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REGIONAL WOOD ENERGY DEVELOPMENT PROGRAMME IN ASIA
GCP/RAS/154/NET

OPTIONS FOR DENDRO POWER IN ASIA:
REPORT ON THE EXPERT CONSULTATION

Manila, Philippines

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For copies write to: Regional Wood Energy Development Programme
c/o FAO Regional Office for Asia and the Pacific
Maliwan Mansion, Phra Atit Road,
Bangkok, Thailand.

Tel: 66-2-280 2760
Fax: 66-2-280 0760
E-mail: RWEDP@fao.org

Or visit our web site: http://www.rwedp.org

FOREWORD

Dendropower is electricity generated from woodfuels. Modern technology allows for efficient, clean and sustainable use of wood for dendropower, as has been demonstrated in several industrialised countries. Is it also cost-effective? The answer depends on site specific conditions and the valuation of external benefits.

In the early 1980's experiences with dendropower in Asia, specifically in The Philippines, were disappointing for a variety of reasons. However, in the last 15 years a lot has changed which calls for a fresh look at the options for dendropower in Asia. Amongst the changes are improved fuel conversion technologies, accommodation of mixed wood-biomass feedstocks and even mixed coal-wood feedstock, improved management methods for tree production systems, improved techniques for woodfuel harvesting and processing, enhanced economies of scale, expanding electricity markets, new regimes for electricity generation and distribution, and new funding mechanisms. Notably amongst the latter is the increasing involvement of large utility companies, oil companies and insurance companies in the renewable energy sector.

All these factors imply that we are in a situation which is totally different from that of 15 years ago. Furthermore, increasing worldwide concerns about the emission of greenhouse gases point to better use of renewable energy sources. Amongst the renewables, wood fuel - if sustainably produced - is the most obvious one.

An expert consultation convened by RWEDP in Manila, Philippines, April 1998, reviewed and analyzed the options for dendropower. A major input into the meeting was a special study by Prof. P.R. Shukla of the Indian Institute of Management at Ahmedabad, India, on 'Dendropower and Wood Fuel Production Systems: Economic Analysis and Implementation Strategies[*]. The experts in Manila discussed this study as well as other reports, and came up with a set of recommendations for the development of dendropower in Asia.

One of the concrete suggestions is to prepare a dendropower demonstration project of 20-40 MW at a suitable location in Asia, based on woodfuels from dedicated tree plantations, perhaps, but not necessarily combined with other biomass feedstocks. RWEDP is in the process of facilitating a study to identify and evaluate the resource potentials for such a plant.

Willem Hulscher,
Chief Technical Adviser,
FAO/RWEDP.

[*] ***included as Chapter 8 in the document***

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PART I: REPORT ON THE CONSULTATION

1. OPENING CEREMONY

Opening statements were delivered by Mr. Sibal, FAO-representative, the Philippines, Dr. W. Hulscher, CTA of RWEDP and Dr. Francisco Viray, Secretary of the Department of Energy of the Philippines. The opening ceremony was attended by the Ambassador of the Royal Government of the Netherlands in the Philippines. The opening ceremony was covered by radio and television and started with the National anthem.

1.1 WELCOME ADDRESS – MR. SIBAL, FAO, THE PHILIPPINES

The FAO Representative in the Philippines, Mr. Sibal reflected on the multisectoral linkages that relate to fuelwood, and the complexity of the issue. He reminded the audience that FAO has, for decades assisted its member countries in wood energy development, originally to guarantee 'cooked food security'. Now, the Regional Wood Energy Development Programme has 16 member countries and covers many aspects of wood energy development, including modern applications. Some of the important issues to be tackled in the Expert Consultation on Options for Dendropower generation are related to resources, managerial and financial options and policy implications, he stated.

Mr. Sibal expressed his appreciation for the timeliness of this meeting in the aftermath of the Kyoto Summit in December 1997, where countries made commitments to reduce greenhouse gas emissions. As RWEDP has shown, woodfuels are typically used in a sustainable way, and contribute significantly to greenhouse gas abatement. Prof. Shukla and Mr. N. P. Singh's draft report is an important input to this meeting on dendropower. Since the Philippines unsuccesful experience with dendropower in the 1980's, new technologies and environmental policies have emerged, and a re-evaluation of development is appropriate. FAO has links to several other international organisations with an interest in this subject. These links are illustrated in the composition of the delegates to this meeting. Mr. Sibal ended his welcome statement by wishing the delegates a fruitful time in the meeting and a pleasant stay in Manila.

1.2 OPENING STATEMENT - DR. HULSCHER, CTA OF RWEDP

Dr. Hulscher, CTA of RWEDP emphasised the need to look at the future of dendropower, rather than re-analysing the failure of the Filipino Dendropower Program in the 80's. He noted that on several international platforms such as the European Bio-energy Conference in Copenhagen and conferences and reports of IEA, WEC, UNDP and FAO, modern biomass energy technologies have recently been identified as clean, reliable and economically competitive both in industrialised and developing countries. An example is the advanced dendropower project in Brazil, initiated by local electricity companies and Shell. Also in Asia, the momentum for biomass based power generation is building up. However, as recently recognised by the Asia Pacific Forestry Commission, appropriate market policies and pricing arrangements are a prerequisite for transforming wood energy from a traditional fuel into a modern form of energy. The ASEAN energy ministers were recently briefed by RWEDP on the recent developments in biomass power generation worldwide.

As a recent RWEDP study revealed, the use of woodfuels in Asia helps significantly in mitigating global warming. Several presentations in this meeting cover how woodfuels fit into the present global climate debate. Other topics in the program are project packaging, power sector developments, institutional requirements and the impacts of the present economic crisis for biomass power development. Dr. Hulscher thanked the Department of Energy of the Philippines for organising the meeting.

1.3 OPENING STATEMENT – DR. F.L. VIRAY, SECRETARY, DOE, THE PHILIPPINES

Dr. Francisco L. Viray, Secretary of the Department of Energy, the Philippines stressed that, similar to all other technologies using New and Renewable Energy Sources (NRES), proper boundary conditions first need to be established. Although dendropower is not included in the present DOE plans, this workshop may be instrumental in the formulation of a window of opportunity for private sector investment in large-scale dendropower projects in future renewable energy policies. This consultation may reveal what went wrong with the past dendropower programme in the Philippines.

2. SUMMARIES OF THE TECHNICAL PAPERS

2.1 ENERGY, CLIMATE AND BIOMASS

2.1.1 FCCC, IPCC and the Kyoto Protocol – Dr. P.R. Shukla

Dr. P.R. Shukla addressed the institutional aspects of the ongoing debate on climate change. After the UNCED meeting in Rio de Janeiro in 1992, the Framework Convention on Climate Change was signed by 170 countries in 1995 in Berlin. The FCCC aimed to stabilize greenhouse gas concentrations in 2000 at 1990 levels, which was considered safe. IPCC had calculated that a 60% reduction in global carbon emissions would be necessary to achieve this.

Since the FCCC contained no binding emission reduction targets and was therefore ineffective, the first Conference of the Parties (COP1) to the FCCC was called in Berlin in 1995. Here, it was recognized and stated in the Berlin Mandate that the so-called 'Annex 1 countries' (these were the member countries of the OECD at the time of adoption of the FCCC) were not on track to meet 1990 emission levels in 2000. There was a need to define emission targets after 2000 as well. Even a reduction to 1990 levels was not considered enough to achieve safe levels of GHG. A working group was formed to produce a draft text to serve as a basis for negotiations at the COP3 meeting in Kyoto, Japan.

The Kyoto protocol provides for binding emission reduction targets for 6 greenhouse gases, which are differentiated for the countries based on the five-year period 2008-1012. It includes carbon sinks as an option to mitigate emissions. It allows for unlimited trading of carbon emission rights amongst Annex 1 countries. Also, it commits all countries to cooperate in the development and transfer of climate friendly technologies.

The protocol mentions Joint Implementation (JI) projects as options to transfer credit and jointly achieve emission targets with multiple Annex 1 countries. Pilot projects under the Activities Implemented Jointly (AIJ) concept are aimed to gain experience, and cannot yet receive carbon credits (this issue will be decided upon in 2000). Both the host and investor country governments should support them using additional resources beyond normal ODA flows. The projects should support broader national development objectives. Annex B countries are also allowed to trade emissions among themselves. Mechanisms and rules for target based emission trading have not yet been established.

The Clean Development Mechanism (CDM) concept differs from JI in that it allows for Annex 1 countries to invest in emission reduction projects in developing countries, under uniform guidelines. Some part of the emission reductions so achieved may be credited to the investor country. CDM project benefits are partially used to support adaptation measures for vulnerable countries, and partially to finance the CDM supervising and certifying body. The CDM concept is still under discussion, but will be operational in 2000.

An OECD study showed that the costs of carbon trading will be around 0.6% of GNP for the OECD countries, or 150 million US$. However, in the absence of trading mechanisms, some 2% of GNP would indirectly be the economic costs. It therefore saves some 250 million US$. Depending on the commitments and geographical coverage, some 3-16 billion US$ is expected to be traded in 2005, and 10-60 billion US$ in 2020. In practice, an independent organization may manage a portfolio of offset projects, which can be sold to industrialized countries and companies. In order for a carbon-trading project to be certified, a baseline assessment by the World Bank, UNFCCC or an independent partner will be needed. The actual credits received will be based on actual savings achieved after project operation starts.

The Kyoto protocol does not yet include commitments of new developing countries to reduce emissions. All countries will however be entered into force in the Kyoto Protocol after countries representing 55% of the current total global emissions have signed it. The USA currently causes some 38% of global CO_2 emissions and is therefore an important actor. Also, the protocol does not yet include harmonized policies for all countries. Though the protocol states that borrowing is not allowed from future reduction targets, there are no mechanisms for enforcement or sanctioning in case countries fail to meet targets.

Since the establishment of the Kyoto protocol, climate change has been a major driving force in the development of biomass energy technologies. Yet, there exists a whole abatement curve constituted of several CO_2 mitigation options, varying from a negative abatement cost until around 100 $/tC for the last amount of carbon to be mitigated in order to reach reduction targets. The no-regret options can already replace current technologies used since they are already cheaper without a carbon tax. Several areas have been afforested as JI pilot projects for carbon sequestration. This is relatively cheap (around 0.5-2 $/tC), but application is limited to around 10% of the totally required abatement volume (Kenneth MacDicken of ADB). Higher cost abatement options of around 20-50 $/tC refer to renewable energy technologies and fuel cells. To fully achieve the required reduction of CO_2 reduction, revolutionary technologies need to be applied.

According to an extensive modelling study for India using technical and economic parameters, a carbon tax would first lead to the disappearance of coal. Secondly, nuclear power will be avoided. Thirdly, renewable energy options will be introduced on a massive scale. In practice however it needs to be realised that technologies once in use are not easy to replace, particularly in developing countries where the technical lifetime of a project is often extended far beyond its economic lifetime.

2.1.2 Dendropower and Woodfuel Production Systems: Economic Analysis and Implementation Strategies - Dr. P.R. Shukla

Dr. P. R. Shukla presented the outcome of the RWEDP financed study he undertook jointly with Dr. N. P. Singh, who was also present at the meeting. The study, entitled “Dendropower and Woodfuel Production Systems: Economic Analysis and Implementation Strategies”, is presently in draft but will be finalized using the outcome of the consultation. It served as an important input basis for the consultation, and all participants received an advance copy.

Prof. Shukla started his presentation by drawing attention to the current carbon mitigation efforts and Figure 1. The supply curve in the figure determines where biomass can fit in. Several experiences worldwide have shown that biomass can be produced sustainably for around 1.5 $/GJ, depending on local climatic and socio-economic conditions, see Table 1. With a utilisation rate of at least 60 percent, several options are already viable without a carbon mitigation subsidy.

Figure 1: The option space for climate change mitigation

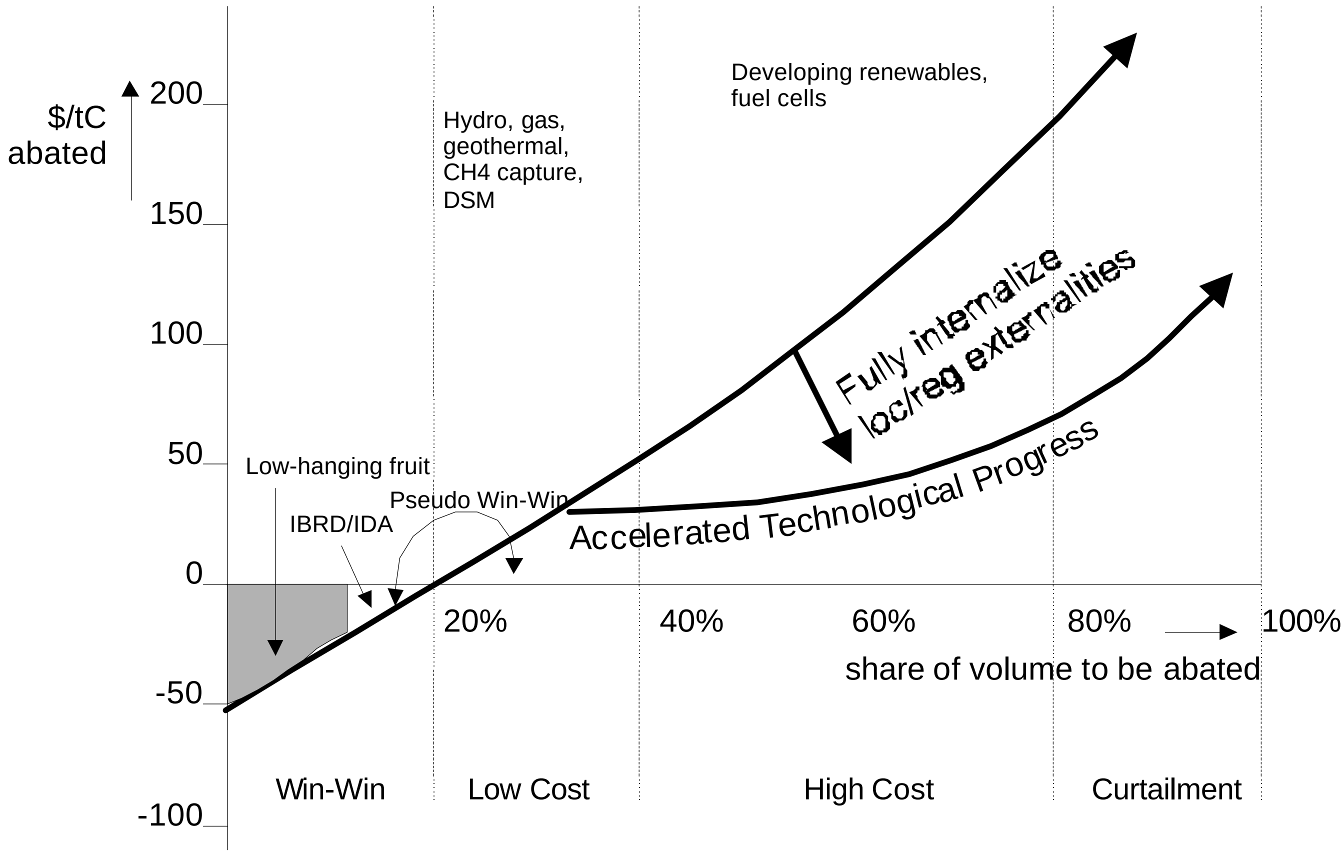


Table 1: Costs and Productivity of Plantation Grown Fuel

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

Source: Perlack et. al., 1995

The study evaluated the impact of a carbon tax on the viability of biomass based power generation in the scale range of 100 kW, 1 MW and 50 MW with coal based power generation. The results without environmental taxes are shown in Figures 2 and 3. For all scale ranges, biomass based power generation is currently slightly more expensive than coal with the assumed price of 2 US$/GJ. Though small-scale generation reduces the need for a centralised grid, large scale generation benefits significantly from economies-of-scale effects of the power plant. However, variations in both the price of biomass (it sometimes has a negative value) and coal make biomass based power generation already viable in many cases.

If a carbon tax of 25 US$/tC were to be imposed, biomass could still be competitive at a price of 2.5 US$/GJ. This would allow for larger scale applications. For example, it has been estimated that in 2020, about 25% of the world's energy needs could be supplied by biomass at a price of 2$/GJ. As of yet there is no biomass supply curve available to estimate the economic potential of biomass power in the region, with or without carbon taxes. It is therefore highly recommended that each country establish its own biomass supply curve to estimate the economic potential of biomass power within the country.

Whereas carbon emissions cause a global problem, sulphur dioxide emissions have a regional impact. In California state, a coal tax of over 200-400 US$/t$SO_2$ has been imposed to cover the costs of flue gas desulphurisation. This adds some 0.5 US¢/kWh to the generation costs of coal based electricity.

Figure 2: Composition of Electricity Generation Cost

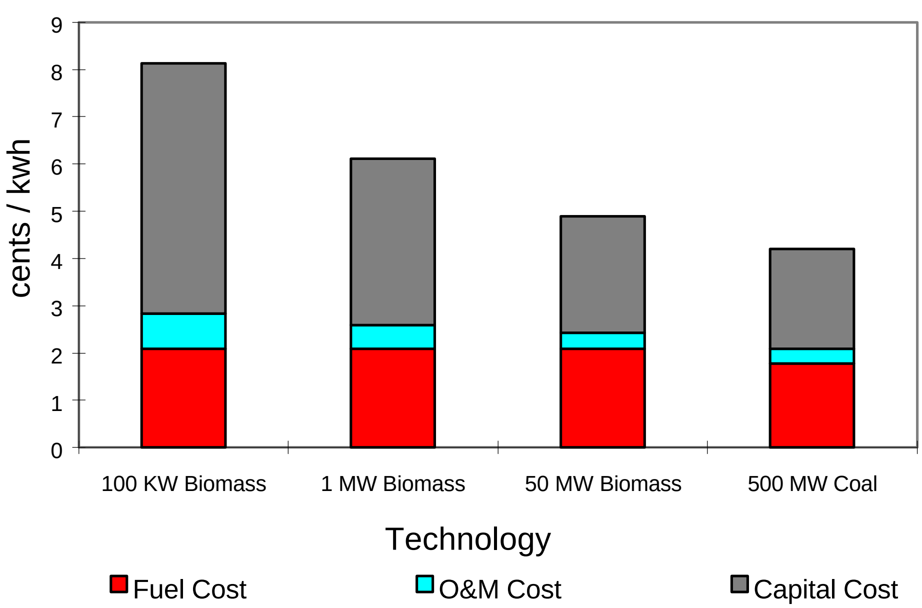
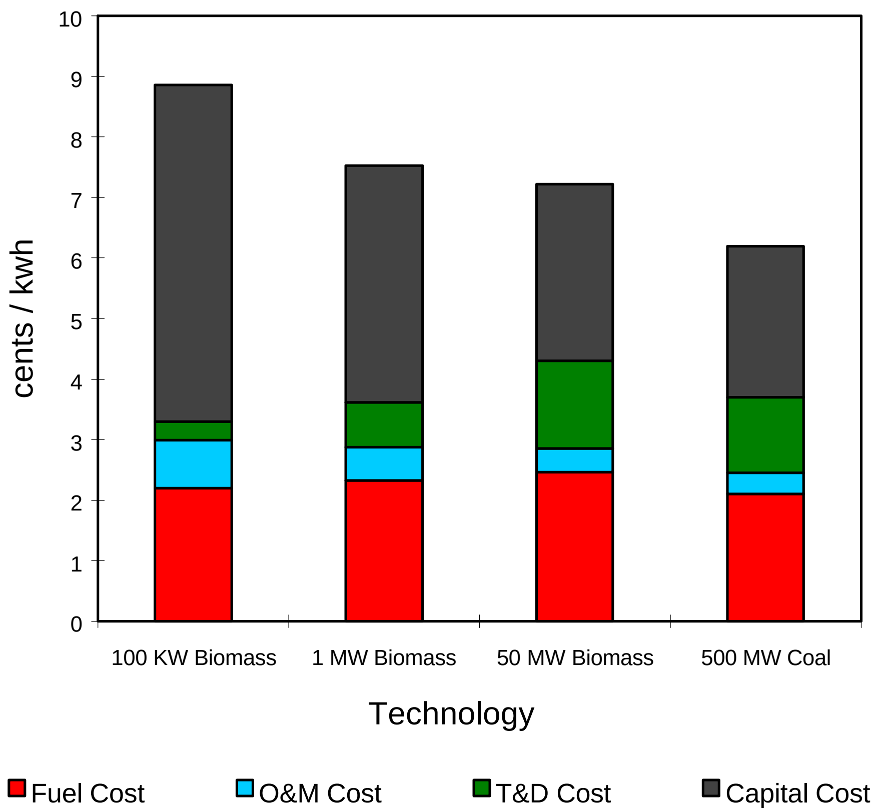


Figure 3: Composition of Delivered Cost of Electricity



A primary concern for biomass power generation is the availability of land and the food-versus fuel dilemma. In India, some 6% of the total land area consisting of degraded and deforested land could be made available to generate some 25,000-30,000 MW of electricity. However, potential entrepreneurs may prefer to use more expensive but more fertile lands, in order to attain higher biomass productivity rates. To avoid conflicts it is therefore necessary that governments control land allocation.

A biomass penetration study performed by Prof. Shukla for the Indian State Planning Commission indicated that modern biomass will have a significant impact after 2015, given current cost and technology trends. When carbon mitigation policies are put into place, coal will first be replaced by natural gas before biomass becomes attractive. It is, however, expected that the costs of biomass power will come down, similar to what happened with wind and PV. At the same time, it is anticipated that importing natural gas will become too expensive. Already at this stage it is necessary to formulate appropriate biomass energy policies and gain experience with the logistics of growing biomass for energy.

