance of certain past demonstration projects in some countries - for example, rice husk gasification in

Thailand, dendropower program in the Philippines and Stirling engines in India - manufacturers, and entrepreneurs often perceive the modern BETs as risky.

Lack of local expertise/manufacturers/agents, lack of maintenance service and in some cases lack of standardization lead to poor performance of BETs. In addition, each of the BETs normally has certain characteristic technical problems of its own. These include problems created by tar in case of gasifier-engine systems, high maintenance requirement of screws in case of briquetting machines and inefficient operation of biogas digesters in winter or cold climate.

2. Institutional Barriers

Lack of coordination among institutions involved in RE development and commercialization, e.g. Ministries of Energy/Science and Technology, research institutes, electric utiltites, financial institutions etc. hinder sustained efforts for promotion of RETs. A government agency specifically mandated to promote RE development through coordinated efforts appears to be important for promoting RE. Thus, the remarkable growth of RE industry in India is largely attributed to the existence of a dedicated ministry, the Ministry of Non-conventional Energy Sources (MNES) and a government established financing agency, the Indian Renewable Energy Development Authority (IREDA).

National research institutes can play a key role in promoting renewable energy technologies (RETs) through their involvement in adaptive research, local manufacturing of RET sytems, providing consultancy service to the industrial users etc. However, most research institutes in developing countries suffer from a host of problems, e.g. lack adequately trained researchers, chronic shortage of funds, lack of access to international literature etc.

Provision of consumer credit is important for successful promotion of small renewable energy systems. As a study of the Global Environment Facility suggests " consumer credit can be provided effectively by microfinance organizations with close ties with the local communities….." (GEF, 1999). However, such microfinance organizations or other mechanisms for providing consumer credit do not exist in most situations; this amounts to another institutional barrier to the diffusion of certain BETs.

Influence of the electric utilities on national policy making has been claimed to be an important barrier to the dissemination of RETs in Africa since the small, dispersed, and modular nature of RE systems is alien to the culture of the conventional utilities, which are more comfortable with large-scale and centralized systems. Also, as pointed out by Karekezi and Ranja (1997), "many national utilities have no institutional interest in fostering competing sources of electricity". Similarly, the multinational petroleum companies often obstruct successful implementation of renewable energy programmes, directly, or through their established national subsidiaries. Examples of such cases of obstruction in two African countries, Kenya and Malawi have been pointed out by Karekezi and Ranja (1997).

3. Information Barriers

Limited information on national renewable energy resource base is a barrier to diffusion of BETs in many Asian countries. This is compounded by the fact that in the case of biomass, resource data are needed at the local level. Considerable efforts and time are normally needed for establishing such resource database.

Lack of information on currently commercial/mature BETs is another barrier to wider use of BETs. In the absence of reliable information, potential users/entrepreneurs are likely to perceive investments in biomass energy systems as risky.

4. Financial Barriers

Although the energy supply accounts for a major share of infrastructure related investments in most countries, investment in the field of bioenergy is still minimal in most Asian countries. This appears to be due to a variety of reasons, including lack of information about resource base, lack of information about efficient and reliable technologies and, probably some sort of bias against biomass energy. The perceived risks of bioenergy, as pointed out above, also act as major barrier to investments by both the public and private sectors.

Existing capital markets do not favour small-scale investments as normally required for some renewable energy (RE) systems for example, solar home systems and improved stoves since financial institutions/agencies cannot efficiently handle small capital requirements for RE systems.

5. Market Barriers

The prevailing low price of oil in the international market has seriously eroded the financial viability of many RE systems. In fact, this has already adversely affected many on-going renewable energy programs, resulting in significant scaling down in some cases, for example, the ethanol program in Brazil.

The situation is further aggravated by subsidy given to fossil fuels in many countries. It has been pointed out that worldwide government subsidies for conventional energy was US$ 250-300 billion per year in the mid-1990s (de Moor and Calamai, 1997). In India, the Government spent about US$ 1.5 billion annually for subsidizing kerosene in the late 1990s (Forsyth, 1998). Subsidy for fossil fuels distorts market in favour of these fuels; for example, this gives diesel generators an unfair advantage over gasifier engine systems.

B. Policy Measures for promoting BETs

1. Investment incentives

Investment incentives serve to promote investments in a target area by reducing capital cost requirements of the private developers and can be in the form of investment subsidies, or tax credits.

Investment subsidy is often provided as a fixed amount of support per unit capacity of the energy plant, e.g. $/kW; it can also be in the form of a fixed fraction of the total investment cost. Investment subsidy is very commonly used to stimulate renewable energy market development; thus, in the Netherlands and investment incentive of 35-40 per cent was given to new wind turbines in the 1980s. In India, investment subsidy is provided to all major RETs; for example, the subsidy is Rupees 3.5-4.5 million per MW of surplus power in case of cogeneration in sugar mills. Although investment subsidy is very commonly used for promoting RETs, one potential disadvantage of this incentive is that the investors may claim an artificially inflated investment cost in order to maximize their benefits.

Tax credits serve to reduce the tax burden of the project developers and thus lower investment costs indirectly. The most common tax credit is investment tax credit, which reduces tax of the developers by an amount depending on the amount of investment. These credits are less transparent than investment subsidies, may be subject to abuse and may not be fully availed by small investors.

Tax credits can also take other forms, e.g. reduction in import duty, accelerated depreciation, reduction in property tax etc.

2. Production incentives

Production incentives are paid per unit of energy generated (e.g. cents/kWh). One advantage of this incentive is that it motivates the project developers to maximize energy generation and promotes more efficient systems. On the other hand, one crucial disadvantage is the risk of possible elimination of the incentive due to policy change at some stage during the lifetime of the energy installation.

3. Power Purchase agreements

Private developers would undertake biomass energy projects for (surplus) electricity generation only if they can sell the power to a party based on a long-term power purchase agreements. Such agreements have played a key role in implementation of most electricity generating projects based on renewable energy/biomass energy in many countries.

The power is commonly sold to the local utility. Alternatively the power can be sold to a third party by "wheeling" through the transmission and distribution grid of the utility.

Power purchase agreements are the most basic requirement for independent power production to be feasible. In fact, the independent power industry came into existence as a result of power purchase agreements incorporated in the 1978 Public Utility Regulatory Policy Act (PURPA) of the USA. As claimed by Roos et al. (2001), the "law created a window of opportunity for alternative energy forms in the country". More details of PURPA are given in Box 3.

Power purchase agreements are vital for promoting large electricity-generating renewable energy based projects. Standardized contracts serve to reduce project development cost.

Box. 3. The Public Utility Regulatory Policy Act (PURPA)

The initial growth of Renewable energy industry in the USA was a result of the Public Utility Regulatory Policy Act (PURPA) of 1978. The act required that all utilities of the country to buy electricity, at their avoided cost, from qualifying independent power producers and small-scale producers of electricity from renewable energy.

The act provided a vital stimulus for growth of renewable energy industry by establishing secure access to market and predictable prices. As a result of the act and federal as well as state incentives, the act resulted in massive development of renewable energy in USA including about 8000 MW of biomass base power generation. The state of California was more aggressive in promoting renewable energy; it developed and standardized power purchase contracts and provided an investment tax credit of 25 per cent in the 1980s. In USA, development of renewable energy was therefore more dramatic in California, which had until recently, the largest wind power capacity of the world.

The nature of incentives for renewable energy underwent changes since the initiation of PURPA. In mid-1980s, some investors could recover more, and in some cases significantly more, than 60 per cent of investment through federal and state tax incentives in California. In order to stimulate energy production, rather than just establishment of projects, subsidy for wind power was changed from investment tax credit to production tax credit in 1992.

Overall, there is no doubt that PURPA and related incentives served to establish renewable energy industry in the USA by providing crucial support during the initial stages of its growth. Also, it generated important lessons for effective promotion of renewable energy. Thus, the California experience showed that creation of standard power purchase contracts can be very useful in reducing transaction costs and delays compared with contracts negotiated separately. Also, investment tax credit has some pitfalls and appears to be less effective than production tax credit.

4. Renewable Energy Set-asides

Basically, under this policy measure, a percentage of the total electricity generation capacity is earmarked for non-fossil energy sources. One of the first set-aside schemes was the Non Fossil Fuel Obligation (NFFO) system of the UK (Mitchell, 1995, Reddy et al., 1997; Lew, 1997). The NFFO required the electricity producers to have a minimum of their generation capacity based on renewable energy. Some details of the NFFO and its impact in the UK are presented in Box 4.

A similar scheme in the USA is the Renewable Portfolio Standard (RPS), under which each retail supplier of electricity must provide a minimum percentage of renewable energy in its portfolio of electricity supplies (Reddy et al., 1999); for this purpose, the retailers can either purchase or produce their own RE based electricity.