Discussion

During the discussion that followed the presentation, the participants expressed their concern about the competitive uses of fuelwood as well as the land it is grown on. Past experiences have shown that village woodlots initially grown for fuelwood, were in the end sold for timber. It was recognised that different parts of trees are often used for different purposes and have different values. If a large dendropower plant is to be fed by wood specifically grown for energy, competitive uses may pose a real threat to the supply. Dr. Shukla mentioned that though the present market size of biomass fuels is small, competitive uses cause relatively high price fluctuations. It is expected that once the market for biomass fuels is fully functioning, prices will become more stable.

Since a stable market for biomass fuels is essential, dendropower development should therefore ideally aim at large scale systems (50-100 MW). At this stage however, fuel supply uncertainties and lack of knowledge with the logistics of large scale biomass fuel supply make that private entrepreneurs investing in dendropower prefer smaller scale installations (smaller than 10 MW) that can be operated on multiple fuels. Dr. Faaij mentioned that one way to enlarge the biomass fuel market is by co-firing wood or biomass with coal. This calls for much less investment, and the consequences of an eventual lack of biomass fuel are less dramatic.

Wood and biomass based power generation have become more favourable with the Kyoto protocol and CO_2 taxes imposed worldwide. One major barrier remaining is the fact that there is no level playing field for biomass as other fuels and sectors are often highly subsidised.

2.1.3 Shadow pricing for carbon emissions - J. Koppejan

When compared with other parts of the world, in particular Latin America, the application of modern biomass energy technologies is still limited in South and Southeast Asia (Table 2). Though some countries such as Bangladesh, Nepal and Pakistan already utilise most of the woodfuel resources, other countries such as Indonesia, Malaysia, the Philippines and Thailand still avail of large quantities of wood residues that can potentially be used for electricity generation, (see Figure 4). In other countries such as India and Sri Lanka, available resources are limited and dendropower schemes will more likely be based on dedicated plantations. Land availability then becomes a crucial factor.

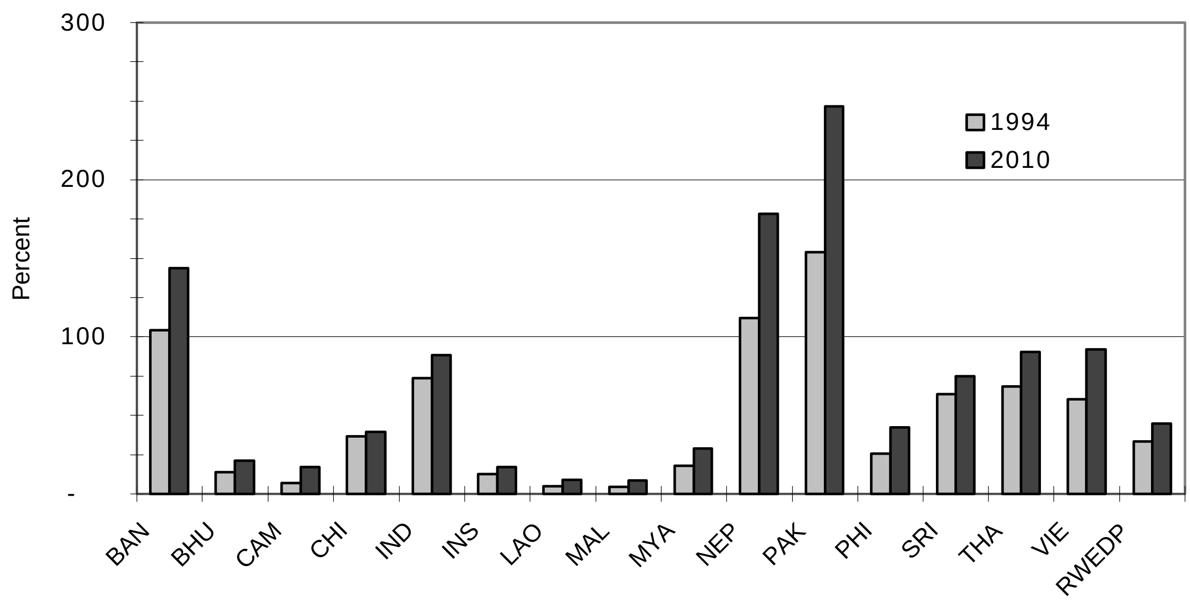
Table 2: Primary energy sources by region (PJ)

Region	Modern Biomass	Traditional Biomass	Other Renewables	Conventional sources	Total primary energy	Modern Biomass as % of primary
North America	454	908	3,320	46,838	51,519	0.9%
Latin America	1,099	2,986	1,982	7,715	13,781	8.0%
Western Europe	239	478	2,603	31,599	34,919	0.7%
Central/East Europe/CIS	239	717	1,433	39,147	41,535	0.6%
Mid East and Africa	119	3,869	382	9,554	13,925	0.9%
Southeast Asia and Pacific	549	8,383	1,887	33,200	44,019	1.2%
South Asia	191	4,872	525	5,064	10,653	1.8%
World	2,890	22,213	12,133	173,116	210,352	1.4%

Note: Other renewables include solar-, wind-, hydro, geothermal-, wave and ocean energy

Source: Adapted from WEC (1994)

Figure 4: Woodfuel consumption as percentage of potential supply

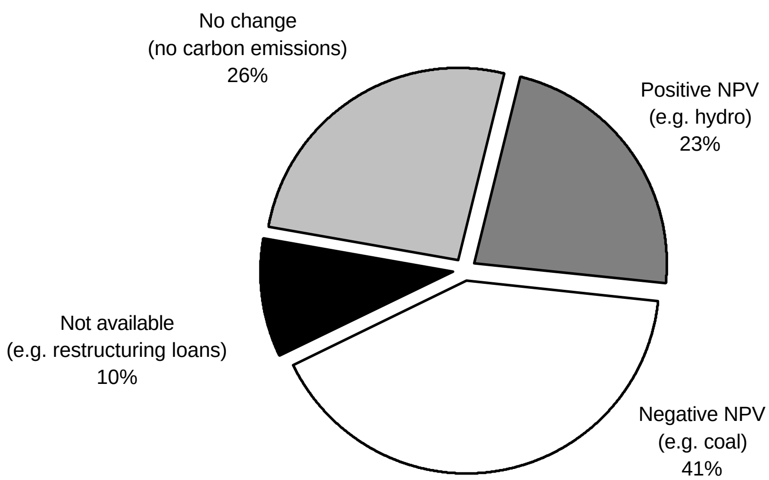


Source: RWEDP Study on Wood Energy Today and Tomorrow in Asia, RWEDP, 1997

The present use of biomass in the RWEDP member countries has a significant impact on CO_2 emissions. If all biomass users would suddenly switch to LPG, CO_2 emission from fossil fuels in the region would increase by 278 Mton, or 6.4%. The figure is about double if coal is to be used. When a relatively high shadow price of 50 US$/t$CO_2$ is assumed, this translates to a shadow cost of some 15 billion US$ per year for the LPG case. When 20 US$/tC is being applied, the shadow cost is 1.5 billion US$/y, which is still significant.

The relevance of carbon shadow pricing on the viability of energy technologies was illustrated by the recently completed 'Carbon Backcasting Study' by SEI Boston[1]. The study estimates the impact of carbon emissions on the economic feasibility of 50 out of 154 randomly selected energy loans during 1990-1996 in the energy portfolio of the World Bank. The results for a shadow price of 20 US$/tC on project emissions are shown in Figure 5. 10% of the loans are not sensitive to a carbon tax since they do not directly deal with generation equipment but with e.g., restructuring of the power sector. 26% of the loans are not affected since they do not have any net carbon emissions. 23% is affected but still positive, while 41% of the loans becomes unfeasible.

Figure 5: NPV of 50 random WB loans with CO_2 shadow price of 20 US$/tC on project emissions



[1] The full title of the report is 'A Shadow Price of Carbon Emissions in the Energy Portfolio of the World Bank – A Backcasting Exercise'. The study was performed for the World Bank by SEI Boston, Hagler Bailly, and the International Institute for Energy Conservation

The above graph shows that valuing the carbon flows produced by a project has a substantial impact on project economics. By modifying a project concept early in the project cycle, there is maximum scope to address the same development need in a less carbon-intensive manner. A major recommendation of the study is therefore that the World Bank should include carbon shadow value analysis in its project preparation process for energy lending.

Discussion

The discussion that followed focused on the issue of cost estimation for carbon abatement. IPCC has estimated that some 600 MtC need to be wiped out from the atmosphere to stabilise the climate at carbon levels of 550-650 ppm. The cost curve for avoiding emissions, constructed by IPCC, ranges from –50 $/tC to +200 $/tC, depending on the option chosen (see Figure 1). The 'cheap' forestry options in the range of 0.5 – 2 US$/tC are now being used, but this covers only some 10% of the total carbon abatement targets. A carbon tax should therefore already account for a price increase associated with the more expensive options. In the Carbon Backcasting study, 20 US$/tC was assumed. The Dutch government has set emission reduction targets using a budget that corresponds to 40 US$/tC.

Cleaner and more efficient end use technologies should be developed in conjunction with better supply technologies. A technology supply curve is different for every country, and can include other economic shadow costs apart from carbon mitigation. It should be realised that the lifetime of technologies used in the South is much longer than in the North, which points to the need for rapid development and introduction of new technologies.

2.1.4 Opportunities for Forestry Investment in Asia and the Pacific through Carbon Offset Initiatives – P. Durst.

The above named study was commissioned by FAO because of the lack of knowledge among senior forestry officials and policy makers on the opportunities and constraints for forestry investment in Asia and the Pacific through carbon offset initiatives. Countries can only adopt the new offset mechanisms after they have established a conducive institutional capacity.

Realising the fact that forests are the worlds major carbon sinks, and existing forest management practices are a major source of carbon emissions, there are large opportunities for improved forest management. Examples are the conservation of otherwise cleared or burned forests by "locking it up" or by curtailing the causes of deforestation, such as increasing agricultural productivity, enhancing the use of fuelwood from outside the forests, etc. However, this raises concerns about national sovereignty over forest use. Additional carbon can be stored in forests through area expansion or density increase. When rehabilitating and reforesting degraded or logged-over lands, care should be taken to avoid monoculture plantations. It is also essential to involve local people in forestry programs.

Conventional forestry practices leave a lot of dead biomass behind, which decays and, in addition to carbon dioxide, forms methane, a harmful gas in terms of global warming. Reduced impact logging reduces these negative environmental impacts. Also, trees can be used on a sustainable basis for energy purposes, thus replacing fossil fuels. Since fossil fuels are left in storage, no net carbon is emitted.

Apart from carbon sequestration, forestry programs can have many other benefits such as job creation, reduced petroleum imports, local environmental benefits, increased investment and technology transfer to priority areas and improved infrastructure. The Asia-Pacific region has good prospects for forestry investment because of the low cost of labour, the available land for forest development and the high biomass growth rates. This therefore attracts carbon-offset initiatives from industrialised countries.

There still exists a lot of confusion on the consequences and implementation of the Kyoto protocol. The present AIJ pilot phase must support national development objectives and be signed by both host and donor country governments. Though projects should be implemented with additional resources beyond ODA, they do not yield carbon credits for emissions avoided. Examples of AIJ projects are a forest rehabilitation project in Sabah, Indonesia and reduced impact logging projects in Sabah and Kalimantan, also in Indonesia.

The Kyoto protocol (already elaborated on by Prof. Shukla) sets legally binding emission reduction targets, which can be implemented through Joint Implementation and the Clean Development Mechanism. CDM makes use of certified Emission Reduction Units (ERU's) which can be credited to projects and traded amongst Annex-1 and non-Annex 1 countries on a voluntary basis. Credits obtained in the period 2000-2008 can be used to achieve compliance in the first commitment period of 2008-2012. The focus of CDM is clearly on market forces and incentives, and developing countries can also submit proposals to CDM.

Developing countries have expressed their concern about the loss of national sovereignty over forest resources, since forest management has suddenly become of major interest to developed countries. It is considered inappropriate that developed countries who are mainly responsible for global warming now simply buy their way out. Also, developing countries feel uneasy to give away their low-cost emission reduction options while they may have to go for more expensive options themselves at a later stage.

Many developing countries do not yet have the institutional capacity to initiate CDM projects. There is a great lack of partners capable of initiating and formulating proposals, and the developing objectives of the host country may not match the interest of the developed country. For example, the developed countries express a bias towards energy sector projects. Up till now, developed countries have been apprehensive about initiating CDM activities since they are uncertain about the credits obtained by such projects. NGO's have expressed their concern over eco-colonialism, socio-economic impacts and the potential adverse impacts on the local environment and indigenous people now living in the forests.

In order to advance carbon offset programmes in Asia, the international framework needs further clarification. Once this has been realised, countries can develop national policies with clear project criteria and role specifications for the interested parties, as well as other guidelines. Then, the awareness of the interested parties can be raised.

Discussion

The participants expressed their concern about the difficulties of estimating baseline emissions that are necessary to project the net impacts of a carbon offset project. In order to make the net impact of a project look favourable, baseline emissions often tend to be too negative.

The forest protection option is highly debatable; for example a proposed 'bad behaviour' baseline could be massive deforestation. The impacts of a plantation project in remote area are therefore much easier to assess. In terms of natural biodiversity however, natural forests are preferable.

2.1.5 Biomass resource base in Asia – A. Koopmans

Of the almost 2 billion tons of fuelwood annually available in the RWEDP member countries, only about one third is presently being used. However, the remainder is not always accessible for geographical, legislative or other reasons. On average, only about one third of the fuelwood consumed actually comes from forest land; the major share coming from trees that are easily accessible (on agricultural land, around the house etc.). Large variations exist per country, because of population density, forest resources available, economic situation etc. This means that some countries are presently more suitable for wood based power generation than others. Process based wood residues are the most economic and easy to use for power generation because of the large quantities that are generated on a single location, with limited alternative uses. The amounts generated in sawmills, plymills and particle board factories for 5 ASEAN member countries, are presented in Table 3.

Table 3: Production of wood residues in ASEAN countries

Source	Residue type	NHV	1994 production (kton)					
		(GJ/ton)	Indonesia	Malaysia	Philippines	Thailand	Vietnam	ASEAN
Sawmilling	Solid	15	3,865.6	4,200.4	183.4	354.4	342.5	8,946.2
	Sawdust	15	1,220.7	1,326.5	57.9	111.9	108.2	2,825.1
Plywood	Solid	22	5.9	0.0	4.1	21.6	0.0	31.6
	Dust	22	0.7	0.0	0.5	2.4	0.0	3.5
Particle board	Dust	22	0.0	0.0	0.3	0.2	0.0	0.5
Total process residues			5,092.8	5,526.9	246.1	490.5	450.6	11,806.9

In addition to wood residues, large quantities of crop residues are generated, varying from rice husk and rice and wheat straw to sugar cane bagasse and maize stalks. Annually, some 1.7 billion tons of field residues are being produced (mainly rice straw, maize stalks, wheat straw and sugar cane tops and leaves). However, these residues have many alternative uses and their availability for power generation can be questioned. Process residues (mainly sugar cane bagasse and rice husk) amount to some 440 million tons per annum. These are the 'easiest' fuels to use because of the limited alternative uses and the large quantities that are generated at a single location.

Dedicated energy plantations using short rotation forestry or energy crops may provide additional employment and restore degraded soils and wastelands if carefully carried out. A lot of wasteland is available in countries like China and India.

Appropriate institutional support from governmental, non-governmental and international organisations is crucial for harnessing the potential of biomass to replace conventional energy. Important issues to be solved in many countries in particular with regard to data and information are:

- The lack of reliable information on the potential and sustainable supply of biomass;
- competing use of such biomass;
- costs and prices of such biomass;

- effect on prices and availability for other users when used in larger quantities; and
- the internalisation of external social and environmental benefits of the use of biomass versus other sources of energy.

Discussion

The participants recognised the large potential of biomass residue based power generation, but stressed the need for data improvement and individual country efforts to assess the actual potential available. Modern Geographic Information Systems may be used to identify suitable sites for dendropower using soil fertility, infrastructure etc. According to a COGEN study, the aggregate economic potential in the wood, sugar, rice, palm oil industries in the ASEAN region amounts to some 7000 MW. The competitive uses of residues depend very much on the kind of residue and the location; a case-by-case assessment is therefore essential. In large parts of China for instance, the heavy competition for biomass has already caused severe deforestation and biogas digesters are now being introduced to fight deforestation. In such cases, establishing a plantation for feeding a dendropower installation may be risky. In Northern Pakistan however, multipurpose trees have a good potential for supplying fuelwood, and at the same time stopping soil erosion and providing animal fodder.

Dedicated dendropower might significantly contribute to the primary energy mix of the RWEDP member countries, but land requirements will be a major constraint. In India for example, the Planning Commission projected that coal based electricity generation will be replaced largely by natural gas in the coming decades, but around 2035 dendropower may contribute some 20% to the primary energy mix. This, however, implies that some 30% of the country area will be used for energy crops, assuming current yields and conversion efficiencies. Improvements in biomass yield and conversion efficiency are therefore highly desirable.

2.2 BIOMASS ENERGY PROJECTS

2.2.1 Optimising Energy from Biomass: Future Prospects, Current Action- Dr. A. Faaij

Dr. Andre Faaij started his presentation with the outlook for modern biomass energy systems. At present, biomass use is mainly consumed in developing countries in the form of forestry residues and agroresidues. It is typically used in a non-commercial way and converted in low efficiency systems for small-scale domestic and industrial applications. Yet, in countries with supportive policies such as Brazil, USA, Sweden, Denmark and Austria, modern biomass systems have emerged. Better performance and lower costs can be achieved through improved biomass production and conversion technologies. Various future scenarios predict that the present global biomass consumption of 45 EJ/y, may go up to 100-300 EJ in the near future. For this it is anticipated that an area of some 700 Mha could be planted for dedicated woodfuel supply, but this depends on the competition of cheap fossil fuels and the availability of land.

Modern biomass applications can be observed especially in countries where supportive policies have been put into practise. Examples are the ProAlcool Programme in Brazil, the PURPA legislation in the USA on purchase of private power by utilities, as well as taxes on energy and carbon emissions in Sweden, Denmark and Austria. In the USA, the Netherlands and in several other countries, biomass based power plants have already proven to be competitive with fossil fuel based power.

Conversion Technologies

(a) Direct combustion

Combustion technologies are relatively 'off-the-shelf' but continuous improvements are being made. Table 4 provides an outlook on the efficiency and costs for biomass combustion plants. The projected efficiencies of 30 to 40% will result in considerable cost reductions.

Table 4: Outlook on efficiency and costs of biomass combustion technology for clean wood (2000-2010, DOE)

Scale (MW_e)	50	60	100	150	184
Efficiency (% on LHV basis)	31	36	36	36	42
Spec. investment (Dfl/kW_e)*	4,000	3,500	3,000	2,700	2,200
Fixed Operating costs (Dfl/kW_e/y	145	121	121	121	99
Variable operating costs (Dfl/kWh_e)	0.034	0.028	0.028	0.028	0.023

**** 1 Dutch Guilder (Dfl) is approx. equal to 0.5 US$.***

Major determining factors for the per kWh costs of a biomass power plant are the fuel price and its conversion efficiency, the plant's load factor, specific investment and lifetime. Since the fuel collection and preparation components in particular determine the delivery costs of fuel, the transportation distance is not very important for the feasibility of a power plant.

One of the promising biomass conversion technologies is co-combustion with another fuel such as coal in a large-scale power plant. This results in lower specific investment costs and higher conversion efficiency.

(b) Gasification

Developments in gasification focus on the preparation of synthesis gas for combustion in common gas turbines, as well as for fuel cells and very small-scale gas turbines. For large-scale biomass energy conversion, biomass integrated gasification, linked with combined cycle heat-to-power conversion (BIG/CC) is a promising option. Table 5 gives cost estimates of BIG/CC technology on three relatively large scales for the Dutch context. Here it is assumed that BIG/CC plants will be available at only 2,000-3,500 Dfl/kW, or 1,000-1,750 US$/kW.