5. Strengthening Public-Private Partnership

It has been pointed out by Faulkner (1999) that the public sector lacks financial and technological resources as well as management skills to meet expanding demand for services including energy. Also, the private sector has such resources as well as "proven track record of providing lower production costs". Thus, for commercialization of RETs to make any significant headway, it is would vital to engage the private sector effectively.

Public-private partnership (PPP) is implicit in the development and demonstration of new technologies, including renewable energy technologies. Involvement of the public sector often serves to instill confidence of the private sector to invest in renewable energy projects.

PPP is likely to be of particular importance in case of large and complex renewable energy projects involving advanced technologies. In the USA, the Department of Energy often funds a substantial portion of complex renewable energy projects; an example in the field of biomass energy is an IGCC plant being implemented by a private entity, Future Energy Resources Corporation, in Vermont (http://www.future-energy.com/ProjectDetails.asp?ProjectID=1). In case of developing counties similar government involvement would be desirable in deployment of complex biomass energy technologies, including those to be transferred from the developed countries.

Government's role in developing renewable energy market is vital for involving the private sector in renewable energy business. Government's role is also important in developing local manufacturing ability, which, besides reducing cost, would also generate employment. Setting up technical standards and technology packages, and providing testing facility and certification by the government can help renewable energy technologies to mature and ensure end-user satisfaction.

An example of government's assistance towards technology standardization/upgrading is the case of renewable energy in India, where the Ministry of Non-conventional Energy Sources (MNES), in order to facilitate development of biomass gasification in India, established four Gasifiers Action Research Centers (GARCs) at Indian Institute of Technology, Bombay; Indian Institute of Technology, Delhi; Indian Institute of Science, Bangalore; and Madurai Kamraj University, Madurai. These GARCs have been developing application packages, undertaking testing and evaluation of gasifiers under field conditions and organizing training for different target groups including manufacturers, operators and users (MNES, 1998).

As a result of active support of the government, biomass gasifier market has been developing steadily and a number of biomass gasifier systems are now available commercially (Tripathi et al., 1999).

While the government can play a vital role in developing and supporting renewable energy market, lack of interaction between the government agencies and the private sector can lead to dramatic failures. In late 1980, a private manufacturer started marketing rice husk powered Stirling engines in India, apparently without any support from the government. A total of about 100 engines were installed in the field; however, the engines developed technical problems and had to be abandoned.

Thus an effective government support for the private sector can make or break a technology.

Box 4. Non Fossil Fuel Obligation, UK

Renewable energy industry grew in the UK as a result of the Non Fossil Fuel Obligation (NFFO) as a part of the 1989 Electricity act, which was originally meant to subsidize nuclear power. Under NFFO, the government introduced a levy on fossil fuel-based electricity to support electricity based on non-fossil sources. NFFO included both nuclear and renewable energy. Initially, most of the money raised was used to subsidize nuclear power originally; however, a small amount of the levy was used to support renewable energy and provided it a vital stimulus for growth.

Originally under the NFFO, the producers were required to have a minimum of their supply capacity in renewable energy based generation. The regional electricity companies were required to buy at a premium price a certain amount of electricity based on designated renewable energy sources; the difference between the premium price and market price of electricity was paid by a 10 per cent levy on fossil fuels consumed by the utilities.

The NFFO is implemented through periodic bids invited from renewable energy based power producers; for each technology band, developers with the least bid (price per kWh) are awarded power purchase contracts.

The details of NFFO have changed since its initiation; for example the levy dropped to 2.2 per cent on the price of electricity in1998. The first two rounds of NFFO guaranteed premium power purchases only until 1998, but for the later rounds the period of premium power purchase price was extended to 15 years.

The latest NFFO round ended in 1998, although the levy still continues and is used to pay for projects with renewables order contracts still running. The Government's new renewable energy strategy puts an obligation on all electricity suppliers to provide an increasing proportion of their power from renewable sources; also an ambitious target, for 10 per cent of electricity to be supplied from renewable sources by 2010 has been adopted.

Overall, the NFFO provided a vital boost to renewable energy in the UK and led to development of renewable energy industries and lobbies. For example, the NFFO 5 involves a total of 261 contracts and total renewable power generation capacity of 1177 MW. The impact of NFFO can be seen from the development of wind energy in UK, which now has a total installed wind power capacity of over 343MW. The price of electricity from wind came down significantly. The average bid price for wind energy projects (regardless of size) fell by 31 per cent between NFFO3 and NFFO4.