Table 5: Calculation of cost of electricity for biomass gasification in BIG/CC systems in 2010-2020

Scale (MW_e)	51 MW_e	110 MW_e	215 MW_e
FUEL LOGISTICS			
Total fuel input (kt/y)	316	674	1,221
Fuel costs (Dfl/t, wet fuel)	66	66	66
Fuel costs (thousand Dfl/y)	**20,844**	**44,481**	**80,581**
Avg. transport distance (km, two ways)	171	181	192
Transport costs (Dfl./t, wet fuel, road)	13	14	15
Specific transfer and storage costs (Dfl./t, wet fuel)	1.2	1.2	1.2
Total logistics costs (Dfl/t, wet fuel)	14	15	16
Fuel logistics (thousand Dfl/y)	**4,604**	**10,351**	**19,799**
TECHNICAL PARAMETERS			
Efficiency (% on LHV basis)	54	55	59
Wet fuel input (t/h)	45	96	174
Fuel input (MW_{th} LHV)	97	207	375
Dolomite consumption (t/h)	1.5	3.3	5.9
Total ash production (t/h)	1.8	3.9	7.1
FINANCIAL COSTS			
Spec. investment (Dfl/kW_e)*	3,500	2,800	2,000
Total investment (Million Dfl)	178.5	308.0	430.0
Annual depreciation costs (thousand Dfl/y)	14,323	24,715	34,504
Maintenance costs (thousand Dfl/y)	3,570	6,160	8,600
Personnel (thousand Dfl/y)	980	1,188	1,404
Catalyst use (thousand Dfl/y)	642	1,371	2,483
Ash disposal (thousand Dfl/y)	0	0	0
NaOH consumption (thousand Dfl/y)	61	130	236
Insurance (thousand Dfl/y)	143	247	345
Operational costs (excl. fuel, thousand Dfl/y)	**5,396**	**9,095**	**13,068**
Costs per kWh produced (Dfl/kWh)	**0.123**	**0.111**	**0.096**

The first plants will be small and, therefore, relatively expensive at around 2,500-5,000 US$/kW. Assuming that fuel can be delivered at 3 US$/GJ, these first biomass power plants can generate electricity at around 8-14 US¢, which is considerably higher than coal or natural gas at 3-4 US¢. Cost reduction can be achieved through higher efficiency and lower specific investment. The latter can be achieved through increased scale, and operating experiences from the first plants need to be translated into later designs. The efficiency can be increased through innovative drying techniques (e.g. low temperature drying combined with storage), new gas cleaning and gas turbine technologies and more severe steam conditions and heat utilisation. Gas turbine efficiency improvements can be reached with improved materials that allow for higher inlet temperatures, intercooling of the compressor and multi-stage expansion with reheating.

Apart from combustion and gasification for large-scale electricity production, large potentials exist for the production of methanol, ethanol and hydrogen, derived from cellulosic biomass. Such fuels may provide a clean and cheap alternative for the transport sector. Although methanol may be relatively expensive compared to gasoline, its capability to be used in a fuel cell with a 3 times higher efficiency than an internal combustion engine fed with gasoline still makes it an attractive fuel.

Biomass Production

In order to guarantee operation of the power plant, biomass supply needs to be stable and predictable. A problem is that the market for biomass fuels is not yet being produced on a large scale, therefore competitive uses still play an important role. This is contrary to the oil market, where oil prices are mainly determined by its use as fuel, not by other end-uses such as plastics. It is therefore highly desirable that large-scale plantations are established as soon as possible. In order to limit investment and risk, such plantations may initially feed into large-scale co-combustion equipment. Once biomass supply is more stable, dedicated power plants with higher efficiency may be more appropriate.

To avoid irregular fuel supply to a power plant or high storage costs, the fuel supply needs to be diversified to guarantee a year-round supply. Also, multifuel boilers that accept a wide variety of fuels, including fossil fuels, should be employed. Both bubbling and circulating fluidized bed boilers are suitable. In the Netherlands for example, various types of biomass are available but only from April to November. During the other months, stored biomass fuels or fossil fuels need to be used, affecting the viability of biomass based power generation.

Large areas of land are available but with the present productivity levels land availability still acts as a significant constraint. To increase productivity and reduce production costs, crop mechanisation, rotation schemes, intercropping and multiple uses should be considered and optimised. Such considerations are highly site-specific. For example, as a result of the Finnish bioenergy industry, dedicated machinery for harvesting, sizing and transferring has been developed, but this may not be appropriate for other countries.

Policy Approach

Compared to the conventional combustion technologies, modern gasification technologies will be much more efficient and cost-effective. With current prices however, many of the desired biomass systems based on dedicated fuel supply systems are currently not competitive with fossil fuels. Consequently, many potential investors wait for someone else to make the first investment so that the learning curve reduces the price. In order to ‘close the gap’, two basic strategies can be followed. Niche markets should first be approached, and the concept of externalities deployed.

Niche markets exist in industries where large quantities of biomass residues are available with little or no value, which can replace expensive fossil fuels. Examples are sugar mills, wood processing industries and the pulp and paper industry. Its financial feasibility is highly location specific.

Compared to fossil fuel based electricity, biomass based power has many external benefits, which make it attractive for the country as a whole. By internalising the external costs through taxes and/or subsidies, the financial feasibility is increased. Some externalities that apply are:

- Emissions to air, land and water
- CO_2 mitigation and reduced impact on climate change
- Employment generation
- Savings on foreign exchange otherwise spent on imported fossil fuels
- Safety issues
- Loss of land, restoration of land, natural diversity

These factors are highly location specific. For example, a study by Utrecht University on the feasibility of a replacing a 5 MW diesel genset in a Nicaraguan sugar mill by a large biomass power plant fired on bagasse and eucalyptus showed high employment generation and savings on foreign exchange. Such benefits may make the project feasible. The direct and indirect costs of electricity from both biomass and coal are given for the Dutch case in Table 6.

Table 6: Influence of externalities on the feasibility of biomass power generation as compared to pulverised coal power generation (in ECU¢/kWh)

	Biomass	Coal
Cost without externalities	**6.8**	**3.8**
GDP increment	(-) 0.6 .. 1.5	(+) 0.69 .. 0.84
Employment benefits	(-) 0.08 .. 0.4	(-) 0.03 .. 0.15
CO_2 emissions	(+) 0 .. 0.06	(+) 0.08 .. 2.1
Agrochemical use	(+) 0.08 .. (-)1	NA
Nitrogen leaching	(+) 0.08 .. (-)3	NA
Total external costs	**-1.5 .. +0.2**	**(+) 0.7 .. 2.4**
Total costs	**5.3 .. 7.0**	**4.5 .. 7.2**

These figures illustrate that the external costs are generally negative for biomass, but positive for coal. This causes both options to fall in the same price range in the Dutch context. Here it is expected that as soon as 2005, dendropower plants fired with short rotation coppice willow will compete with coal. The externalities, and consequently the economic attractiveness of coal or biomass power, mainly depend on the local situation, the design of the project and the value that is given to externalities. Also, estimating external effects in monetary terms is often hard to do, or even ethically unacceptable.

As shown above, the external costs analysis still encounters many uncertainties, and the knowledge base needs to be improved in various ways. However, notwithstanding the uncertainties, it does give an estimate of the social costs, which is relevant for decision making.

Conclusions

There is an impressive potential to improve biomass energy systems to compete with fossil fuels in the short term, but new concepts for electricity generation based on modern biomass fuels need to be developed. Large-scale systems (i.e. 100 MW_{th} input, 45 MW_e output and up) are likely to have the best chances to reach the lowest cost levels and facilitate large contributions of biomass to the total energy supply. Although the current biomass applications may at present not always be fully competitive in terms of cost of energy carriers produced, there is a large ‘niche-market’ to start with.

Furthermore, the difference between external benefits of appropriate bioenergy systems and external costs of fossil fuel use can be considerable. Macro-economic benefits, reductions of emissions to air and the potential for land-use (erosion prevention etc.) are major assets of bio-energy and should be identified as such in national energy policies. This is also the major advantage of the use of biofuels in the transport sector.

Efforts over a prolonged period of time are required to demonstrate and develop improved crops and cultivation methods, conversion systems and infrastructure. For this, long running research, development and dissemination programmes are essential. This can be achieved best through international collaboration.

Infrastructure for large-scale bioenergy needs to be developed, initially through small-scale projects, co-combustion and retrofit projects at various industries. International trade of bioenergy fuels can be part of this.

2.2.2 Institutional Developments in Private Sector Participation in Power Generation in Asia - P.C. Saha

Reliable and sufficient supplies of electricity are essential for sustained economic growth. Although the recent economic turmoil in the South East Asian region has significantly slowed down economic growth, it is expected that this situation will be overcome within a few years. Simultaneously, the share of people with access to electricity is increasing. The energy demand will therefore continue to grow at a high rate of around 8-10% per annum. The associated investments for energy infrastructure are enormous. ESCAP estimated that for the years 1990-2000, over 50 billion US$ would be needed per year in the ESCAP region. This figure would increase to over 140 billion US$/y in 2000-2010 and more than 190 billion US$/y during 2010-2020. For comparison it can be mentioned that in 1996, the ODA to the same countries amounted to only 54.4 billion US$, of which only 4.4 billion US$ was allocated to the energy sector. Many governments are therefore seeking involvement from the private sector through Independent and Small Power Producer (IPP and SPP) programmes. SPP programmes tap the large potential for small scale applications in industries with biomass residues and are relatively successful as compared to IPP programmes. Significant private power investments have been established in Malaysia and the Philippines. In India, progress has been less successful because of the lack of a coherent policy at the state level. In the short term, the current economic crisis may delay implementation of some projects due to uncertainties in currency exchange rates and expected lower energy demand growth rates. In the longer term however, private power will be more efficient and cost effective, and therefore gain market share.

To allow the shift from the public to the private sector, generation, transmission and distribution need to be unbundled so as to support true competition and efficiency. A true regulatory and policy framework for private power is essential, including wheeling and banking facilities. On the other hand, government involvement is essential to safeguard social, economic and environmental objectives. In order to achieve this, the present public utilities may change their role from actual generators into facilitators, co-ordinating and dispatching power to consumers under acceptable tariff structures and environmental performances. It is very likely that fossil fuels will continue to be of major importance for the power sector, but satisfactory environmental performance can still be achieved through enforced emission standards and appropriate fuel supply policies.

There is a general trend amongst Asian countries to attract private sector investments in the power sector, and some countries have had more success than others. By sharing experiences in developing (renewable) energy resources and technology dissemination programmes, countries may mutually benefit.

2.2.3 Project Preparation – R. Schurmann

General

The FAO Investment Centre Division does project packaging (identification, preparation and post-impact evaluation reports) for all kinds of agricultural and forestry projects. This is often done on behalf of development banks such as the World Bank and the Asian Development Bank. FAO-ICD therefore is aware of the issues that make a project ‘bankable’; these are often different from the obvious benefits that technologists appreciate.

Project preparation has become more complicated over the years. While projects were first target driven with clear objectives, e.g. IRR, they are now more people oriented. For example, the ADB has concessional funds to support its objectives of poverty alleviation and environmental performance, apart from economic growth. New computer tools have been developed to do Goal Oriented Project Planning, in order to analyse risks and fine-tune projects. One can also observe that project implementation in all sectors is increasingly done through private sector involvement.

Biomass energy projects

Biomass energy links to multiple social and environmental objectives, which may or may not make it bankable. The costs of biomass always have to be compared with the alternatives such as oil and coal, after consideration of the externalities it may or may not be viable. While fuelwood as a by-product from other industries may be relatively cheap, supply may be uncertain because of competitive uses and dedicated energy plantations may be quite expensive.

Biomass energy plantation projects seem not very suitable for achieving social objectives such as poverty alleviation, since the poor people who are targeted are typically not very much market oriented, they do not have access to land or they prefer to grow food or cash crops with rapid returns. Some factors that increasingly work against biomass are the higher costs of land caused by increased population pressure of land for food and other purposes, and the price of oil which is still declining in real terms.

Since many biomass energy technologies are still in an early stage of development, it has often been said that additional monetary funds should be spent on research and development. It can however be questioned what the net effect would be if the same amount of money were spent on improving fossil fuels, which are intensively used around the region.

Also, one tends to focus on the positive externalities such as job creation, CO_2 mitigation, foreign currency savings etc. There are also, however, externalities that work negatively for biomass such as the consequences of indoor air pollution, drawdown of the water table caused by fast growing tree species and occupation of land that could otherwise be used for food or other productive purposes. The formulation and implementation of biomass projects should be done very carefully because of all the external linkages. For instance, in an FAO farm forestry project in Uttar Pradesh, India, the wrong tree species were selected so that there was competition between crops and trees for nutrients and water.

In order to properly internalise all kinds of externalities in the price of biomass, one first has to quantify the external effects so that they can be monitored. Secondly, the political will of authorities needs to be created to include these externalities in policy formulations. Finally, the institutional arrangements need to be established to implement such policies.

Multilateral development banks (such as ADB) can be instrumental in developing biomass energy through the public sector. By funding research and strengthening institutional capacities, they can help to create a level playing field for biomass, so that ultimately a fully functioning market for biomass is established.

Discussion

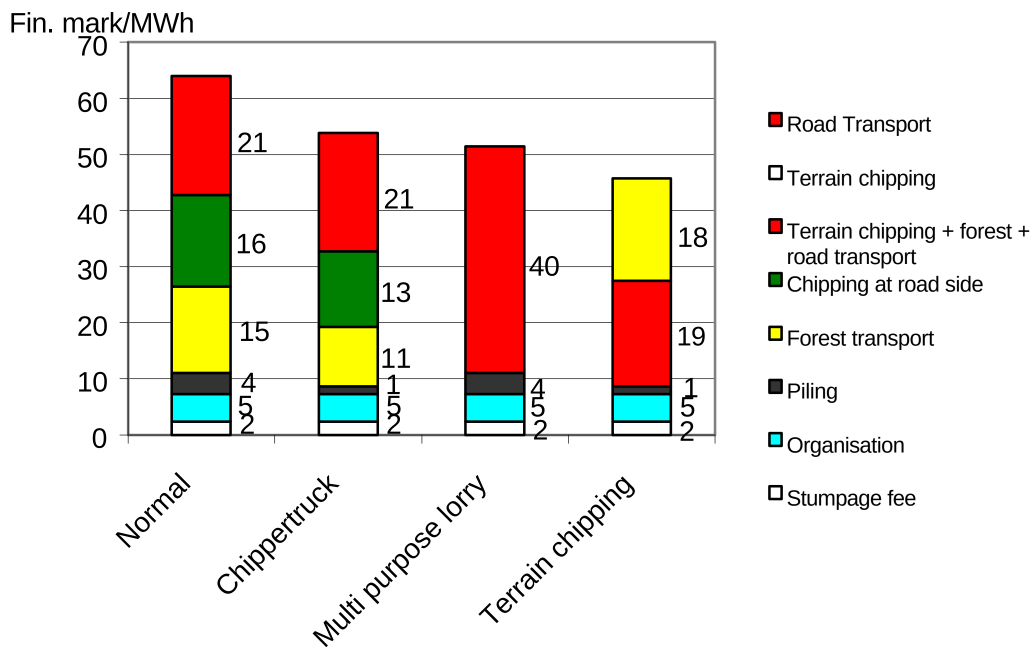
During the discussion that followed, the necessity of a mature biomass fuel market was stressed. No bank will provide credit if the fuel supply is uncertain. From an economical point of view, the existing large scale technologies for biomass energy conversion are most attractive but the fuel logistics may be obstructive. In the Philippines for example, there recently was a proposal to establish a 40 MW rice husk fired power plant, but the complex logistics to collect rice husk from the many surrounding rice mills stopped the project.

The costs of fuel collection and transportation are very much country specific. In the Netherlands for example, local harvesting is the major fuel price component, while the good roads allows fuel could to be easily and economically transported over 100 km to fire a 400 MW power plant. The different collection and transportation systems that are being used in Finland are illustrated in Figure 6. The production costs of producing woodchips from a forest 100 km away have come down from 63 to 47 Finnish mark/MWh, using new technologies. This illustrates that road transport constitutes only a minor contribution to the overall production costs in the Finnish context.

In contrast, countries in South and Southeast Asia generally have low labour costs but high transportation costs because of difficult geographic conditions, bad road conditions, lower truck carrying capacities etc, therefore fuel needs can only be collected from a small area to fuel a much smaller power plant. Table 7 below illustrates the experience with large scale biomass conversion in power plants in Finland.

To develop a market for biomass fuels, it was agreed that first, the niche applications in agroprocessing and forestry industries with large amounts of residues and high economic returns should be tapped. Fuel supply for dedicated power plants should then be made more mature and reliable through diversification of the types and origin of the fuels used. Large areas of wasteland can be made available for wood energy plantations. Experience on fuel logistics can be gained with relatively low additional costs through large scale co-firing with conventional fuels such as coal. Large scale shipment in bulk carriers can be very cost-effective. The Netherlands for example, can economically import fuelwood chips from Uruguay and Estonia. In a mature market for biomass fuels, trade is being done on the basis of energy content.

Figure 6: Production costs of woodfuel from logging residues in Finland (Finnish bioenergy research programme)



For the RWEDP member countries, around 70% of the investment in a biomass power plant consists of imported technology. On a lifetime basis, the expenses are around 30% in foreign currencies. One way to lower the technology costs and save on foreign exchange is therefore to produce the technologies in the region. Regional bodies such as ASEAN can be instrumental in stimulating transfer and adoption of these technologies. The ADB is still interested in public sector funding of dendropower, because of the social and environmental objectives that can be achieved. Because of the carbon mitigation aspects, co-financing under a JI or CDM programme is also a likely option.

Table 7: Biomass power plant references in Finland

Plant	Type of boiler	Year of comm.	Steam flow kg/s	Pressure bar	Temp °C	El. output MW_e	Process heat MW_{th}	District heat MW_{th}	Fuels
Aittaluoto	CFB(1)	1990	40	110	520	37	-	75	Wood waste, peat
Chudowo	BFB	1996	2,6	10	184	-	6	-	Bark, sawdust
Haapavesi	PF	1986	125	180	530	155	-	15	Peat
Joensuu	PF	1986	75	115	533	52	-	120	Wood, bark , peat
Kauttua	CFB	1981	25	83	500	18	40	10	Wood waste, coal, peat
Kokkola	CFB	1994	33+17	60	510	184(2)	106	82	Process waste, peat, coal
Kuusamo	BFB	1993	8	60	510	6	-	21	Wood waste, peat
Lieksa	CFB	1994	10	60	510	8	8	14	Peat
Lohja	BFB	1986	15	25	240	-	26	10	Wood waste, paper waste, coal
Mikkeli	CFB	1989	33	114	535	26	-	54	Wood waste, peat, coal
Rauhalahti	BFB	1991	110	136	533	87	140	65	Wood waste, peat, coal
Sachsen Papier	BFB + HRSG	1994	11+28	84	490	44	120	-	Sludge, waste paper, natural gas
Toppila I	BFB (3)	1996	100	119	540	90	-	185	Peat
Toppila II	CFB	1995	103	156	540	140/113	-	170	Peat
Uimaharju	BFB	1993	32	83	480	105	230	-	Bark, sludge

Source: IVO Power Engineering Ltd

Abbreviation:	**Description of boiler type:**	**Legend:**
CFB	Circulating Fluidised Bed	1) by others
BFB	Bubbling Fluidised Bed	2) total plant output
PF	Pulverised Fuel	3) retrofit
HRSG	Heat Recovery Steam Generator	

2.2.4 Examples of Cogeneration Projects – Dr. L. Lacrosse

The EC-ASEAN COGEN programme tries to link wood processing and agroprocessing industries in the ASEAN countries that have wood and biomass available in large quantities with European manufacturers of modern biomass combustion systems. Typical examples are sawdust, rice husk, sugar cane bagasse and empty fruit bunches in palm oil mills. Since these fuels often have a negative market value or even constitute a disposal problem, making good use of the residues is often attractive. Because of its high silica content, good quality rice husk ash can even be sold as a high value product to electronics and steel industries. Typical payback periods for the investment in energy equipment are around 3-5 years.

For the wood sector, projects have been implemented in Thailand, Malaysia and Indonesia. For most of the projects, steam generated in a boiler is directly used for kiln drying. For the larger mills however, the steam generated in a boiler is first expanded in a backpressure turbine to generate electricity, after which kiln drying can still take place. In cases where only power is required, a condensing turbine is used.

Considering the positive CO_2 mitigation aspects and short payback periods, all projects are part of the so-called win-win category as described in Figure 1.

2.2.5 Case study: Bagasse Power in Indonesia – M. Mendis

The Renewable Energy Small Power (RESP) project in Indonesia aims to facilitate development of small renewable energy projects to sell electricity to the PLN grid within the framework of a least cost rural electrification strategy. It promotes environmentally sound energy resource development in Indonesia and reduces the energy sector's dependence on fossil fuel. Through the RESP project it is expected that Indonesia's institutional capacity to sustain renewable energy development will be strengthened.

For the RESP programme, 13 biomass power projects have been identified in the sugar sector with an aggregated electricity potential of 82 MW_e, 1 palm oil mill with 3 MW_e capacity as well as 4 mini hydro plants with a total capacity of 15 MW_e. The total projected capacity is therefore around 100 MW, and the average capacity investment 1.4 MUS$/MW.

The total project financing of 141 million US$ was provided by IBRD, GEF, the local banks, private equity and the Government of Indonesia are presented in the table below.

Financing inst.	US$ million
IBRD	66.4
GEF	4.0
Local banks	28.6
Private Equity	41.8
Gov. of Indonesia	0.2
Total	141.0

AED, as the leading consultant for the programme, prepared the loan through a long process of discussions and negotiations with

- the Government of Indonesia
- the private sector
- PLN (the national electricity board)
- WB/ASTAE (the Asia alternative energy unit of the World Bank)
- DGIS (the Dutch ministry for development affairs)
- The UNDP environment and atmosphere programme (EAP).

In order to develop the project portfolio, AED first defined the status of the commercial conditions of the sugar mills, such as the availability of adequate resources and the key market conditions. Examples of the latter are the demand for energy capacity within and outside the company, the government policy, requested terms of the Power Purchase Agreement with PLN, the credit worthiness of the company and the availability of capital. The most promising potential can be found in large, expanding agro-industries with presently under-utilised waste resources and seasonal kW deficits. Other important factors are their access to the grid and their desire to diversify income generating activities.

For individual mills, pre-feasibility and feasibility studies were undertaken, which included their individual environmental compliance. Through this interaction, the mills became aware of the technical options available and their financial feasibility. The individual mills were prioritised and grouped on the basis of their financial condition, guaranteed future resource supply, and their investment potential. Then a business and finance plan was developed, and through the influence of the World Bank, an appropriate Power Purchase Agreement (PPA) was established between PLN and the sugar mills.

For the dimensioning of the projects, the captive resources available at present were not the only relevant factor. Since sugar mills only operate for around 200 days a year and purchasing other fuels outside the milling season can increase the project's capacity factor and viability, assuming there is a real demand for the extra electricity generated and this is reflected in the PPA. Similarly, the technology selection was not based on maximising the efficiency, but on maximum return on investment.

With the economic crisis that occurred, the exchange rates suddenly increased dramatically, and market interest rates went up from 20 to 30 per cent. There was little space to raise the PLN tariff paid to project developers, and although the projects were still feasible from an economic point of view, they were no longer financially feasible. Therefore, a restructuring of the whole financing package was necessary. In the end, additional funding was obtained from the Carbon Investment Fund of the Dutch government. While the initial attitude of the government of Indonesia towards selling CO_2 mitigation space was negative, the carbon avoided by the projects was ultimately sold for just under 30 US$/tC. This made the whole programme financially feasible again.

2.2.6 Case study: Dendropower in India – Dr. N.P. Singh

India has a large potential for biomass in the energy supply mix, and dendropower on degraded lands not suitable for agriculture may play a strategic role. The government has pursued development of biomass energy resources and technologies through MNES and IREDA. Private power investment has been attracted since 1991 with a clear and favourable framework, and renewable energy projects up to 30 MW have been realised using solar, wind and biomass. The policies have been so successful, that the 100 MW window in the private power plans for renewable has already attracted 1,400 MW.

Regarding resource development on dendropower, research and development is done on 70 fuelwood species, and packages of practices have already been prepared for 35 species with a yield of about 15-20 tonnes of biomass per hectare per year of a 5 or 6-year rotation cycle. On the conversion technology side, experience has been gained in wood gasification up to the MW level, and direct combustion of wood for power generation has been done up to around 5 MW. Other research focuses on the environmentally benign disposal of ash and other effluents.

Dr. N.P. Singh's paper described three case studies on dedicated dendropower and a few agroresidue based power projects in India that have been supported by the Ministry of Non-conventional Energy Sources (MNES).

In Kutch, Gujarat State, 1,000 hectares of wasteland are planted with *Prosopis juliflora* for energy purposes. This is enough to support 3-4 MW of electricity, but so far only a 500 kW gasifier-cum-diesel generator has been commissioned. The investment will amount to some 18.7 million Rs (around 660.000 US$) and electricity will be generated at around 2.25 Rs/kWh (6.3 US¢/kWh).

In Gosaba island village, 100 km from Calcutta, 1,000 hectares of land have been made available for a fuelwood plantation. At present, a quarter of the plantation yield is used for local consumption, and the remainder is sold elsewhere for around 300-400 Rs/tonne. Recently, a 5x100 kW gasifier project has been realised to supply electricity to about 300 families and commercial establishments. The investment of 9 million Rs (around 330.000 US$) was fully subsidized by MNES and the state government. The electricity generation costs are some 2 Rs/kWh, or 5.6 US¢/kWh.

250 km from Hyderabad, Andra Pradesh state, a 6 MW dendropower plant will be installed by M/s HCL Agro Ltd. to supply to the nearby 33 kV grid of the Andra Pradesh State Electricity Board. The total investment is 18 million Rs., and around one fourth is subsidised by MNES. A plantation of *Prosopis juliflora* and other species will supply 45,000 tonnes of fuelwood per year to the plant, and coal, bagasse and pulp mill rejects are used as back-up fuels.

Apart from the power plants based on fuelwood, many biomass power plants are being developed in the rice sector and the sugar sector. Because the equipment presently used in sugarmills is often very inefficient, great improvements can already be achieved with relatively cheap but more efficient second hand equipment.

Discussion

Prof. Shukla presented some background information on biomass and dendropower development in India. As is the case in many other countries as well, very old, polluting and inefficient technologies are still employed, and application of ‘off the shelf’ biomass energy technologies are often very attractive for both economic and environmental reasons. One way to stimulate this is through more strict environmental legislation.

There is a great potential for biomass energy development in India, large areas of wasteland are available that may be used for dedicated dendropower. In other sectors as well there is a large potential. In the sugar sector alone, some 3,500 MW can be realised economically. For political reasons however, the 9^{th} plan for 1997-2002 only includes 100 MW for private biomass power. Instead of providing direct subsidies to the private sector, the Government prefers to create attractive boundary conditions, for example by providing cheap land for dendropower plantations. During the discussion, some participants stressed the need for more strategic government support, e.g. in infrastructure.

The Kyoto protocol however has led to greater eagerness at the Indian Ministry of Environment to develop biomass energy. This Ministry has asked MNES to develop more renewable energy projects for which other countries may be willing to pay carbon offsets, as was the case in the RESP programme Mr. Mendis presented.

In Thailand, the tariffs the utility pays for biomass power and coal power are equally low, there is therefore hardly any incentive for the private sector to start biomass based power generation. Recently however, the multiple external benefits of biomass power generation have been recognised in Thailand. ECGO now develops attractive standard promotion packages, initially for the sugar sector with a targeted IRR of 20%.

On the issue of carbon trading, Mr. Vanapruk of Yala Power was eager to know if he could obtain carbon offset funds for the 20 MW dendropower project he is developing in Southern Thailand. The economic crisis has heavily affected the financial feasibility of the project. The Clean Development Mechanism is intended to support CO_2 mitigating projects that are not feasible without this support. In the coming years many issues related to CDM will be clarified, before it becomes operational after the year 2000. Once countries sign the protocol, carbon brokers can arrange the funding with interested Annex-1 countries for project developers. Though Thailand (like many other countries) has not yet signed the CDM protocol, the Yala project could still qualify as an AIJ demonstration project.

2.3 Economics, Investments and Financing

2.3.1 Investments in Bio-Power and Financial Packaging of Projects – M. Mendis

In his presentation, Matthew Mendis first overviewed the three Climate Change operational programs of the Global Environmental Facility of the World Bank. He then presented some biomass energy projects that have been financed by GEF. Following this, he went into constraints and opportunities for financing renewable energy projects in general.

The GEF climate change operational programs

The Global Environmental Facility of the World Bank has started three climate change operational programs. The emphasis of these programs is to remove barriers to the implementation of climate-friendly, commercially viable technologies; and to reduce the costs of prospective technologies that are not yet commercially viable. The three GEF operational programs in the climate change focal area are:

1. Removal of barriers to energy conservation and energy efficiency;
2. promoting the adoption of renewable energy by removing barriers and reducing implementation costs; and
3. reducing the long-term costs of low GHG emitting energy technologies.

During the initial GEF program periods, the emphasis will be on the preparation of national GHG inventories, National Action Plans to FCCC objectives and identification of GHG mitigation and climate change adaptation options;

On the subject of biomass power generation, GEF has been involved in at least five different programmes, varying from biomass energy applications at village level in rural India to a 30 MW dendropower demonstration project using biomass integrated gasification and gas turbine technology in Brazil.

Financing renewable energy projects

It is clear that different financing strategies are required for different types of energy projects. Some key factors that should be properly assessed are the scale of the project, the point of sale, fuel supply and the status of the technology.

As compared to the large conventional energy projects, renewable energy projects tend to have relatively high initial costs for capital and project development, as compared to the O&M and fuel costs. In order to limit the annual debt service payments, project developers have to seek long term loans. Because of their relatively small size however, large financial institutions are often not interested and project developers are referred to commercial banks that may charge higher interest rates and ask for shorter term debt servicing. These commercial banks often have their doubts about the reliability of the technology or the fuel supply and expect that the new technology is hard to sell off if the project fails.

In most of the cases, small, off-grid systems such as solar home systems and windmills are directly sold to the better-off end-users that can afford it. In order to make the technologies available to a broader target group, cascade financing may be applied through leasing programs, micro-utilities or an increased mortgage on the overall costs of a house. The somewhat larger isolated grid systems are often initiated by a project developer that can be held financially responsible, but such medium sized projects are relatively hard to assess.

Large, grid-connected projects are often developed jointly with financial institutions that are well informed about the technological aspects. This is very similar to conventional energy projects. It is possible to insure the risk associated with new, large-scale technologies such as biomass gasification for power generation, but this adds significantly to the overall financing costs.

Equity, debt and grant financing can be obtained from different institutions. A project developer can seek additional equity from venture capitalists or equity fund investors that support risky investments for high returns. Equipment suppliers often offer equity financing opportunities as well. Debt financing is principally provided by commercial banks, who take minimal risks. Grants are provided by the World Bank’s GEF, international and national agencies such as UNDP, DGIS or MNES, and philanthropic foundations to promote environmental or social development.

Recently, several financing programmes have been established specifically for renewable energy. Examples are the Asia Alternative Energy Unit (ASTAE) of the World Bank, the Renewable Energy and Efficiency Fund (REEF) of the IFC and a 100 Million US$ loan of ADB to IREDA for biomass cogeneration in India. A new source of bilateral funding comes from AIJ projects. Some green banks and funds, such as the Triodos Bank in the Netherlands, specifically target financing support for RE projects.

Discussion

Professor Shukla gave some more background information to Mr. Mendis' presentation. He remarked that the majority of the cases presented so far focussed on biomass power options on the win-win side of Figure 1. In order to bring the cost curve down for future technology options such as BIG/STIG and biomass derived fuels, large investments research and development are essential. The 30 MW biomass power project in Brazil is praiseworthy in this respect.

One can observe that in general, renewable energy has matured significantly in terms of reliability and costs of the technology, professionalism of the developer, scale and grid integration. Wind power applications have evolved from small-scale water pumping windmills to large wind turbines with grid interconnection. Dr. Faaij opposed Mr. Mendis' statement that the 'big boys' are not interested. Shell, BP and even large insurance corporations and pension funds have recently invested hundreds of millions of US$ in development and application of renewable energy technologies. Examples of large projects are a 1,000 MW windpower project in the North Sea, a 1,000 roofs PV project in the Netherlands, and biomass combustion plants that already reach 150 MW. In India, equipment costs may come down significantly through indigenisation of the technologies by local manufacturers. Under current Indian conditions biomass power can be competitive with coal if the biomass yield is around 15-20 dry tonnes per ha.

The market for biomass fuels however does not yet exist and has very weak linkages. Therefore, one of the most crucial economic issues for the development of dendropower is the uncertainty of yield, price and competing needs of the woodfuels grown. In India, research is being done on 70 fuelwood species suitable for wasteland. The Indian government has provided wasteland for dendropower, but this is mainly being used for other purposes. Mr. Quadri also expressed his concern about the competitive uses in the future for both the species selected as well as the low productivity wasteland for dendropower. As long as the social and economic consequences can be overseen and are acceptable, it may even be more appropriate to use highly fertile land for growing trees. In Sri Lanka where oil import has become unaffordable, dendropower has attracted a lot of attention. Here, it was found that multipurpose trees and agroforestry are the most promising options.

Some other economic barriers are the existing subsidies on nuclear and conventional fuels such as coal, diesel and kerosene, and the complex logistics of a large-scale power plant that is desired from an economic point of view.

It may be most appropriate to start developing dendropower in the niche markets, such as the sugar industries and the waste-to-energy market. Sugar industries are normally only operated during the milling season, and large fuelwood plantations may be used to supply off-season fuel. This option is currently being examined in Nicaragua.

One cannot expect vertical integration of plantation and power plant by the private sector, because they are very different types of operations. An entrepreneur interested in building a power plant would find it very complicated to start operating a fuelwood plantation. In Thailand for example, natural gas is still much cheaper than wood from plantations. Also, the first rotation of the trees is only after 5 years, so a bank would decide to provide a loan 5 years before operation. This makes such an integrated project hardly bankable.

3. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were formulated jointly by the participants of the expert consultation.

3.1 OPTIONS FOR DENDRO-POWER IN ASIA

Conclusions

1. Dendro-power provides a significant potential to contribute to national economic growth and employment generation in rural areas, as well as local and global environmental management.
2. With modern technologies, wood and other biomass can provide a competitive and sustainable fuel for processing and conversion into electricity.
3. The development of dendro-power fits well into the general trends towards deregulation and privatization in the power sector, and/or decentralized power supply in remote areas.
4. Mainstream as well as niche markets for dendro-power do exist in RWEDP member-countries in Asia. The governments of these countries can formulate a strategy for the development of modern dendro-power.

Recommendations

1. RWEDP member countries should explore the sustainable potential of wood and other biomass fuels to help meet their growing demand for electricity, in addition to the existing use of these fuels for process heat.
2. RWEDP member countries can initiate the identification and preparation of viable dendro-power projects in niche markets. Amongst potential niche markets are power plants based on combinations of woodfuel with agro-residues. This will help to overcome seasonal shortages in the supply of the agri-residues.
3. Co-firing of woodfuels with coal or lignite using modern technologies should be explored and experience with large-scale supply of biomass should be gained in such applications.
4. The potential of dendro-power for mainstream applications in suitable areas in Asia should be studied.
5. Authorities should proceed with the implementation of clear regulations and mechanisms for wheeling and banking of power so as to accommodate independent power production.
6. FAO and other international organisations should assist in preparing dendro-power policies, strategies and projects in member-countries.

3.2 BIOMASS ENERGY RESOURCE BASE

Conclusions

1. RWEDP member countries possess a large potential resource base for bio-energy fuels. The resource base consists of (1) agro- and forest residues that cause a disposal problem, (2) agro- and forest residues that have alternative uses but can be used under certain conditions and (3) wood and biomass specifically grown for energy purposes – there is only a small amount at present but it can be expanded.

2. Site-specific data and evaluation of the resource base and its potential are not yet available. Efforts can be made to obtain detailed and site-specific information on present and future alternative uses of bio-resources.
3. There is limited experience with large-scale woodfuel plantations.

Recommendations

1. RWEDP member countries should engage in establishing databases for evaluating the potential of bio-energy resources for modern applications in the power sector on an area-specific basis. Competing uses, supply patterns, markets and prices should be included in these databases.
2. The potential of diversified biomass fuel supplies (dedicated wood plantations, available wood residues, other biomass) should be evaluated for feeding multi-fuel boilers and gasifiers.
3. The potential of dedicated woodfuel plantations and residues from other sources should be inventoried in various areas in the context of complementing and competing interests. Special consideration areas are buffer zones around protected areas and areas where erosion prevention, water retention, biodiversity conservation etc. can be obtained.

3.3 PROJECTS, TECHNOLOGY AND MANAGEMENT

Conclusions

1. Several mature and proven small-scale and large-scale technologies for dendro-power plants are available and more technologies are emerging.
2. Economies of scale provide substantial benefits for dendro-power plants. The feasibility of such options must be traded-off against constraints in the resource base, logistics of support, and other potential limitations.
3. Vertical integration of activities in dendro-power (from biomass resource development to power generation) provides the most feasible approach in the initial stages of local market development since it shields the resource base from competition.
4. Expertise is available and can be further complemented to prepare and implement dendro-power strategies and projects.

Recommendations

1. RWEDP member countries should seek international cooperation for the preparation and implementation of dendro-power projects. Partners can be technology suppliers as well as specialised technical and financial consultants, and others.
2. At the same time, RWEDP member countries should make efforts to further develop local technologies and expertise required for dendro-power plants, including manufacturing capabilities for dendro-power equipment.
3. South-South cooperation in R&D efforts for dendro-power development should be promoted. RWEDP member countries should also seek cooperation with bilateral and multilateral organizations for supporting R&D on dendro-power in Asia.
4. State-of-the-art proven technologies should be selected for current applications in Asia.
5. The feasibility of a demonstration project for dedicated dendro power generation should be studied.

3.4 ENERGY AND CLIMATE POLICIES

Conclusions

1. The sustainable use of wood and other biomass fuels provides a strong support to the implementation of international policies which address global climate change issues.
2. Many industrialised countries have made substantial progress in applying modern technologies for biomass fuel utilisation. Developing countries are now gaining experience in these options.
3. Financial support mechanisms are being developed by international financial institutions and/or industrialised countries that enable developing countries and economies in transition to apply modern bioenergy options.
4. The role of governments is to provide the policies and framework for implementation by the private sector. It is increasingly being accepted that internalisation of externalities in the energy sector is economically feasible and environmentally desirable.

Recommendations

1. Developing countries and economies in transition should convert the new options for dendro-power into projects, making full use of the modalities for funding and implementation.
2. In order to fully exploit the new options, capabilities should be developed with expert inputs from the energy, environment, forestry and financial sectors.
3. Initiatives should be taken for the provision of information, training and demonstration for policy makers, professionals (engineers, environmentalists, foresters, economists, and others) and the general public on the positive impacts of biomass energy for economic development, employment generation and environmental management.

3.5 FINANCING

Conclusions

1. The renewable energy sector is professionalising rapidly, resulting in higher success rates for projects.
2. The major barriers for obtaining financing for dendropower are related to uncertainties in fuel supply caused by competitive use of both the lands that it is on, the long tree harvesting times as well as alternative uses of the biomass once harvested. A technology related financing barrier is the low scrap value of the modern and highly specific equipment.
3. More financing options besides the World Bank and GEF are becoming available such as the Clean Development Mechanism (CDM) and green banks.

Recommendations

1. RWEDP member countries should take advantage of the new mechanisms for financial assistance, at the same time serving their domestic priorities for power sector development and local environmental management.
2. Governments should assist private sector organisations to actively access financial options.

PART II: TECHNICAL PAPERS PRESENTED

1. BIOMASS ENERGY RESOURCES FOR POWER AND ENERGY

by

Auke Koopmans
Wood Energy Conservation Specialist
Regional Wood Energy Development Programme, FAO - Bangkok

1.1 INTRODUCTION

The strong economic growth rates of many Asian economies can only be maintained with sufficient supplies of reliable energy sources. Huge investments have been made in energy infrastructure, and the import of conventional fuels puts a heavy burden on foreign exchange reserves. Associated impacts on the local, regional and global environment are high. Moreover, many countries still face a large suppressed electricity demand due to financial and technical constraints on building additional generation and distribution facilities. For serving remote areas with low power densities, many governments are now promoting New and Renewable Energy Sources (NRES) such as PV, wind and geothermal energy as alternatives for large scale, conventional power generation. In the megawatt range however, not all NRES will be able to compete with conventional energy sources in the foreseeable future.

Asian countries are at present encouraging private power generation, preferably using locally available fuels, including biomass. World-wide environmental concerns with regard to energy use and advancements in efficiency, fuel acceptability, and cost-effectiveness of biomass energy technologies, have resulted in the re-emergence of biomass as a competitive, sustainable and environmentally benign energy option.

The potential for private power generation using agroresidues, forest residues or dedicated energy plantations in Asia is vast. However, this can only be harnessed if the private sector finds a conducive investment climate, enabled by appropriate government policy reforms in which financial, economic, social, institutional and environmental issues are properly addressed.

1.2 ENERGY CONSUMPTION AND TRENDS

In 1994, the total energy consumption of the region was about 50,000 PJ, accounting for about 21% of the total world energy consumption (see Table 1.1)[1]. Total energy consumption includes both conventional and traditional energy consumption. During the last decade, the total energy consumption growth rates of countries in the region grew faster than the world average. The average annual growth rates ranged from 1.5% to 8.0% compared to the world average of 1.9%. However, energy consumption per person in the

[1] ***Little information is available which gives an accurate overview of the composition of the traditional fuels used in most countries in the region. The overview shown in table 1.1 was compiled from various sources. In some cases a selection had to be made from several conflicting data sources. These are further referred to as "best estimates" (see also FAO-RWEDP Field Document No. 50: Regional Study on Wood Energy Today and Tomorrow in Asia, RWEDP, 1997a).***

region is lower than the world average and is still much lower than that of the developed countries. Per capita energy consumption in the region ranges from 1 to 50 GJ compared to the world average of 42 GJ and to the OECD average of 133 GJ.

Table 1.1: Consumption of conventional, wood and biomass energy in 1993-1994 (PJ)

Country / Area	Total Energy	Conventional Energy	Woodfuels	Biomass Energy	Share of Woodfuels in Total	Share of Biomass in Total
Bangladesh	714	210	141	504	20%	71%
Bhutan	14	2	12	12	86%	86%
Cambodia	94	14	79	81	84%	86%
China	31,256	23,866	3,290	7,390	11%	24%
India	8,751	5,822	2,603	2,929	30%	33%
Indonesia	2,796	1,978	818	818	29%	29%
Lao PDR	47	5	42	42	89%	89%
Malaysia	994	898	93	96	9%	10%
Maldives	2	1	1	1	55%	55%
Myanmar	348	77	271	271	78%	78%
Nepal	279	23	192	256	69%	92%
Pakistan	1,984	1,066	521	918	26%	46%
Philippines	965	507	298	458	31%	47%
Sri Lanka	174	79	85	95	49%	55%
Thailand	1,837	1,352	353	485	19%	26%
Vietnam	1,076	260	423	816	39%	76%
RWEDP	51,331	36,159	9,223	15,172	18%	30%
RWEDP without China	20,075	12,293	5,933	7,782	30%	39%
RWEDP without China & India	11,324	6,471	3,330	4,853	29%	43%

Source: Estimated from data of IEA, WRI, Country data and RWEDP's "best estimates" (FD 50)

With the population and economy of the region growing and stimulating the socio-economic transformation that moves societies to more diverse and intensive uses of energy, we can expect the demand for and the consumption of energy to accelerate. This will result in more people moving up the income ladder and adopting more energy-intensive lifestyles. Given that economic growth rates in the region are higher than the global average, and with a population accounting for over half of the world's population, the region's energy consumption growth rate is expected to outpace the world average and the energy use in the region will grow far beyond what it is today.