6. Other Options

a) Research, Development and Demonstration

In general, research and development efforts are needed to enhance local manufacturing ability, improve self-reliance and reduce foreign exchange spending for imports.

Some biomass energy devices, for example improved stoves and energy devices used in traditional/cottage industries need to be designed considering local needs and traditions. Therefore these devices need to be manufactured locally and call for research and development efforts at the local/national level. Also some biomass energy devices, for example gasifiers, are characterized by small capacity. Local manufacturing of these is vital for reducing cost and improving availability of spare parts and reliability of maintenance service. Again, research and development activities are needed for this purpose. In the ESCAP region, many renewable energy technologies have been developed as a result of local research and development activities- these include gasifiers in China and India, biogas digesters in China, India and Nepal, small wind turbines in China and Vietnam, micro-hydro turbines in Nepal etc. Further efforts will be necessary to improve the existing technologies and develop new ones.

Demonstration projects on RETs serve to stimulate public interest as well their markets. Therefore, such projects should be undertaken in the initial stages of commercialization of technically mature RETs.

b) Institutional development

Suitable policy intervention by the government would be necessary to overcome obstruction by electric utilities and other vested interest groups to diffusion of RETs. Establishment of independent rural electrification agencies could be an important step in removing this type of barrier. Alternatively, existing electric utilities could be mandated to base a part of their total electricity production on renewable energy sources. The renewables Non-Fossil Fuel Obligation (NFFO) in the United Kingdom is an example of such government interventions.

Considering the constraint of technical manpower that many developing countries face, a regional network of research institutes could also be useful. The participants of a regional workshop on commercialization of RETs for sustainable development also recommended sub-regional and international cooperation, particularly within the framework of Technical Cooperation among Developing Countries (ESCAP, 1999). The group also recommended the operationalization of a regional network for promotion of RETs in the region.

The Swedish International Development Cooperation Agency (Sida) has been funding a regional research and dissemination programme on RETs in Asia. The first phase of the programme, coordinated by the Asian Institute of Technology (AIT) involved twelve national research institutes of six Asian countries: Bangladesh, Cambodia, Lao PDR, Nepal, the Philippines and Viet Nam. More details of the RETs in Asia programme is presented in Box 5; the experience of the programme shows that a regional networking of this type creates a unique opportunity of sharing work, joint product development, exchanging results and learning from each other so that, for a given input of resources, much more can be accomplished compared with conventional projects.

Box 5. Renewable Energy Technologies in Asia: A Regional Research and Dissemination Programme - Phase I

RETs in Asia: A Regional Research and Dissemination Programme was initiated by Sida in 1996 to promote a few selected RE technologies - photovoltaics (PV), solar drying, and biomass briquetting - in Bangladesh, Cambodia, Lao PDR, Nepal, the Philippines and Vietnam. The programme is coordinated by a senior faculty member of the Asian Institute of Technology, a Thailand-based international postgraduate institute. The first phase of the (RETs in Asia-I) involving 12 National Research Institutions (NRIs) covered the period of 1997-1998. A three-year second phase of the programme started in 1999.

The programme addressed country-specific requirements of RE technologies. Adaptive research under the programme has led to the develoment and demostration of the following:

* Solar and solar-biomass hybrid dryers
* Improved PV accessories
* Improved briquetting systems
* biomass/briquette-fired improved stoves

The programme has developed local expertise through training programmes and collaborative research. The systems developed have been demonstrated to users, entrepreneurs and policy makers. Manuals for construction, operation, maintenance, and troubleshooting, often in local languages, have been prepared. The technologies developed and related issues have been made known to a broader audience including policy personnel in the participating countries through dissemination seminars, publications of articles in journals, conferences, production of brochures and videos, and through a website <http:www.retasia.ait.ac.th>. The seminars were very successful in bringing policy personnel, researchers, entrepreneurs and media together.

The major impact of the programme has been the strengthening of the research capacities of the participating institutions in the area of RE technologies through sharing of work and learning from each other. Demonstration and dissemination of RE systems has already resulted in a number of measures undertaken in the countries involved, for example introduction of standards for PV equipment and technician training as well as subsidy for solar drying in Nepal. Development of PV accessories have substantially reduced their cost in local markets and dependence on imports. The programme has also launched certain RE technologies in some countries, for example, solar drying & PV in Cambodia. Overall, the RETs in Asia-I has given a significant thrust towards the commercialization of RE technologies in the countries involved in the programme.

c) Information dissemination

If decision makers and planners do not have information on new developments/ status regarding RETs, and their advantages/disadvantages, it is unlikely that they would undertake initiatives or establish policies to promote these technologies.