In order to predict how the future scenario with regard to energy use will look, use is made of mathematical models to project future energy consumption. In its simplest form this consists of extrapolating energy consumption trends over time, either on the basis of population or economic growth rates. The results arrived at with the various models are usually different to a greater or lesser extent. Other more complex methods are available which combine the effects of population and economic growth, energy prices, etc. on energy consumption. However, whichever method is used, it appears that all results point to continued significant increases in energy consumption in the countries discussed above.

Wood Energy Consumption Trends

In most countries in the region, wood has been, and in many cases still is, one of the most important sources of energy. In order to provide some insight into what the future holds with regard to wood energy consumption, attempts were made to make a forecast by using a mathematical model[1] developed by FAO (FAO, 1997). The model takes into account population growth, level of economic activity, etc. The results of the forecast are shown in Table 1.2.

Table 1.2: Potential supply and estimated consumption of woodfuels in 1994 and 2010 in the 16 RWEDP member countries.

	1994		2010	
	Potential supply *(kton)*	Estimated consumption *(kton)*	Potential supply *(kton)*	Estimated consumption *(kton)*
Bangladesh	8,999	9,396	9,271	13,320
Bhutan	5,946	819	5,624	1,195
Cambodia	81,565	5,375	43,827	7,553
China	598,546	219,122	639,733	252,819
India	235,167	173,412	255,729	225,725
Indonesia	439,049	54,474	394,923	67,465
Laos	46,006	2,329	38,902	3,496
Malaysia	137,301	6,187	97,777	8,216
Maldives	34	80	41	123
Myanmar	129,935	23,058	106,930	31,183
Nepal	11,444	12,787	10,304	18,378
Pakistan	22,569	34,687	21,144	52,167
Philippines	89,267	23,051	71,171	30,329
Sri Lanka	8,963	5,681	9,044	6,769
Thailand	67,030	46,069	59,157	53,390
Vietnam	48,960	29,368	42,730	39,418
RWEDP	**1,930,778**	**645,895**	**1,806,307**	**811,548**

Source: RWEDP, 1997a

However, while this macro analysis model provides a simple approach to studying forest products consumption, including woodfuels and projecting future consumption, such techniques do not account for the many factors that drive energy consumption and the types of fuel used. Therefore, this model is not an accurate tool in terms of projecting trends in the consumption of specific fuels such as woodfuels where fuel switching to other sources of energy may take place[2].

[1] The Global Forest Product Model or GFPM is a dynamic spatial equilibrium model developed with the Price Endogenous Linear Programming System. The theoretical structure is that of spatial equilibrium in competetive markets. The model solves the equilibrium by maximizing the sum of producer and consumer surplus subject to material balance and capacity constraints in each country or region, in each projection year. Because material flows must balance, it is a good way of checking data consistency.

[2] Applying only macro-factors such as population or economic growth rate overlooks the other determinants of wood energy consumption. Among the more important determinants are pattern of income distribution, location of users and available infrastructure, fuel prices and fuel accessibility. The pattern of income distribution is an important parameter determining consumption of woodfuels.

The results of the macro analysis however is useful for a) providing a quick overview of where things are heading with regard to wood and biomass energy use, b) defining broad policy measures for wood and biomass energy development and c) for defining further specific data collection activities to be used to formulate more specific strategies e.g. detailed programme development, designing projects, and making decisions for investments.

However, consumption is only one part of the equation, as the amount consumed has to be supplied from somewhere[1]. Unfortunately, independent data on supply are rarely available if not non-existent. This makes forecasting an even more tricky exercise in comparison to fossil fuels and electricity, where supply data are available. Future supply requirements are governed by demand forecasts based on present consumption data. The fine-tuning of demand forecasts allows, therefore for more accurate supply planning.

By contrast, the fine-tuning of woodfuel demand forecasts remains an academic exercise, as long as data on present and future woodfuel supplies are not available or are considered to be unreliable (estimates, etc.). In order to overcome this situation attempts were made to estimate present and future potential woodfuel supplies. To do this, use was made of the "best estimates" on consumption given earlier in Table 1.2. Various assumptions (see also Annex 1) had to be made of which one - the fact that non-forest areas are a very important source of supply of woodfuels - is considered to more important than all the others. Main sources of woodfuels, besides natural forests, include government-, private - and community forests, agricultural land, village and private woodlots, scattered trees on farm boundaries, road sides, canal and river banks, homesteads, gardens, etc. Evidence suggests that these non-forest sources, including wood residues from processing, etc. in many cases supply over 50-75% of all wood consumed as energy.

Potential woodfuel supply figures are based on data, estimates and projections for land use, wood productivity for several land use classes, and the availability of wood for energy use. FAO publications were used as a data source for land use and wood productivity for various land types. For forestland, other wooded land and agriculture area, the potential supply is based on average annual yield estimates, assuming a sustainable use of resources. This implies that:

- For natural forests it has been assumed that the Mean Annual Increment (MAI) of forests could potentially be available for timber and fuel as it would not change the forest cover area.
- Wood waste from deforestation refers to wood potentially available from natural forestland cleared due to commercial logging, expansion of agriculture land or other reasons. This has been termed as non-sustainable as it has a direct impact on the forest area. However, it should be noted that fuelwood is the by-product of the deforestation.
- With regard to agricultural land and other wooded lands the same assumption was made for natural forests i.e. that only the MAI would potentially be available as woodfuel.

[1] The GFPM model is based on a dynamic spatial equilibrium model i.e. takes into account that supplies may limit consumption. However, the model apparently does not take into account the fact that many woodfuels are derived from non-forest sources and include wood residues and recycled wood.

These assumptions indicate that information on woodfuel supplies needs to be updated, substantiated and/or collected in order to make demand forecasting a more rational exercise. This is particularly true for data relating to MAI as well as tree cover on agricultural land, non-forest land, etc.

For the time being, the results shown in Tables 1.2, 1.3 and Annex 1 can be used to identify broad policy issues. However, it should be emphasised that national aggregate data still bear little meaning as they hide large local variations. Ultimately, supply and demand information should be area-based.

Table 1.3: Potential sources and estimated consumption of woodfuel for 16 RWEDP member countries

	1994			2010		
	Area (Mha)	Mass (Mton)	Energy (PJ)	Area (Mha)	Mass (Mton)	Energy (PJ)
Potentially available woodfuels	**1,382.0**	**1,930.8**	**28,962**	**1,419.7**	**1,806.3**	**27,095**
from forest land (sustainable)	416.2	669.8	10,047	370.4	629.3	9,440
from deforestation (non-sustainable)	-4.25 p.a.	605.6	9,083	-3.11 p.a.	437.8	6,566
from agricultural areas (sustainable)	876.9	601.4	9,021	971.1	692.1	10,381
from other wooded lands (sustainable)	93.1	54.0	810	81.4	47.2	708
Total woodfuel consumption	**1,382.0**	**645.9**	**9,688**	**1,419.7**	**811.5**	**12,173**
from forest land		205.8	3,088		257.3	3,860
from non-forest land		440.1	6,601		554.2	8,513

Source: RWEDP (1997a)

The data as shown give an overview of the woodfuel consumption and the potential supply from forest and non-forest resources, for the whole RWEDP region and for each country (annex 1). Although largely based on assumptions regarding future trends and natural resources productivity, it can be concluded that for the region as a whole and for most countries, the potential woodfuel supply can meet the aggregated consumption. Indeed non-forest lands, including agricultural land and other wooded land have in theory the potential to supply all regional fuelwood requirements on a sustainable basis.

However, there are large variations and this should be kept in mind. For some countries there appears to be a gap between supply and consumption (Bangladesh, Nepal, and Pakistan). Such imbalances may be caused by data inaccuracy and/or overly conservative assumptions regarding supply. Nevertheless, it can be assumed that these countries will need special attention with respect to wood energy, particularly the domestic sector where wood and biomass are often the only fuel available to the rural population. The same comment also applies to India, Sri Lanka, Thailand, and Vietnam, which may face critical situations sometime after the year 2010.

The data shown do not include wood processing residues such as sawmill off-cuts, sawdust, etc. nor recycled wood e.g. that derived from the demolition of buildings, pallets and packing crates, etc. Although the latter are known to be important sources of energy for many poor people, it is not known how much of such recycled wood be available on an annual sustainable basis within the region. It is known however, that in Europe this wood is available in relatively large quantities and is used for power generation such as co-firing with coal, etc. (Faaij, 1997). Apparently there appears even to be an export market for such wood as is evidenced by the fact that plans for a power generation facility in the Netherlands had to be abandoned as the recycled wood was exported to Nordic countries rather than sold on the domestic market.

With regard to wood processing residues, some information is available. Only about 20 percent of a tree initially harvested for timber purposes results in sawn timber. The other 80% is discarded as field residues (40%) and process residues (40%) such as bark, slabs, sawdust, trimmings and planer shavings (RWEDP, 1996). Plymills produce about the same amount of residues as sawmills.

Process residues are increasingly being used for cogeneration where the electricity is used to power the equipment and the heat is used for kiln drying purposes. In 5 of the ASEAN countries alone, some 12 million tons of wood process residues are produced annually (see Table 1.4). Malaysia and Indonesia are for the moment the most favourable places in the ASEAN region for power generation in view of the large average sizes of the mills and the certainty of future wood resources (COGEN, 1997). Part of these residues may be used as input for fibre board, etc. but a large part, in particular the fines and dust, would be available as a source of energy.

Supply and consumption of crop residues. Besides fuelwood and charcoal, agro-residues are also an important source of energy in the region both in the domestic and the small-scale industrial sector. Table 1.5 shows that in 1994 some 2.1 Gt of crop residues was produced in the RWEDP countries, of which some 1.7 Gt are field based residues (normally left in the field) and 0.4 Gt process based residues (residues normally available in larger quantities at central processing centres).

Table 1.4: Production of wood residues in ASEAN countries

Source	Residue type	NHV (GJ/ton)	1994 production (kton)					
			Indonesia	Malaysia	Philippines	Thailand	Vietnam	ASEAN
Sawmilling	Solid	15	3,865.6	4,200.4	183.4	354.4	342.5	8,946.2
	Sawdust	15	1,220.7	1,326.5	57.9	111.9	108.2	2,825.1
Plywood	Solid	22	5.9	0.0	4.1	21.6	0.0	31.6
	Dust	22	0.7	0.0	0.5	2.4	0.0	3.5
Particle board	Dust	22	0.0	0.0	0.3	0.2	0.0	0.5
Total process residues			5,092.8	5,526.9	246.1	490.5	450.6	11,806.9

Source: Estimates based on FAO (1997)

It should be noted that not all of the crop residues produced are available as a source of energy as some of the residues are used as fuel, fertiliser, feedstock, food/fodder or fibre. Besides, part of the residues may have to be left in the field for soil conservation purposes and for that reason also would not be available as a source of energy. Table 1.5. also gives rough estimates of the amount of residues which could be available in 2010 based on various assumption (see also Annex 1).

The present consumption of these crop residues for fuel purposes is shown in Table 1.6 for those countries for which data were available or reliable estimates could be made. In particular, the relatively poor countries with limited wood resources are already using these residues to a large extent. The fact that agro-residues provide a ‘safety net’ for fuelwood users in case of scarcity should not be neglected when considering alternative uses of these residues. As is the case for other non-commercial energy sources, the table shows that recent and accurate data on crop residue consumption is hardly available. Being a residue of crop production, in almost all cases little or no attention is given to it by governments and/or related departments[1]

Table 1.5: Total estimated crop residue production in 16 RWEDP member countries

	1994		2010	
	Mt	PJ	Mt	PJ
Field-based residues	**1,698.5**	**25,605**	**2,376.5**	**35,963**
Rice straw	812.0	13,008	1,033.2	16,552
Wheat straw	307.6	3,808	429.6	5,318
Millet stalks	27.1	336	19.2	238
Maize stalks	257.2	4,321	452.8	7,607
Cassava stalks	3.1	53	3.0	53
Cotton stalks	68.2	845	101.4	1,256
Soybeans straw and pods	77.0	953	112.7	1,395
Jute stalks	8.8	109	1.4	17
Sugar cane tops	137.1	2,167	222.5	3,518
Cocoa pods	0.5	6	0.8	9
Processing-based residues	**437.8**	**6,917**	**644.0**	**10,211**
Rice husk	123.4	1,922	157.0	2,446
Rice bran	38.4	536	48.8	682
Maize cob	35.1	572	61.8	1,006
Maize husks	25.7	318	45.3	561
Coconut shells	4.5	81	5.8	104
Coconut husks	15.6	290	20.1	375
Groundnut husks	9.6	149	13.3	208
Groundnut straw	46.0	570	63.9	791
Oil palm fibre	1.7	19	3.3	37
Oil palm shell	0.8	14	1.5	28
Oil palm bunches	2.7	22	5.3	44
Sugar cane bagasse	132.5	2,399	215.1	3,893
Coffee husk	2.0	25	2.9	36
Total amount of agricultural crop residues	**2,136.3**	**32,522**	**3,020.6**	**46,173**

Source: RWEDP (1997a)

Although data quality is unsatisfactory, it can be concluded from the data available and field observations that a large portion of the crop residues could still be available. This is particularly valid for process residues such as rice husk and bagasse, which are already available at centralised locations and often have no other uses or even cause disposal problems. This opens up prospects for its use as a source of energy on a larger scale not only for traditional energy use but also, and more importantly for modern biomass energy applications.

[1] ***As a consequence, appropriate policy measures are often forsaken. This is spite of the fact that biomass usually constitutes a major form of energy. Except for Nepal where biomass contributes some 95% to the primary energy consumption, woodfuels, animal waste and crop residues are almost never disaggregated in national energy balances available to the general public. Thailand produces annual consumption data of bagasse and rice husk, but Sri Lanka only mentions "commercial bagasse" in its energy balance. Pakistan still uses data from the World Bank funded 1992 Household Energy Strategy Survey.***

Table 1.6: Best estimates of crop residue production and consumption for energy purposes in RWEDP member countries

	Production (1994)			Consumption		
	field based	process based	total production	all crop residues		
	(PJ)	(PJ)	(PJ)	(PJ)	(%)	year and source
Bangladesh	804	177	981	181	18%	1992/93, BBS (1996)
Bhutan	3	1	4			
Cambodia	67	14	81	7	9%	1994, RWEDP estimates
China	12,061	2,339	14,399	4,103	28%	1994, RWEDP estimates
India	6,814	2,286	9,099	328	4%	1994, RWEDP estimates
Indonesia	1,777	654	2,430			
Laos	51	10	61			
Malaysia	72	64	136	3	2%	1994, RWEDP estimates
Maldives	-	0	0			
Myanmar	545	132	678			
Nepal	158	32	189	53	28%	1994/95, WECS (1996)
Pakistan	887	274	1,160	307	27%	1992, HDIP (1997)
Philippines	584	337	922	48	5%	1994, RWEDP estimates
Sri Lanka	84	38	122	5	4%	1995, ECF (1996)
Thailand	958	362	1,320	313	24%	1995, DEDP (1996)
Vietnam	741	198	940	507	54%	1994, RWEDP estimates
RWEDP	25,605	6,917	32,522			

Sources: ***Production: RWEDP (1997a), Consumption: see last column.***

1.3 MODERN BIOMASS ENERGY TRENDS IN ASIA

In the past few years, several countries in the region have become involved in modern applications of wood and biomass energy. These are not research or pilot projects – these are actual investment projects that exploit wood and other biomass fuels to generate heat, steam and/or electricity for use by industries through more efficient, convenient and modern technologies. These projects are proving to be technically successful and economically profitable. They show what the role of wood and biomass energy could be in the future. They also prove that biomass energy can be a technically efficient, economically viable and environmentally sustainable fuel option.

Table 1.7 indicates that modern biomass energy technologies are at present not yet widespread, especially when compared to traditional biomass energy consumption. This is even more so considering the fact that statistics on traditional biomass use are often underestimated.

Table 1.7: Use of energy sources by region in PJ primary energy

Region	Modern biomass	Traditional biomass	Other renewables	Conventional sources	Total primary energy	Modern biomass as % of primary
North America	454	908	3,320	46,838	51,519	0.9%
Latin America	1,099	2,986	1,982	7,715	13,781	8.0%
Western Europe	239	478	2,603	31,599	34,919	0.7%
Central/East Europe/CIS	239	717	1,433	39,147	41,535	0.6%
Mid East and Africa	119	3,869	382	9,554	13,925	0.9%
SE Asia and Pacific	549	8,383	1,887	33,200	44,019	1.2%
South Asia	191	4,872	525	5,064	10,653	1.8%
World	2,890	22,213	12,133	173,116	210,352	1.4%

Note: Other renewables include solar-, wind-, hydro-, geothermal-, wave and ocean energy
Source: Adapted from WEC (1994)

In particular, in Asia, modern biomass applications still have a long way to go in particular in comparison with Latin America. However, it should be clear that large opportunities exist to broaden the market for modern biomass energy technologies. Large amounts of biomass residues still remain unused and could potentially be available in South and South East Asia for use as a source of energy[1]. The same is true for wood residues, particularly those which are generated by wood processing industries. Both could provide a significant part of the energy demand if the appropriate technologies are introduced.

Worldwide, major advancements have been realised in biomass power technologies. The most promising concepts are direct combustion, co-firing (wood/biomass in combination with other fuels), pressurised and atmospheric gasification and pyrolysis. Pressurised gasification promises higher efficiencies but is also more expensive than atmospheric gasification. Though typical biomass power plants used in Asia have efficiencies of around 15-20% with unit electricity costs of around 5-8 ct/kWh, modern combustion systems reach 35-40% with unit costs of 4.5-5.5 ct/kWh, and gasification coupled with a combined cycle could go up to 48% (Moreira et al, 1997). Many pilot projects with gas turbine linked biomass gasification are underway. In Northeast Brazil, a 30 MW BIG/GTCC plant is due for commissioning in 1997 at a total cost of 30 MUS$. The gasification of biomass is relatively easy because of its high reactivity and low sulphur content, but the low calorific value and different composition of the gas requires adjustment of the connected gas-turbine.

Most Asian countries have large scale sugar industries, which already use bagasse as fuel. However, many of those installations were originally designed to burn all residues using low-pressure boilers (10-20 Bar). This way, the captive energy demand could be covered relatively cheap and disposal problems could be eliminated. Nowadays however, the demand for bagasse for other purposes has increased considerably, as did its market value. Modern sugar industries employ high-pressure boilers and condensing turbines, generating electricity more efficiently and cost-effectively. In India alone, the potential for bagasse based power generation amounts to 3,500 MW (MNES, 1993). Surplus electricity may be supplied to the grid or surplus bagasse may be sold for paper making or other purposes.

Modern rice industries increasingly use the available rice husk as boiler fuel. Properly burned rice husk ash is a high value input for many industries (e.g. steel production, electronics etc.) because of its high silica content. Careful combustion of rice husk is also necessary since heating the ash above the silica melting point may completely clog the flow of fuel in the boiler. Together with the highly abrasive nature of rice husk, this may ultimately destroy the boiler. Modern rice husk boilers are now commercially available that generate both high quality ash as well as energy in an efficient way without clogging or excessive wear.

1.4 RESOURCE DEVELOPMENT

In contrast to the process-based residues such as bagasse, ricehusks, sawmill offcuts, etc, the use of field based residues pose different problems. Field based residues such as rice straw, wheat straw and sugar cane tops and leaves could in principle be collected, bale

[1] Very rough estimates, based on the tables in this paper, indicate that over 1,000,000 kiloton of wood and other biomass remains unused each year. Even if only a small part were to be used for modern biomass energy applications like co-generation, etc. it is clear that the potential to substitute conventional sources of energy with biomass would still be very large.

pressed, and transported to a biomass power plant. However, it requires additional field operations and cost, and adverse weather conditions may cause the residues to deteriorate. Also, traditional producers are unlikely to consider the fate of the residue until the primary product has been harvested. Harvesting main crops and residues simultaneously therefore seems to be the most desirable approach, but such systems are not yet available. However, this is not seen as the major deterrent to the utilisation of biomass residues for energy. Once supportive market institutions have been established and modern biomass energy takes off on a large scale, it is assumed that optimised collection systems will become available. In fact some are already operational, in particular in the cane sugar industry with baling of the sugar cane trash.

At the same time it may be assumed that at present field crop residues are not likely to support a biomass energy market alone because of the variable quality and quantity, and the low density. However, together with other biomass fuels or in combination with conventional sources of energy (co-firing, etc.), crop residues may deliver a stable supply to a power plant.

In addition to the agricultural residues, residues from forest plantations (for timber and/or pulp for paper making) as well as dedicated energy plantations using short rotation forestry or fast growing grasses may be an option. Again little information exists on the potential for such crops in the Asian region. Information from experiences in Europe indicate that some 12-15 oven dry tons of willow can be harvested per hectare while in the case of miscantus the yield would be about the same. It is expected that under more favourable conditions the yield would be higher (Faaij 1997).

This option would in particular be possible in those cases where large areas of idle or unproductive (and unused) land are available. Waste lands, etc. are at present already being utilised i.e. regenerated through tree planting activities (see box 1). Unfortunately, not much information is available on the size of such areas in the various countries in the region.

However, it is important to consider the amount of biomass removed and retained from such lands to prevent soil erosion and excessive nutrient and organic matter removal from the soil. At the same time, by replanting such wasteland, the degradation of other lands may be prevented, i.e. it may have environmental benefits.

Energy plantations may also help to restore degraded soils if nitrogen-fixing species are used with sufficient long rotation periods and fertilisation. Wood ashes from biomass based power plants can be returned to the soil in order that nutrients contained in the ash are recycled. Ash granulating systems have been developed which can be used in combination with biomass based power plants.

Before any large-scale biomass energy use is promoted a proper environmental impact analysis should be carried out to consider and weigh the entire pros and cons. The latter should not be limited to the direct impact on the land used but should also cover employment effects[1] as well as external impacts i.e. on the local/global environment (greenhouse gas issues), siltation of rivers through erosion, health impacts of the use of biomass as well as competing fuels, the food versus energy question, the influence of

[1] The collection, transport and trade in woodfuels is labour intensive. It has been estimated that fuelwood requires some 2-20 times more labour input for the same energy output than conventional sources of energy such as coal, oil, gas and electricity (RWEDP, 1997a)

widespread use of wood and biomass for power generation on the price of such fuels and the effect this may have on traditional users of these fuels, etc.

Box 1: Wastelands and other Degraded Lands

Wastelands or other lands of low productivity have great variety. In some countries, wastelands are predominantly eroded landscapes that may have been formerly productive - this occurs throughout the region; in others, they are deserts and/or desertic, this being important in Australia, China, India and Pakistan. In a few locations, the land has been destroyed by salination due to inappropriate irrigation; in yet others, forest clearing has given way to undesirable grasses or shrubs (such as the *Imperata* grasslands of Indonesia). It is not important to estimate a regional total for such lands but to emphasise that they represent an enormous potential area which, because it is attractive for little else, may be relatively easily released for forestry. There are also positive reasons for highlighting wastelands - they have a tendency to expand and trees and forests are one of the keys to arresting their advance. Placed in such roles, trees and forests serve as a nursery for agriculture: they renew the productivity of wasteland soils or protect them from further degradation, so increasing agricultural production potential.

India has large areas of wastelands or degraded areas. Estimates of uncultivable lands were about 38 million hectares in the 1950-51 period but only about 20 million hectares for 1990-91 probably due to definition change. By the latter year, India had, in addition to the declared uncultivable land, about 15-17 million hectares of "cultivable" wastelands so giving a total wasteland expanse of nearly 35 million hectares. Fallow land, much of it degraded, covers another 10 million hectares. Thus, within the cultivated lands, there are over 25 million hectares of degraded land available in scattered patches but within easy reach of where people live. Apart from extensive wastelands, about half of India's recorded forest areas have already become degraded or open due to disproportionate withdrawals of forest produce. Total annual afforestation efforts from all sources fluctuate between 1.0 to 1.3 million hectares of which government-funded afforestation covers about 1.0 million hectares per year. Altogether, efforts are much below assessed needs and earlier-announced plans for 5 million hectares planting annually.

China probably has wasteland reclamation and containment programs on the largest scale in the region and perhaps the world. As an example, the "Three-North Shelterbelt Development Program" covers some 4 million square kilometers (over 42 percent) of the country's total land area in north China. This is reportedly the world's largest ecological program. It commenced in 1978 and is planned to be completed by 2050 with a planned afforestation/tree-planting target of 35.08 million hectares. By 1994 it had achieved some control over 30 percent of the soil and water erosion area in the Loess Plateau so reducing sand/mud flow into the Yellow River by 10 percent, There are also similar programs to protect the upper and middle reaches of the Yangtze river (the largest river in China with a catchment population equalling a third of the country's total). This program will also protect vital infrastructure, including the "Three Gorges Dam". There is also a "Coastal Shelterbelt Development Program" that covers 18,000 kilometers of the coastline. China also carries out sand dune stabilisation and aerial sowing techniques in the arid, semi-arid and arid sub-humid areas, anti-desertification programs along highways and railways, and rehabilitation of salinised soil. It intends that increasing amounts of desert land be reclaimed for farming.

***Source*: FAO, 1998**

1.5 CONCLUSIONS

A large physical potential exists for using wood- and biomass residues for modern applications with many associated social and environmental benefits. The ‘easiest’ fuels to use are wood- and biomass process residues that often form a disposal problem or fire hazard such as bagasse, rice husks, etc. Using field based residues for power generation causes more conflicts with other uses, and guaranteeing a future supply may be more difficult. Dedicated energy plantations using short rotation forestry or energy crops may provide additional employment and restore degraded soils and wastelands if carefully carried out. Appropriate institutional support from governmental, non-governmental and international organisations is crucial for harnessing the potential of biomass to replace conventional energy. Important issues to be solved in many countries, in particularly with regard to data and information are:

- The lack of reliable information on the potential and sustainable supply of biomass;
- competing use of such biomass;
- costs and prices of such biomass;
- effect on prices and availability for other users when used in larger quantities; and
- the internalisation of external social and environmental benefits of the use of biomass versus other sources of energy.

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Annex 1 - Background Notes on the Potential Woodfuel Supply Tables 1.8 and 1.9

Land Use

Land use data for 1990 (row 1-4) was obtained from FAO Forest Resources Assessment 1990 (FAO, 1993), for 1995 (row 5-6) from "State of the World's Forests" (FAO, 1997a). Land use data for 1994 was required because data on woodfuel consumption are available only up to 1994. Since these were not available, they were obtained (see row 7-9) by interpolation of the 1990 and 1995 data, assuming a constant annual growth rate during the 5 year interval.

Since data on the area under other wooded land in 1995 were not available, it was assumed constant (row 4, 10). The area under coconut, rubber and oil palm plantations (row 11) was distinguished because data and wood production could be derived from specific data on crop production, productivity and residue-to-product ratios.

Row 13-18 give the average annual change of land use in absolute terms and growth rates. The natural forest area (row 19) for the year 2010 was projected by assuming the same average annual growth rate as during 1990-95 (row 16). The area of plantations was projected by assuming the same average annual increase in hectares as during 1990-95 (row 14). As in 1994, the area of other wooded land (row 23) was assumed constant, and the area of coconut, rubber and oil palm plantations (row 24) was obtained from projected production figures.

Wood Production

Data on wood productivity of natural forest was derived from FAO data on biomass density for natural forest per country (FAO, 1993), assuming an average annual yield of 1% of the biomass density (excluding leaves, see row 27-29). For plantations and other wooded land a constant figure was assumed for all countries, based on various sources (row 30-31).

Not all wood from the resources will be available as fuel, so assumptions were made on the percentage of wood for fuel (80% for all land use types, see row 32-35).

Rows 36-43 show the potential supply of woodfuel from the various land use types for 1994 and 2010, given the data used and the assumptions on land use, productivity and availability.

Wood from Agricultural Lands

Data on the agricultural area for 1984 and 1994 (row 44-45) were obtained from FAO statistics (FAO, 1995b). The agricultural area for 2010 was projected assuming that the area will remain constant in the case of a decrease during 1984-94, and otherwise that it will increase with the same average annual increase as during 1984-94 (row 46).

The area under coffee, tea and cocoa was distinguished because the wood production for these land use types could be derived from data on crop production, productivity and residue-to-product ratios. As for wood from forest and wood land, assumptions were made on the productivity and the availability of wood for fuel (row 53-54).

Rows 55-58 show the potential supply of woodfuel from agricultural land for 1994 and 2010, given the data used and the assumptions on land use, productivity and availability.

The woodfuel supply evaluation only considers forests, other wooded land and agriculture land. Since these may not comprise the whole geographical area of a country, and other land use types may also supply wood, there may exist an additional potential or hidden supply of (fuel)wood (row 59-61).

Rows 62-67 give an overview of the potential fuelwood supply for the various land use types in kiloton per year. Rows 68-73 give the same in petajoules per year. The corresponding figures for the year 2010 are given in rows 82-87 and rows 88-93, respectively.

Fuelwood Consumption

Data on fuelwood consumption were adopted from the best estimates available to RWEDP, from various data sources (row 79). For those countries for which data on sources of fuelwood were available, i.e. the share of fuelwood from forests (row 76), the data were used to estimate the origin of the consumed fuelwood. For those countries for which such data were not available a regional average of 32% coming from forest areas was applied.

Table 1.8: Potential Woodfuel Production and Requirements in 1994 and 2010

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
	Wood from Forest and Other Wooded Land																			
1	1990 natural forest area	*FAO 90*	*1000 ha*	769	2,809	12,163	101,968	51,729	109,549	13,173	17,583		28,856	5,023	1,855	7,831	1,746	12,735	8,312	376,101
2	1990 plantation area	*FAO90*	*1000ha*	235	4	7	31,831	13,230	6,125	4	81		235	56	168	203	139	529	1,470	54,317
3	1990 total forest area	*FAO90*	*1000ha*	1,004	2,813	12,170	133,799	64,959	115,674	13,177	17,664	-	29,091	5,079	2,023	8,034	1,885	13,264	9,782	430,418
4	1990 other wooded land	*FAO90*	*1000ha*	468	355	1,554	28,230	17,689	29,434	8,259	4,584		20,683	672	1,105	5,606	2,113	1,704	13,717	136,173
5	1995 natural forest area	*FAO97*	*1000ha*	700	2,748	9,823	99,523	50,385	103,666	12,431	15,371		26,875	4,766	1,580	6,563	1,657	11,101	7,647	354,836
6	1995 total forest area	*FAO97*	*1000ha*	1,010	2,756	9,830	133,323	65,005	109,791	12,435	15,471		27,151	4,822	1,748	6,766	1,796	11,630	9,117	412,651
7	1994 natural forest area	*in.*	*1000ha*	713	2,760	10,252	100,007	50,651	104,817	12,576	15,790	-	27,260	4,816	1,632	6,799	1,674	11,410	7,776	358,933
8	1994 plantation area	*d.*	*1000ha*	296	7	46	33,411	14,345	6,151	7	120	-	279	57	171	221	139	547	1,474	57,271
9	1994 total forest area	*in.*	*1000ha*	1,009	2,767	10,298	133,418	64,996	110,968	12,583	15,910	-	27,539	4,873	1,803	7,020	1,814	11,957	9,250	416,204
10	1994 other wooded land	*FAO90*	*1000ha*	468	355	1,554	28,230	17,689	29,434	8,259	4,584		20,683	672	1,105	5,606	2,113	1,704	13,717	136,173
11	Of which rubber, coconut, palmoil	*es.*	*1000ha*	98	-	121	704	8,805	17,922	-	4,767	14	358	-	1	10,503	1,702	4,382	1,429	50,805
12	1994 other land than rubber, coconut, palmoil	*es.*	*1000ha*	370	355	1,433	27,526	8,884	11,512	8,259	-	-	20,325	672	1,104	-	411	-	12,288	93,140
	Change of Area																			
13	av. An. Change in natural forest area	*d.*	*1000ha/y*	(14)	(12)	(468)	(489)	(269)	(1,177)	(148)	(442)	-	(396)	(51)	(55)	(254)	(18)	(327)	(133)	(4,253)
14	av. An. Change in plantation area	*d.*	*1000ha/y*	15	1	10	395	279	6	1	10	-	11	0	1	4	0	4	1	739
15	av. An. Change in total forest area	*d.*	*1000ha/y*	1	(11)	(468)	(95)	9	(1,177)	(148)	(439)	-	(388)	(51)	(55)	(254)	(18)	(327)	(133)	(3,553)
16	Av. an. Growth rate of natural forest	*d.*	*percent*	(1.9)	(0.4)	(4.2)	(0.5)	(0.5)	(1.1)	(1.2)	(2.7)		(1.4)	(1.0)	(3.2)	(3.5)	(1.0)	(2.7)	(1.7)	(1.2)
17	Av. an. Growth rate of plantation area	*d.*	*percent*	5.9	16.3	60.2	1.2	2.0	0.1	16.7	10.2		4.4	0.5	0.5	2.1	0.1	0.8	0.1	1.3
18	Av. an. Growth rate of total forest area	*d.*	*percent*	0.1	(0.4)	(4.2)	(0.1)	0.0	(1.0)	(1.2)	(2.6)		(1.4)	(1.0)	(2.9)	(3.4)	(1.0)	(2.6)	(1.4)	(0.8)

*Land use data available for 1990 and 1995 (FAO1993, FAO1997a). Land use in 1994 estimated because consumption data available up to 1994. Natural forest area in 1994 estimated by assuming a constant deforestation rate between 1990 and 1995. Plantation area in 1994 estimated by assuming a constant average annual increase between 1990 and 1995 (area in 1994 = area90 + {{area95-area90}*4/5})*

Plantation area in 1995 derived by total area minus natural forest area. Area of other wooded land assumed constant. Area for rubber, coconut and palm oil estimated from production and productivity.

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
	Projection for Forest Area																			
19	2010 natural forest area	*ex.*	*1000ha*	528	2,573	5,174	92,534	46,559	87,846	10,446	10,269	-	21,711	4,071	976	3,863	1,416	7,353	5,955	301,275
20	Area deforested in 2010	*ex.*	*1000ha*	(10)	(11)	(216)	(448)	(244)	(964)	(120)	(272)	-	(307)	(43)	(31)	(134)	(15)	(199)	(98)	(3,114)
21	2010 plantation area	*ex.*	*1000ha*	538	21	203	39,731	18,804	6,254	21	274	-	455	61	185	291	141	617	1,492	69,088
22	2010 total forest area	*ex.*	*1000ha*	1,066	2,593	5,377	132,265	65,363	94,100	10,468	10,543	-	22,166	4,133	1,162	4,154	1,557	7,970	7,447	370,363
23	2010 other wooded land	*ex.*	*1000ha*	468	355	1,554	28,230	17,689	29,434	8,259	4,584		20,683	672	1,105	5,606	2,113	1,704	13,717	136,173
24	Of which rubber, coconut, palmoil	*ex.*	*1000ha*	118	-	203	1,336	14,235	22,474	-	5,331	17	525	-	1	13,815	2,015	7,030	2,004	69,104
25	2010 other land than rubber, coconut, palmoil	*ex.*	*1000ha*	350	355	1,351	26,894	3,454	6,960	8,259	-	-	20,158	672	1,104	-	98	-	11,713	81,368

Land use projections are based on the assumption of constant deforestation rates for natural forest and a constant annual increase of plantation area. Other wooded land was assumed to be constant.

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
	Productivity																			
26	Natural forest standing stock (stem volume)	*FAO90*	*m3/ha*	77	150	122	96	47	179	128	214		145	55	87	182	45	62	119	125
27	Biomass in Natural Forest (incl. leaves)	*FAO90*	*ton/ha*	136	181	178	157	93	203	193	261		217	109	110	236	113	125	183	173
28	Biomass in Nat. For. (excl.leaves=-5%)	*es.*	*ton/ha*	129	172	169	149	88	193	183	248	-	206	104	105	224	107	119	174	164
29	Biomass Annual Increment	*es.*	*ton/ha/yr*	1.3	1.7	1.7	1.5	0.9	1.9	1.8	2.5	-	2.1	1.0	1.0	2.2	1.1	1.2	1.7	1.6
30	Plantation productivity	*as.*	*m3/ha/y*	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
31	Other wooded lands productivity	*as.*	*m3/ha/y*	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Biomass density data available by country from FAO Forest Resources Assessment 1990 (FAO,1993). Leaves assumed to be 5% of total biomass, subtracted because not woody biomass. Annual increment assumed to be 1.0% of biomass density, based on FAO figures on stock and increment in Asia.

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
32	Availability for fuel from natural forests	*as.*	*percent*	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
33	Availability for fuel from plantations	*as.*	*percent*	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
34	Availability for fuel from other wooded lands	*as.*	*percent*	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
35	Availability for fuel from wood waste	*as.*	*percent*	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
	Production																			
36	1994 sust. Production from natural forests	*d.*	*kton/yr*	737	3,797	13,869	119,329	35,800	161,711	18,446	31,321	-	44,957	3,990	1,364	12,195	1,438	10,840	10,814	470,608
37	1994 production from wood waste	*d.*	*kton/yr*	1,426	1,678	63,311	58,347	18,999	181,526	21,767	87,754	-	65,341	4,258	4,598	45,486	1,529	31,046	18,498	605,565

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
38	1994 production from plantations	*d.*	*kton/yr*	1,028	25	160	116,212	49,895	21,394	26	416	-	970	199	596	767	485	1,902	5,128	199,204
39	1994 production from other wooded lands (no rubber, coconut, palm oil)	*d.*	*kton/yr*	215	206	831	15,957	5,150	6,673	4,788	-	-	11,782	390	640	-	239	-	7,124	53,994
40	2010 sust. Production from natural forests	*d.*	*kton/yr*	546	3,539	7,000	110,412	32,908	135,528	15,323	20,370	-	35,806	3,373	816	6,929	1,216	6,985	8,282	389,032
41	2010 production from wood waste	*d.*	*kton/yr*	1,016	1,551	29,283	53,465	17,280	148,794	17,665	54,044	-	50,571	3,524	2,578	24,052	1,266	18,923	13,697	437,710
42	2010 production from plantations	*d.*	*kton/yr*	1,870	71	705	138,194	65,406	21,754	73	954	-	1,582	213	645	1,012	490	2,148	5,190	240,306
43	2010 production from other wooded lands (no rubber, coconut, palmoil)	*d.*	*kton/yr*	203	206	783	15,591	2,002	4,035	4,788	-	-	11,686	390	640	-	57	-	6,790	47,170

Note: only direct, natural sources are considered here. Wood used for construction and furniture may end up as fuelwood, but no estimates could be made because a lot may be exported or disposed of in other ways.

Wood from agricultural lands

44	1984 agr. area	*FAOSTAT*	*1000ha*	9,732	394	2,691	461,746	181,080	37,052	1,610	5,565	4	10,422	4,289	25,330	10,060	2,311	20,051	6,910	779,247
45	1994 agr. area	*FAOSTAT*	*1000ha*	9,300	413	5,338	495,782	181,000	41,971	1,700	7,885	4	10,421	4,500	26,510	10,650	2,323	21,245	7,086	826,128
46	Av. an. Increase 1984-1994	*d.*	*1000ha*	(43)	2	265	3,404	(8)	492	9	232	-	(0)	21	118	59	1	119	18	4,688
47	Av. an. Growth rate agr. area 1984-1994	*d.*	*percent*	(0.5)	0.5	7.1	0.7	(0.0)	1.3	0.5	3.5	-	(0.0)	0.5	0.5	0.6	0.1	0.6	0.3	0.6
48	1994 agr. area of cocoa, tea, coffee	*es.*	*1000ha*	48	-	-	894	654	1,127	12	261	-	4	1	-	158	215	87	177	3,638
49	1994 other agr. areas	*es.*	*1000ha*	9,252	413	5,338	494,888	180,346	40,844	1,688	7,624	4	10,417	4,499	26,510	10,492	2,108	21,159	6,909	822,490
50	2010 agr. area	*ex.*	*1000ha*	9,300	443	9,573	550,240	181,000	49,841	1,844	11,597	4	10,421	4,838	28,398	11,594	2,342	23,155	7,368	901,958
51	2010 agr. area of cocoa, tea, coffee	*es.*	*1000ha*	53	-	-	604	729	1,734	27	459	-	6	1	-	157	161	145	481	4,555
52	Other agr. areas	*es.*	*1000ha*	9,248	443	9,573	549,636	180,271	48,107	1,818	11,138	4	10,416	4,837	28,398	11,437	2,181	23,011	6,887	897,404

Agriculture area available from FAO DataBase. Area of coffee, tea and cocoa estimated from production and productivity. Agriculture area in 2010 projected based on the assumption that area will remain constant in case of decrease over 1984-1994 (e. g. Bangladesh, India) or increase with the same average constant annual increase as during 1984-1994.