Development and maturity of many RETs are taking place rapidly. Preparation and dissemination of technology assessment reports and regular updating of such reports should go a long way in helping government energy planners and entrepreneurs to make a rational selection of their energy options.

Potential entrepreneurs interested in entering in to biomass energy business, often do not have access to the necessary information to assess projects, technology, suppliers, successful references, power purchase agreements, government support available etc. Preparation and dissemination of information packages, including case studies of successful packages for them would facilitate their entry into biomass energy business.

V. Medium- and Long-Term Considerations

A. Technology Transfer

Most of the advanced BETs are being developed in the industrialized countries. Examples of such technologies include Stirling engines, advanced biomass based power generation and cogeneration technologies, alcohol production from cellulosic materials etc. For facilitating rapid dissemination of biomass energy technologies and increasing its share the total national energy consumption, it would be important to facilitate transfer of the modern BETs to the developing countries.

The Kyoto Protocol emphasized the importance of the transfer of GHG mitigating technologies; it urged all parties concerned "…..to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies, know-how, practices and processes, in particular to developing countries….". Thus, climate change concerns are expected to promote transfer of GHG mitigation technologies, including BETs.

Similar to diffusion of RETs inside a country, transfer of RETs across countries faces a range of barriers. The results of an UNFCCC study, based on a survey of a limited number of projects are shown in Table 8 (FCCC, 1998). The table suggests that the key barriers, in decreasing order of importance are: financial, economic, technological, institutional, and cultural. Also, access to national and international funding was seen a major obstacle to technology transfer.

Although, most of the countries included in Table 8 are not from the Asia Pacific region, the results are likely to be largely valid for this region also.

B. Integration

As pointed out by Roos et al. (1999), integration of biomass energy activities with industries generating wastes, e.g., forest industries, agro-industries or municipal solid waste, including skills and structures is an important factor for market development. They also cited an example of successful pellet market development in the USA, where integration of pellet making with other activities is accomplished as follows:

" Pellet stoves are co-produced with other stoves
Pellet factories use wood industry residues and contract local transporters

Pelletizing equipment is co-manufactured with agricultural equipment
Pellet and stove dealers also sell other stoves, equipment for swimming pools etc."

Market development of biomass energy in ESCAP region can be facilitated through such integration due to complementarily effects of activities and reduction in transaction costs as a result.

Cost of establishing a new dissemination infrastructure for renewable energy alone can be significantly reduced by using an existing system. For this purpose, renewable energy dissemination can be carried out as an integral component of an existing rural development programme, community welfare programme etc.

Table 8. Barriers to the transfer of technologies as identified by Parties (FCCC, 1998).

Reporting Countries	Key Barriers	Category
Belize, Guinea, Latvia, Mali, Poland, Korea	Lack of finance, terms of funding	Financial
Mali	Inability to obtain international finances for dissemination of indigenous technologies	Financial
Mali, Kiribati	High investment cost	Economic
Mali, Poland	High cost of service and maintenance	Economic
Zimbabwe	Affordability for technology users	Economic
Albania, Panama	Lack of access to technical information	Technological
Mali	Lack of supply of spare parts	Technological
Egypt	Lack of technical capacity	Technological
Egypt, Guinea, Indonesia	Lack of local management skills, training of personnel	Institutional
Barbados, Costa Rica	Lack of public acceptance: low level of public awareness	Institutional
Mali	Cultural, including perceived comfort	Cultural

C. Human Resource Development

Renewable/biomass energy development involves a number of rather complex issues. These include

- assessment of the emerging technologies
- identification of the most appropriate technologies that would suit the country/district/community in question
- identification of a host of barriers to dissemination/development of RETs
- formulation of policy measures to overcome the barriers
- keeping track of developments of the Kyoto mechanisms
- research, development and adaptation of RETs

Many developing countries, particularly the least developed ones, lack human resources needed to address the above issues; this is a major barrier to dissemination of RETs in these countries.

Capacity building in the developing countries, especially the least developed amongst them, is vital for facilitating development and dissemination of renewable energy.

D. Environmental Taxation

Externalities can be included in energy price by imposing appropriate taxes on emissions, for example sulphur tax to mitigate acid rain, carbon tax to mitigate carbon dioxide emission, and energy tax to improve energy efficiency.