53	1994 wood productivity from other agr. land	*as.*	*m3/ha/y*	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
54	Availability for fuel	*as.*	*percent*	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%	80%
55	1994 wood fuel production from agr. areas	*es.*	*kton/yr*	5,363	239	3,094	286,892	104,548	23,678	979	4,420	2	6,039	2,608	15,368	6,082	1,222	12,266	4,005	476,806
56	1994 wood production from rubber, palmoil, coconut, cocoa, tea, coffee	*es.*	*kton/y*	229	-	299	1,809	20,774	44,066	-	13,389	32	845	-	2	24,737	4,051	10,977	3,391	124,601
57	2010 woodfuel production from agr. areas	*es.*	*kton/yr*	5,361	257	5,550	318,630	104,505	27,888	1,054	6,457	2	6,038	2,804	16,463	6,630	1,264	13,340	3,992	520,234
58	2010 wood production from rubber, palmoil, coconut, cocoa, tea, coffee	*es.*	*kton/y*	275	-	506	3,442	33,627	56,924	-	15,953	39	1,246	-	2	32,547	4,750	17,762	4,780	171,854

Land Use

59	Total land area	*FAOSTAT*	*1000ha*	13,017	4,700	17,652	932,641	297,319	181,157	23,080	32,855	30	65,755	14,300	77,088	29,817	6,463	51,089	32,549	1,779,512
60	Total considered area	*d.*	*1000ha*	10,763	3,523	16,722	656,941	263,416	181,196	22,394	27,936	4	58,247	9,994	29,363	23,022	6,232	34,579	29,920	1,374,252
61	Percentage considered of total area	*d.*	*percent*	83%	75%	95%	70%	89%	100%	97%	85%	13%	89%	70%	38%	77%	96%	68%	92%	77%

Fuelwood Productionin1994

62	From natural forests(sust)		*kton/y*	737	3,797	13,869	119,329	35,800	161,711	18,446	31,321	-	44,957	3,990	1,364	12,195	1,438	10,840	10,814	470,608
63	From natural forests (woodwaste)		*kton/y*	1,426	1,678	63,311	58,347	18,999	181,526	21,767	87,754	-	65,341	4,258	4,598	45,486	1,529	31,046	18,498	605,565
64	From plantations (sust)		*kton/y*	1,028	25	160	116,212	49,895	21,394	26	416	-	970	199	596	767	485	1,902	5,128	199,204
65	From other wooded lands (sust)		*kton/y*	215	206	831	15,957	5,150	6,673	4,788	-	-	11,782	390	640	-	239	-	7,124	53,994
66	From agricultural areas (sustainable)		*kton/y*	5,593	239	3,394	288,700	125,323	67,744	979	17,809	34	6,884	2,608	15,371	30,819	5,273	23,243	7,396	601,407
67	**Total 1994 fuelwood production**		*kton/y*	**8,999**	**5,946**	**81,565**	**598,546**	**235,167**	**439,049**	**46,006**	**137,301**	**34**	**129,935**	**11,444**	**22,569**	**89,267**	**8,963**	**67,030**	**48,960**	**1,930,778**
68	From natural forests (sust)		*PJ/y*	11	57	208	1,790	537	2,426	277	470	-	674	60	20	183	22	163	162	7,059
69	From natural forests (woodwaste)		*PJ/y*	21	25	950	875	285	2,723	327	1,316	-	980	64	69	682	23	466	277	9,083
70	From plantations (sust)		*PJ/y*	15	0	2	1,743	748	321	0	6	-	15	3	9	12	7	29	77	2,988
71	From other wooded lands (sust)		*PJ/y*	3	3	12	239	77	100	72	-	-	177	6	10	-	4	-	107	810
72	From agricultural areas (sustainable)		*PJ/y*	84	4	51	4,331	1,880	1,016	15	267	1	103	39	231	462	79	349	111	9,021
73	**Total 1994 fuelwood production**		*PJ/y*	**135**	**89**	**1,223**	**8,978**	**3,528**	**6,586**	**690**	**2,060**	**1**	**1,949**	**172**	**339**	**1,339**	**134**	**1,005**	**734**	**28,962**

Fuelwood Requirements in 1994

74	**Total 1994 requirements**	*RWEDP/EDP*	*PJ/y*	**141**	**12**	**81**	**3,287**	**2,601**	**817**	**35**	**93**	**1**	**346**	**192**	**520**	**346**	**85**	**691**	**441**	**9,688**

				BAN	BHU	CAM	CHI	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRI	THA	VIE	RWEDP
75	From forest	*es.*	*PJ/y*	18	2	26	1,052	780	261	11	30	0	111	127	140	52	21	346	110	3,088
76	From agr land + other sources	*es.*	*PJ/y*	123	10	55	2,235	1,821	556	24	63	1	235	65	380	294	64	346	330	6,601
77	total 1994 requirements	*RWEDP/EDP*	*1000m3/y*	14,455	1,260	8,269	337,110	266,788	83,806	3,583	9,519	123	35,474	19,673	53,364	35,463	8,740	70,875	45,182	993,684
78	**Total 1994 requirements**	*d.*	*kton/y*	**9,396**	**819**	**5,375**	**219,122**	**173,412**	**54,474**	**2,329**	**6,187**	**80**	**23,058**	**12,787**	**34,687**	**23,051**	**5,681**	**46,069**	**29,368**	**645,895**
79	From forest	*as.*	*percent*	13%	17%	32%	32%	30%	32%	32%	32%	32%	32%	66%	27%	15%	25%	50%	25%	32%
80	From forest	*es.*	*kton/y*	1,221	139	1,720	70,119	52,024	17,432	745	1,980	26	7,379	8,440	9,365	3,458	1,420	23,034	7,342	205,844
81	From agr.land + other sources	*es.*	*kton/y*	8,174	680	3,655	149,003	121,389	37,042	1,584	4,207	54	15,680	4,348	25,321	19,593	4,261	23,034	22,026	440,051
Fuelwood Production in 2010																				
82	From natural forests (sust)		*kton/y*	546	3,539	7,000	110,412	32,908	135,528	15,323	20,370	-	35,806	3,373	816	6,929	1,216	6,985	8,282	389,032
83	From natural forests (wood waste)		*kton/y*	1,016	1,551	29,283	53,465	17,280	148,794	17,665	54,044	-	50,571	3,524	2,578	24,052	1,266	18,923	13,697	437,710
84	From plantations (sust)		*kton/y*	1,870	71	705	138,194	65,406	21,754	73	954	-	1,582	213	645	1,012	490	2,148	5,190	240,306
85	From other wooded lands (sust)		*kton/y*	203	206	783	15,591	2,002	4,035	4,788	-	-	11,686	390	640	-	57	-	6,790	47,170
86	From agricultural areas(sustainable)		*kton/y*	5,636	257	6,056	322,072	138,132	84,813	1,054	22,409	41	7,284	2,804	16,465	39,177	6,015	31,101	8,772	692,088
87	**Total 2010 fuelwood production**		*kton/y*	**9,271**	**5,624**	**43,827**	**639,733**	**255,729**	**394,923**	**38,902**	**97,777**	**41**	**106,930**	**10,304**	**21,144**	**71,171**	**9,044**	**59,157**	**42,730**	**1,806,307**
88	From natural forests (sust)		*PJ/y*	8	53	105	1,656	494	2,033	230	306	-	537	51	12	104	18	105	124	5,835
89	From natural forests (woodwaste)		*PJ/y*	15	23	439	802	259	2,232	265	811	-	759	53	39	361	19	284	205	6,566
90	From plantations (sust)		*PJ/y*	28	1	11	2,073	981	326	1	14	-	24	3	10	15	7	32	78	3,605
91	From other wooded lands(sust)		*PJ/y*	3	3	12	234	30	61	72	-	-	175	6	10	-	1	-	102	708
92	From agricultural areas(sustainable)		*PJ/y*	85	4	91	4,831	2,072	1,272	16	336	1	109	42	247	588	90	467	132	10,381
93	**Total 2010 fuelwood production**		*PJ/y*	**139**	**84**	**657**	**9,596**	**3,836**	**5,924**	**584**	**1,467**	**1**	**1,604**	**155**	**317**	**1,068**	**136**	**887**	**641**	**27,095**
FuelwoodRequirementsin2010																				
94	**Total 2010 fuelwood requirements:**	*ex.*	*PJ/y*	**200**	**18**	**113**	**3,792**	**3,386**	**1,012**	**52**	**123**	**2**	**468**	**276**	**783**	**455**	**102**	**801**	**591**	**12,173**
95	From forest	*es.*	*PJ/y*	26	3	36	1,214	1,016	324	17	39	1	150	182	211	68	25	400	148	3,860
96	From agr.land + other sources	*es.*	*PJ/y*	174	15	77	2,579	2,370	688	36	84	1	318	94	571	387	76	400	443	8,313
97	Growth rates in WE consumption	*as.*	*percent*	2.21%	2.39%	2.15%	0.90%	1.66%	1.35%	2.57%	1.79%	2.75%	1.90%	2.29%	2.58%	1.73%	1.10%	0.93%	1.86%	1.44%
98	**Estimated 2010 requirements:**	*ex.*	*kton/y*	**13,320**	**1,195**	**7,553**	**252,819**	**225,725**	**67,465**	**3,496**	**8,216**	**123**	**31,183**	**18,378**	**52,167**	**30,329**	**6,769**	**53,390**	**39,418**	**811,548**
99	From forest	*as.*	*percent*	13%	17%	32%	32%	30%	32%	32%	32%	32%	32%	66%	27%	15%	25%	50%	25%	32%
100	From forest	*es.*	*kton/y*	1,732	203	2,417	80,902	67,718	21,589	1,119	2,629	39	9,978	12,130	14,085	4,549	1,692	26,695	9,854	257,332
101	From agr.land + other sources	*es.*	*kton/y*	11,588	992	5,136	171,917	158,008	45,876	2,377	5,587	84	21,204	6,249	38,082	25,780	5,077	26,695	29,563	554,216

Projection of fuelwood consumption based on population growth estimates available from World Resources 94-95 (WRI,1995), with correlation coefficient 1.

FAO90: FAO Forest Resources Assessment 1990 (FAO,1993) ***a:assumed*** ***ex:extrapolated*** ***es:estimated*** ***d:derived*** ***in:interpolated***
FAO97: FAO State of the World's Forest 1997 (FAO,1997a)
FAOSTAT: FAOSTAT DataBase

*Table1.9: Crop production and amount of residues produced in 2010 (*1,000 tons) and oil equivalent*

Crop	Type	Residue	LHV	Crops (kton)	Residues (kton)	Oil equiv. (kton)	PJ
Field-based residues							
Rice	Straw	1.757	16.02	588,052	1,033,206	388,544	16,552
Wheat	Straw	1.750	12.38	245,463	429,559	124,834	5,318
Millet	Stalks	1.750	12.38	10,994	19,239	5,591	238
Maize	Stalks	2.000	16.80	226,409	452,818	178,576	7,607
Cassave	Stalks	0.062	17.50	48,680	3,018	1,240	53
Cotton	Stalks	2.755	12.38	36,820	101,439	29,479	1,256
Soyabeans	Straw+pods	3.500	12.38	32,189	112,662	32,741	1,395
Jute	Stalks	3.000	12.38	451	1,352	393	17
Tobacco	Stalks, etc.	2.000		0	0	0	0
Sugar cane	Tops	0.300	15.81	741,636	222,491	82,572	3,518
Cocoa	Pods	1.000	12.38	761	761	221	9
Processing-based residues							
Rice	Husk	0.267	15.58	588,052	157,010	57,423	2,446
Rice	Bran	0.083	13.97	588,052	48,808	16,006	682
Maize	Cob	0.273	16.28	226,409	61,810	23,621	1,006
Maize	Husks	0.200	12.38	226,409	45,282	13,159	561
Coconut	Shells	0.120	18.10	48,053	5,766	2,450	104
Coconut	Husks	0.419	18.62	48,053	20,134	8,800	375
Groundnut	Husks	0.477	15.66	27,786	13,254	4,872	208
Groundnut	Straw	2.300	12.38	27,786	63,908	18,572	791
Oil Palm	Fibre	0.140	11.34	23,219	3,251	865	37
Oil Palm	Shell	0.065	18.83	23,219	1,509	667	28
Oil Palm	Bunches	0.230	8.16	23,219	5,340	1,023	44
Sugar cane	Bagasse	0.290	18.10	741,636	215,074	91,381	3,893
Coffee	Husk	2.100	12.38	1,382	2,90[illegible]	843	36
Total amount of field based residues					2,376,545	844,191	35,963
Total amount of processing based residues					644,049	239,684	10,211
Total amount of agricultural crop residues					3,020,594	1,083,876	46,173

Table1.9: Estimated amount of residues produced in the 16 RWEDP member countries in 2010 based on residue to product ratio data (ktons)

Crop	Residue type	RPR	BGD	BHU	CMB	CPR	IND	INS	LAO	MAL	MLD	MYA	NEP	PAK	PHI	SRL	THA	VIE	RWEDP
FIELD BASED RESIDUES																			
Rice	Straw	1.757	48,868	25	3,206	370,817	284,991	116,139	2,513	4,465	0	50,596	5,143	13,561	25,118	4,776	39,408	63,581	1,033,206
Wheat	Straw	1.750	1,407	0	0	221,930	159,975	0	0	0	0	102	2,481	43,663	0	0	2	0	429,559
Millet	Stalks	1.750	31	12	0	500	17,765	0	0	0	0	92	637	198	0	4	0	0	19,239
Maize	Stalks	2.000	6	0	100	369,499	29,068	28,125	302	143	0	463	3,393	3,348	9,039	70	5,023	4,239	452,818
Cassave	Stalks	0.062	0	0	0	202	403	1,105	4	32	0	0	0	0	133	0	1,024	114	3,018
Cotton	Stalks	2.755	351	0	0	47,106	30,790	0	92	0	0	72	0	22,825	0	0	95	107	101,439
Soyabeans	Straw+pods	3.500	0	1	282	63,095	34,874	10,211	18	0	0	317	86	16	0	0	2,998	767	112,662
Jute	Stalks	3.000	0	0	2	0	1,211	111	0	0	0	29	0	0	0	0	0	0	1,352
Tobacco	Stalks, etc.	2.000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sugar cane	Tops	0.300	2,606	5	0	26,773	117,974	12,525	62	715	0	0	911	20,913	8,880	807	26,673	3,648	222,491
Cocoa	Pods	1.000	0	0	0	0	9	557	0	179	0	0	0	0	11	6	0	0	761
PROCESSING BASED RESIDUES																			
Rice	Husk	0.267	7,426	4	487	56,351	43,308	17,649	382	679	0	7,689	782	2,061	3,817	726	5,989	9,662	157,010
Rice	Bran	0.083	2,309	1	151	17,517	13,463	5,486	119	211	0	2,390	243	641	1,187	226	1,862	3,004	48,808
Maize	Cob	0.273	1	0	14	50,437	3,968	3,839	41	20	0	63	463	457	1,234	10	686	579	61,810
Maize	Husks	0.200	1	0	10	36,950	2,907	2,813	30	14	0	46	339	335	904	7	502	424	45,282
Coconut	Shells	0.120	14	0	9	11	1,495	1,916	0	95	2	53	0	0	1,542	222	219	190	5,766
Coconut	Husks	0.419	47	0	32	37	5,219	6,689	0	333	7	184	0	1	5,384	775	764	663	20,134
Groundnut	Husks	0.477	26	0	2	7,470	4,803	459	0	1	0	120	0	81	15	0	57	219	13,254
Groundnut	Straw	2.300	125	0	12	36,019	23,158	2,215	0	5	0	580	0	392	71	2	273	1,057	63,908
Oil Palm	Fibre	0.140	0	0	0	15	0	1,244	0	1,866	0	0	0	0	16	0	111	0	3,251
Oil Palm	Shell	0.065	0	0	0	7	0	578	0	866	0	0	0	0	7	0	51	0	1,509
Oil Palm	Bunches	0.230	0	0	0	24	0	2,044	0	3,065	0	0	0	0	25	0	182	0	5,340
Sugar cane	Bagasse	0.290	2,519	5	0	25,881	114,041	12,107	60	691	0	0	880	20,216	8,584	781	25,784	3,526	215,074
Coffee	Husk	2.100	0	0	0	173	278	837	34	23	0	2	0	0	284	29	309	933	2,902

Source: Production data - Selected Indicators of Food and Agriculture Development in Asia-Pacific Region 1985-1995. FAO-RAP Publication 1996/32 (FAO, 1996a)

Total Biomass Residues (field based)	kton	53,269	43	3,589	1,099,921	677,059	168,772	2,991	5,535	-	51,670	12,650	104,524	43,181	5,664	75,222	72,456	2,376,545
Total Biomass Residues (process based)	kton	12,467	10	717	230,890	212,639	57,875	666	7,869	9	11,127	2,707	24,184	23,069	2,777	36,787	20,257	644,049
Availability of field residues for fuel		0%																
Availability of process residues for fuel		50%																
Field based biomass residues	kton	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process based biomass residues	kton	6,234	5	358	115,445	106,319	28,938	333	3,934	4	5,563	1,354	12,092	11,535	1,389	18,393	10,128	322,024
Field based biomass residues	PJ	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Process based biomass residues	PJ	98	0	5	1,718	1,759	457	5	49	0	84	22	212	198	24	317	157	5,105

2. POWER DEVELOPMENT NEEDS AND THE POTENTIAL OF PRIVATE SECTOR PARTICIPATION IN THE ASIA-PACIFIC REGION

by

Pranesh C. Saha, Officer-in-Charge, a.i.,Energy Resources Section
Environment and Natural Resources Management Division
United Nations ESCAP Secretariat, Bangkok

2.1 INTRODUCTION

The purpose of this paper is to review the status and potential of the electric power infrastructure in the Asia-Pacific region and put into perspective the potential role of the private sector in power development. Some issues have been raised that need to be addressed if private sector projects are to be integrated into the overall development and management of the power sector. An attempt has also been made to look at the opportunities and challenges that have arisen as a result of changes in the power market structure and the power industry.

To meet sustained high economic growth, the demand for electricity in developing economies of the ESCAP region has been growing at a remarkably high rate and this growth is expected to continue in the future. Although the recent financial turmoil in some countries in East and South East-Asia has significantly slowed down economic development, it is likely that the situation will be better in a year or two. Though this may result in some delays in development projects, including power projects, the long term outlook remains bright.

2.2 CURRENT STATUS AND PROSPECTS

Current situation.

Electricity demand and production in the Asia-Pacific region has been increasing at a much higher rate than total energy consumption. Whereas in the 1980s the overall energy consumption in the region as a whole increased at an average annual rate of 5.2 per cent, electricity production increased at 6.6 per cent during the same period. In developing economies the situation presented even more of a contrast, with significantly higher growth in electricity production (8.5 per cent) as opposed to a little over 6 per cent growth in total commercial energy consumption. Figure 2.1. shows the past growth trend in developing economies of the region broken down to the sub-regions of Asia, including central Asia, and the Pacific. Figure 2.2 shows the average annual electricity generation growth rate in the Asia-Pacific Region for the period 1973-1993.

These high growth rates of electricity consumption are due to the region's rapid economic growth coupled with its high population growth. With much demand as yet unmet (table 1: access of population to electricity), and consequent per capita electricity consumption (figures II and III) being at a very low level, as compared with industrialised economies, the high growth in electricity demand is expected to continue in developing economies of the region. As of 1995, the per capita electricity consumption in developing economies of the ESCAP region was only 746 kWh, compared with 8,170 kWh of the developed economies. Electricity, as a high-grade and clean form of energy, has many advantages in comparison with other forms of energy. Therefore, electricity production and consumption will continue to increase at a faster rate than overall energy demand.

Over the years the electric power industry has become increasingly complex and capital intensive. Many utilities in developing economies have seen phenomenal growth (two digits in some countries) in capacity addition in the recent past.

Figure 2.1. Average annual electricity generation growth rate in the Asia Pacific Region

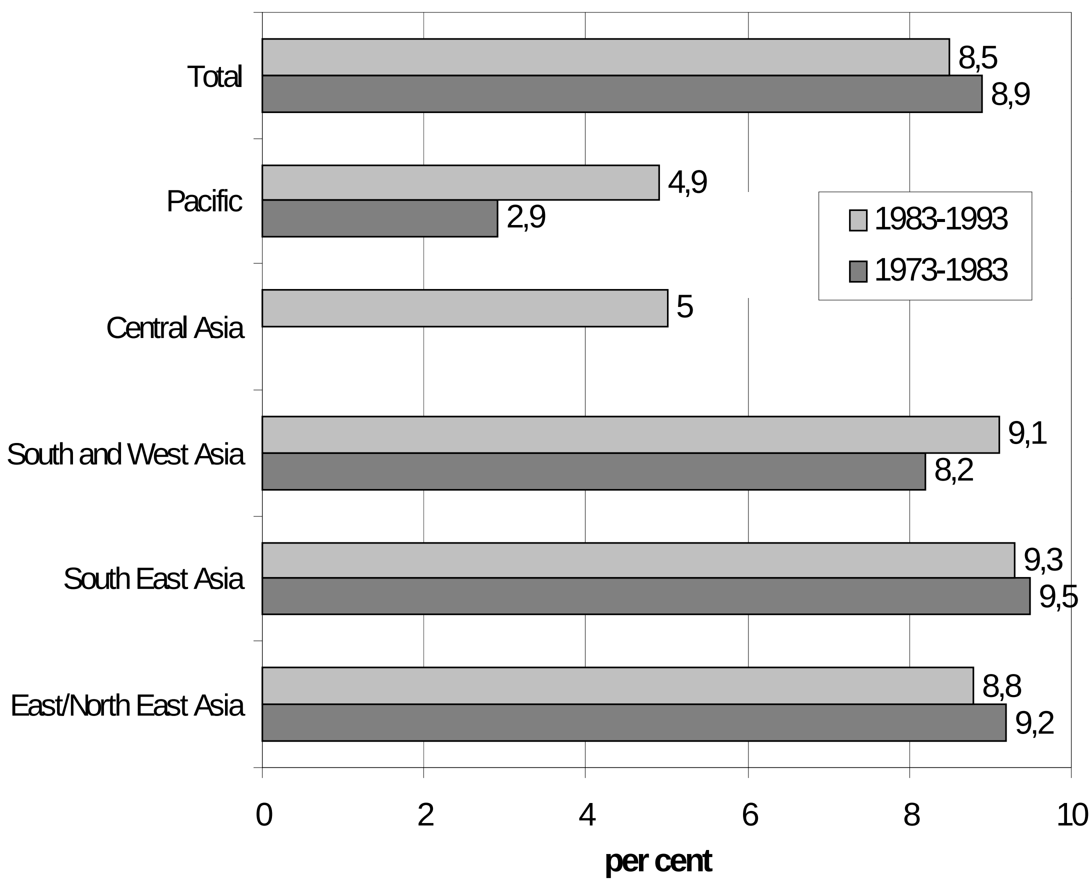
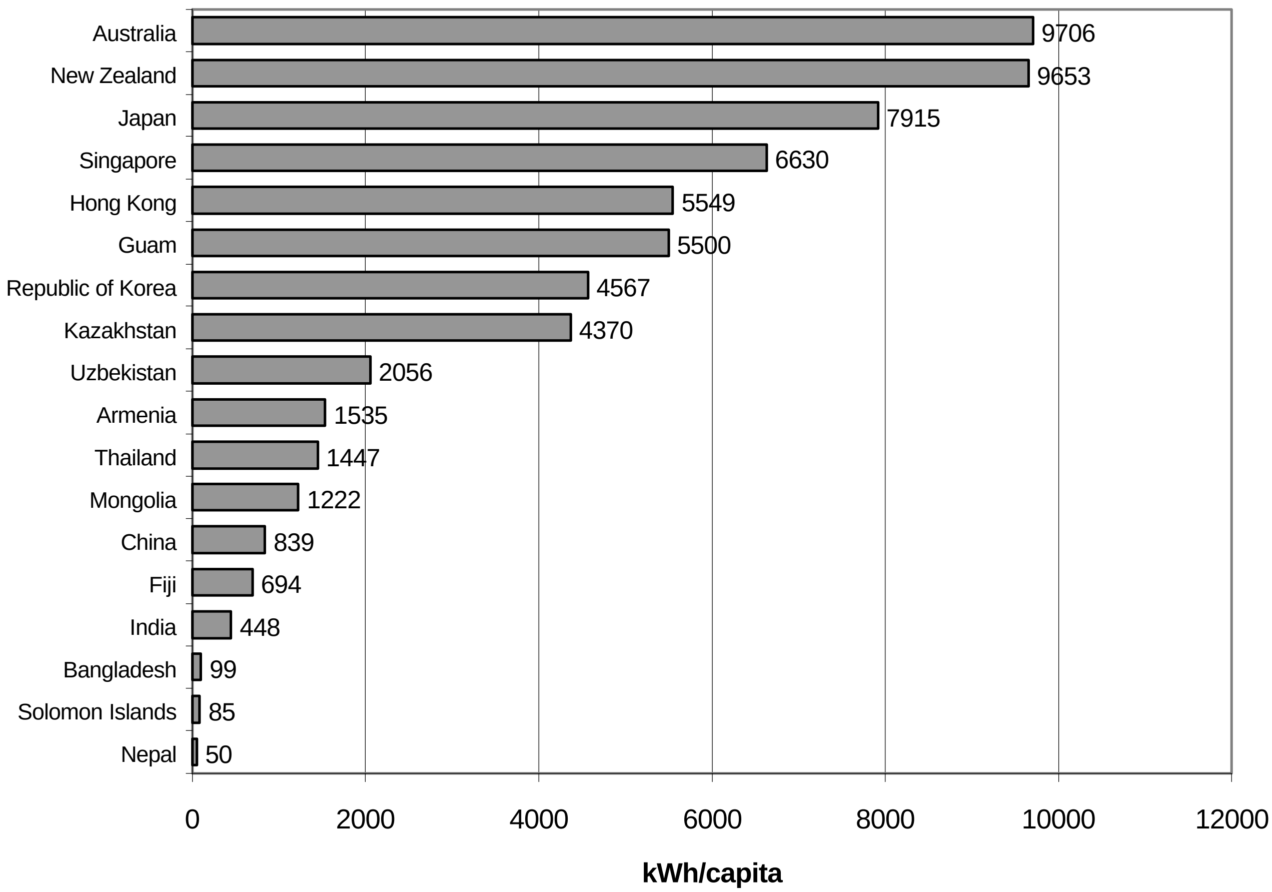