Worldwide, there is a great deal of experience about such taxes. The taxes make renewable energy, which is exempted from environmental taxes, relatively more attractive. The growing popularity of biomass pellets in Sweden, where 500,000 tons of pellets are consumed annually, is mostly due to environment and energy tax levied on fossil fuels. Developing countries of Asia could benefit from such experiences in the developed countries in formulating suitable policy measures aimed towards internalizing externalities.

Figure 1 suggests that the cost of power generation from coal should increase relative to biomass by about US cents 4/kWh if externality is taken into consideration. Shukla (2000) estimated that the cost of power generation from coal would increase by 1.2 US cents/kWh under a low environment tax case and by 2.4 US cents/kWh under a high tax case. A recent study assessed the environmental externalities of coal and biomass to be 1.20 and 0.21 US cents (1997) per kWh respectively for the case of Thailand suggesting that the externality of coal relative to biomass is about 1 US cent/kWh; this appears to be lowest estimate of expected increase in power generation cost from coal relative to biomass if externalities are internalized. Even if this lowest value is taken into account, many biomass energy systems can become viable in comparison with coal energy systems. As shown in Figure 2, the estimated generation cost of large biomass plants (50 MW) is higher by about US cents 0.70 per kWh in comparison with large-scale generation based on coal for a moderate biomass fuel cost of US$ 2.0/GJ. If a relative externality of US cent 1/kWh is added to coal based generation, cost of power generation from a large biomass plant becomes cheaper compared with coal based generation. This suggests that with a fair pricing of energy, biomass based power generation would be viable even at present, in spite of the prevailing low price of fossil fuels.

Since one of the main reasons behind the current interest of renewable energy is the environmental impact of large-scale use fossil fuels, it appears irrational that this concern is not reflected in pricing of energy today.

VI. CONCLUDING REMARKS

Energy consumption in the developing countries of Asia is rising rapidly. It is likely that environmental considerations will constrain their access to fossil fuels in the future. As a result, the share of renewable energy in general and biomass in particular, in the total energy supply is expected to rise in the future.

Table 9. Major Barriers to BETs and possible measures

Technology	Some major Barriers	Some selected measures
All	Subsidy for fossil fuels Lack of a national RE coordinating agency Lack of national technical expertise High cost Lack of information/awareness	Abolish subsidy Establish a national RE coordinating agency Human resource development, Regional networking, TCDC Introduce subsidy for initial market development, standardized procedures and agreements Technology assessment, publicity campaign, demonstration
Improved stoves	Initial cost Lack of awareness of health impact Lack of suitable design for local habits/traditions in some countries	Establish micro-financing entities. Publicity campaign, integrate with rural development efforts. R & D, certification, train stove manufacturers
Gasifier	Lack of reliable designs and successful references in some countries	Technology transfer, R & D, Certification, Demonstration Pilot SRC based Others Training of technicians and entreprenuers
Biogas digesters	Lack of reliable designs and successful references High cost	Technology transfer, R & D, Certification, Demonstration, Training of technicians Subsidy, slurry use as fertilizer, integrate with rural development efforts.
Improved charcoal making	Lack of reliable designs and successful references	Technology transfer, R & D, Certification, Demonstration, Training of technicians.
Cogeneration and power generation.	Lack of successful references High risk investment High transaction cost	Demonstration Financial incentives, power purchase agreements and reasonable power purchase rate Standardize Power purchase agreements
New technologies: Alcohol, Biodiesel, Stirling engines, Fuel cells, IGCC	High cost	Technology transfer Subsidy

Many modern biomass energy technologies are fully or nearly mature at present. Some of these are already commercially demonstrated. The pace of commercialization and deployment of these technologies is expected to accelerate in the future as the climate change debate intensifies; commercialization can be further facilitated through removal of a host of barriers these technologies face at present. Table 9 presents a summary of the major barriers to BETs and selected measures for removing them.

One of the most important barriers BETs face is subsidy provided for fossil fuels and fossil fuel based power generation. Most of the poor people do not have access to subsidized energy. There is an urgent need to revisit energy pricing policies.

The private sector, which normally has funds to invest, needs to be involved in renewable energy development. Also, considering the need for governments to remain involved in providing essential services (including energy), public-private partnership would also be an important approach to renewable energy development.

Provision of modern energy services is a vital ingredient of rural development. Also, RETs often offer the most appropriate option for meeting energy demand in rural/remote areas; these therefore should be promoted as an integral part of rural development programmes.

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