Figure 2.2. Per capita generation in selected ESCAP regional economies (1995)



Electricity demand forecast

According to an ESCAP study[1], the projected installed capacity of developing economies of the Asia-Pacific region in 2000 was estimated to reach 735,478 MW (this figure was later revised upward to 778,983 MW). The revised forecast of the likely electricity demand up to the year 2020 in the region, dis-aggregated to the sub-regional level, is shown in Figure 2.3. Table 2.2. gives possible shares of different types of fuel in power generation.

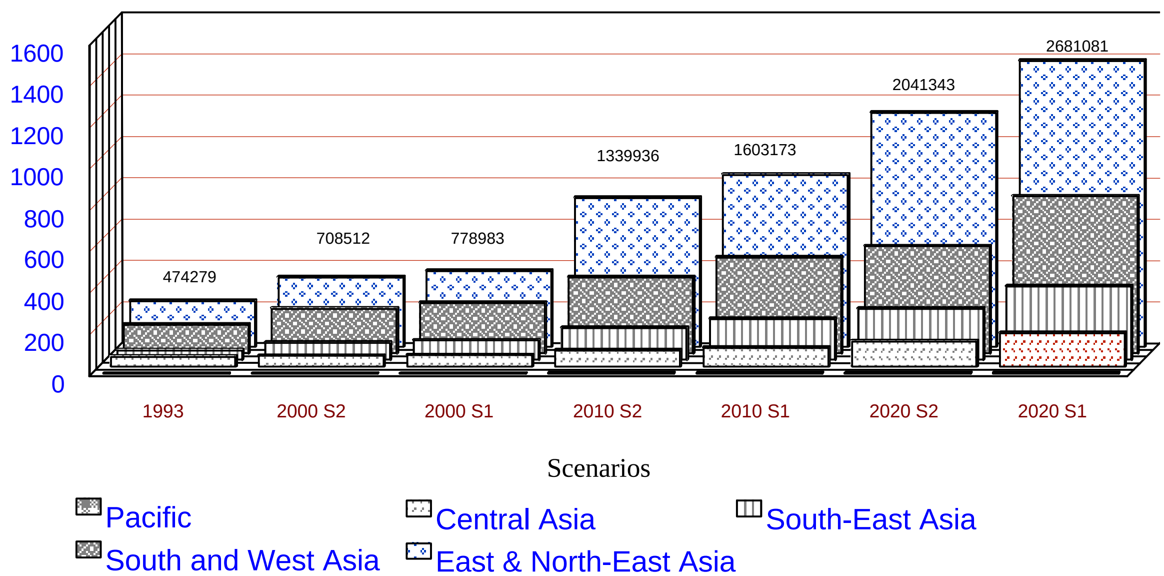
[1] ***Infrastructure Development as Key to Economic Growth and Regional Economic Cooperation, United Nations, 1994, ST/ESCAP/1364.***

Table 2.2: Future electricity generating capacity breakdown for ESCAP developing economies (High growth scenario)

Energy source	Actual		Forecast/estimate					
	1993		2000		2010		2020	
	%	MW	%	MW	%	MW	%	MW
Primary	26.3		26.2	185,630	27	432,857	33	884,757
Hydro	23.7		23.5	166,500	23	368,730	23	616,649
Nuclear	2.4		2.4	17,004	3	48,095	5	134,054
NRSE	0.2		0.3	2,126	1	16,032	5	134,054
Secondary	73.7		73.8	522,882	73	1,170,316	67	1,796,324
All sources	100	474,279	100	708,512	100	1,603,173	100	2,681,081
Growth rates			5.9		8.5		5.3	

Source: ESCAP estimates based on World Tables and UN Statistics Yearbooks
Notes:
**** Generating capacity which utilizes new and renewable sources of energy***
***** Mostly steam power; diesel and gas turbines contribution is in the range of 5-6 per cent***

Figure 2.3: Projection of installed capacity growth in the Asia-Pacific Region (developing countries)



2.3 INVESTMENT REQUIREMENTS

ESCAP estimated that US$576-674 billion[1/] would be required for the supply of electrical power infrastructure in the developing economies of the ESCAP region between 1990 and 2000. The corresponding ADB estimate of investment is US$500 billion for its member countries. This shows that the average yearly capital requirement will be over US$50 billion. The three largest contributors to the ESCAP estimate are China (US$143-181 billion for 102,000-129,000 MW), India (US$83-92 billion for 55,000-61,000 MW) and the Republic of Korea (US$42-46 billion for 22,000- 24,000 MW). These three countries account for nearly 50 per cent of the total investment requirement. The estimate, which includes associated transmission and distribution infrastructure, is indicative and likely to vary from country to country and with the type of power plants, environmental requirements and plant siting. ADB estimates that the desirable limit for investment need in the transmission and distribution system is 40-45 per cent of the total investment in the power sector. Further work of ESCAP on long-term power development scenario (business as usual), as shown in Table 2.2, indicates that the installed capacity would grow at an average annual rate of 7.5 per cent during 2000-2010 and at 5.5 per cent thereafter up to 2020. The total installed capacity is expected to reach over 1,600 GW in 2010 and further to almost 2,700 GW in 2020 in the developing economies of the region. It is obvious that the investment needed is huge: over US$1,400 billion for the decade 2000-2010 and almost US$1,900 billion for 2010-2020. Traditional funding sources, which can lend only a fraction of the requirement, cannot meet these huge capital needs.

2.4 ROLE AND POTENTIAL OF PRIVATE SECTOR PARTICIPATION

Evolution of power infrastructure

A recent major policy change noticed in the energy sector, particularly in the electricity sector, is in the investment and ownership pattern: private sector participation is increasingly seen as a source of funding in developing countries. With the rapid social, political and economic changes in the region, many governments are now increasingly opening up their state owned economic sectors to private sector participation. This trend has been quite visible in the power sector in recent years, particularly during the 1990s. Whereas in the past, most, if not all, utility power sector investments had been based on public sector loans with state guarantees, more and more governments of developing countries, including those from Asia, are now turning to the private sector for the development of new electric power generating capacity. Figure 2.4 shows the evolution of the power infrastructure investment and ownership pattern over the years and the likely future trend.

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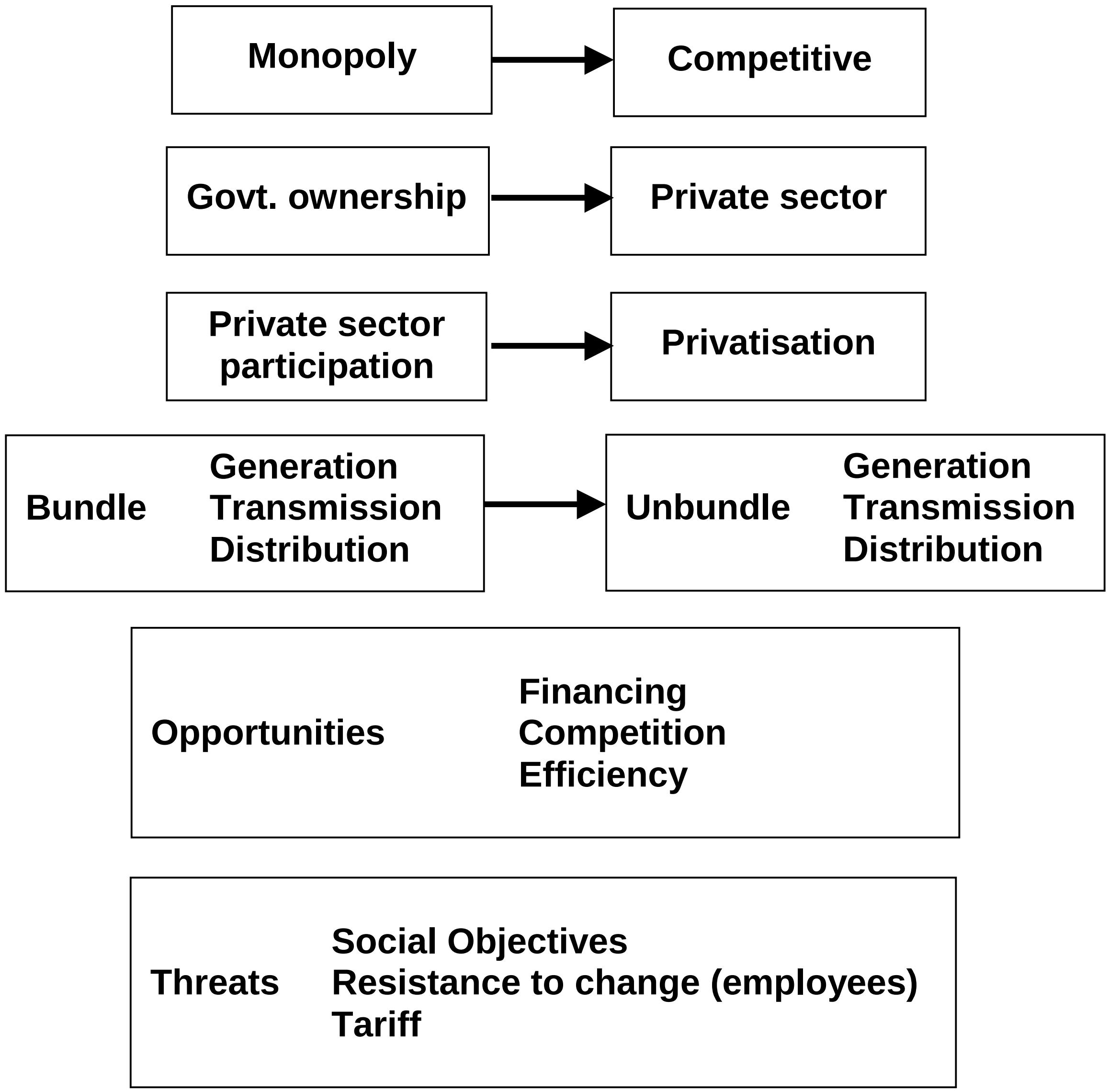
[1] ***The cost of developing power infrastructure varies significantly depending on the energy source, manufacturing technology, labour and material costs, site conditions, etc. Thermal power station based development costs are of the order of $1 million per MW of plants, excluding transmission and distribution, using imported equipment. With mostly endogenously manufactured equipment the costs could range from US$600,000 - 800,000 per MW. Hydroelectric schemes are site-specific and could be significantly more capital intensive but would incur lower long term operating costs because of no fuel costs are involved. For the above ESCAP study the average cost of supply of electricity and supporting transmission and distribution infrastructure has been estimated at US$1.75 million per MW at 1992 prices. Some country specific figures have also been used in the estimation of the investment requirement. This compares with a 1990 World Bank costing of US$1.94 million per megawatt and a 1993 ADB figure of US$2.12 million.***

Figure 2.4 Evolution of structural changes in power industry



Countries where significant private sector investments have taken place include Malaysia and the Philippines. On the other hand there are some other countries (e.g. India, Pakistan), where major efforts towards private sector participation are underway but progress has been slow. The boxes contain summaries of the status in India and Malaysia as of early 1997. In Thailand, bids were evaluated in 1997 for projects to be implemented during 1998-2001 but no offer has yet been made. It appears that the current economic crisis in South East Asia may delay implementation of some projects due to expected lower growth rate in demand and uncertainties in the currency exchange rates; the latter affects the tariff policy.

2.5 ROLE OF PRIVATE POWER

Private sector funding, being often non-recourse, may have positive impacts on the balance of payments. While many sectors such as communications, construction (infrastructure) have been opened to private sector participation in a number of countries, the recent development of IPP's (independent power producers) in a number of countries has made a headway in the capital investment market for the power sector. A niece to the IPP is the so-called SPP or small power producer, wherein small and medium size non-utility generations are encouraged to produce electricity for own consumption, selling to the utility or supplying directly to consumers in nearby areas.

The concept of captive power or decentralised generation is not new. What is new is the renewed interest resulting from the recent change in the power market towards liberalisation. Deregulation of the power industry from a government-controlled monopoly towards a competitive business has given a push towards revitalising small-scale generation. In many countries, while IPP's are still struggling to get on to their feet, small scale generation, including cogeneration utilising agricultural wastes (such as bagasse), has already become the market leader as a part of the SPP. The market deregulation has opened up an excellent opportunity for entrepreneurship development in this area. Unlike IPP's, these facilities can be small and often linked with other needs such as the electrification of unelectrified areas or providing power to rural industries. Being small, it needs less investment than that of an IPP. Given a policy in place, a framework power purchase formula or guideline may help avoid complex negotiation process. Some technologies, such as biomass gasification, have matured and the equipment is readily available in the market.

Current Power Infrastructure Situation in Malaysia

Malaysia, an energy producing and exporting country, has been following the "four fuels policy" for many years as a part of its diversification policy away from dependency on oil alone: coal, oil, hydro and gas. Now they are in the process of adding a fifth fuel - new and renewable sources of energy. During the past few years the Government has been encouraging private sector participation in the energy sector, including the electricity and gas sub-sectors.

Malaysia has been successful in launching a massive IPP's (Independent Power Producers) programme. As a result, within a short period of time (1994-1996), a total of over 4,100 MW or almost half of the TNB's own generating capacity has been added by IPP's. The system maximum demand (1995) being at around 6,381 MW, there is currently a capacity surplus of almost 50 per cent. However, with the demand growing at an average annual rate of 10-11 per cent, the excess capacity will be used up by the year 2000.

So far the IPP plants are operating with good performance records. As the experience of dealing with the private sector was new in the country, all the contracts were unsolicited and negotiated rather than through an open bidding process. Currently TNB is purchasing all electricity generation of IPP's based on an agreed price under Power Purchase Agreements (PPA).

While the above scenario appears to be a success from the point of view of the private sector participation in power generation, from TNB's perspective it has been an unfair deal as the purchasing power agreements (PPA's) concluded between them are said to be more in favor of the IPP's. As TNB is still the provider of T&D facilities, the seller to customers and revenue collectors, their profits have been declining as the tariff was not allowed to be adjusted corresponding to the cost increase. TNB also believes that with similar incentives given to IPP's, they could also be competitive in generation. On the other hand the system losses in TNB are still considered relatively high and the government wants them to reduce cost through reducing system losses. Another problem is the question of who supplies electricity to rural areas. The cost of supplies there being high and revenue collection being low, rural electrification is considered to be a social service. TNB has requested the Government to allow it to revise the tariff according to the reality.

Current Power Infrastructure Situation in India

India, an energy producing but also an energy importing country, has been trying hard to cope with the high growth of energy demand. Part of this has remained unmet for many years as a result of the the inadequate energy infrastructure capacity addition despite sustained economic development. Although India has large energy resources, such as coal and hydropower and some amount of oil and gas, production, transportation, handling and distribution facilities of coal are inadequate and often based on old technologies. Its indigenous energy supplies (production) are not enough to meet the growing energy demand resulting in the importation of a huge amount of crude oil and oil products. Although India has abundant coal reserves, the transportation of coal from the mining area to the load centers is a major obstacle to its increased use. Moreover, most of the steam coal is of poor quality with high ash contents. These supply constraints, together with lack of adequate financial resources, have had an impact on power generation in the country.

At the end of the 1995-96 fiscal year the total installed generating capacity was 83,288 MW, with thermal power's share of 60,087 MW or over 73 per cent of the capacity. Power demand, with a significant amount of it still unmet, has been growing at a high rate of about 7 per cent (8th plan, 1992-1997) with an estimated shortfall of 7.1-11.2 per cent in energy demand and peak demand and 16.5-20.5 per cent of peak demand. However, the implementation of the policy generally lies with the State Electricity Boards. Although India has been successful in initiating an ambitious IPP program, it ran into difficulties in putting together projects that needed commitment at the State level. Proposed IPP projects remain mostly unimplemented for the lack of a coherent policy at the State level. In that respect an Agenda of Chief Ministers has been proposed to agree on a policy that will keep politics out of the power sector.

Although the initial response of domestic and foreign investors was encouraging, the project development activities for several of the proposed projects that were initiated could not be concluded successfully and a number of them have encountered unforeseen hurdles.

2.6 FUTURE PROSPECTS OF PRIVATE POWER

Once the direction of IPP becomes clear in the area of generation, the next logical candidate will be transmission lines. Already some ESCAP countries have either initiated and/or are in the process of preparing the so-called "Grid Code" that would facilitate the power trade by the IPP's through a new concept, power wheeling. Some are also working towards opening up their transmission and distribution systems for private sector participation. Thus it is expected that the entire power sector will undergo a structural change over the next decade or so.

Some of the major conclusions and recommendations of the Workshop on Private Sector Participation in Power Generation and its Consequences on Environmental Quality, held in 1994 are noted below. This collective opinion of countries of Asia still holds good and is worth sharing with others.

The Workshop "recognised that the power supply situation in most developing countries of the ESCAP region was such that there was a big gap between demand and supply. That was owing to the fact that the demand for electricity had been growing at a faster rate than the utilities' ability to develop new capacities. As a consequence, the quantitative and qualitative services of the sector had been deteriorating effecting economic activities. Under those circumstances and taking the advantage of economic liberalisation policies, independent power production from the private sector was considered as a good option to mobilise capital investments both from inside and outside a country."

The Workshop " recommended that due consideration should be given to protecting the interest of consumers in concluding an independent power producers' deal. On the other hand to attract adequate investments, governments and/or utilities should create a conducive atmosphere by streamlining their policies and deregulating earlier stringent rules and regulations for speedy development of independent power producers. Ways and means should be found to do integrated resource planning involving both the utilities and the independent power producers to achieve the socio-economic objectives of power supply."

In dealing with environmental aspects, the Workshop "considered that environmental standards and regulations were to be applied equally to all, whether it be a utility or an independent power producer. A concern, however, was expressed on how to ensure better monitoring and compliance of applicable environmental standards and regulations."

2.7 ISSUES AND OPTIONS IN PRIVATE POWER

Institutional and policy aspects

While the latest development in private sector participation in power generation has attracted a great deal of interest, implementation has proven to be complex and difficult and as a consequence only a few countries have succeeded in getting independent power generation projects underway so far. Although there is a mixed feeling from the investors' point of view regarding their successes or failure in projects' financial closing or implementation, it is obvious that the potential market is too big to be ignored. The trend is therefore that the concept of IPP’s or for that matter the private sector participation in power infrastructure business, is here to stay. Therefore, understanding the difficulties encountered by investors and governments is essential if private power business is to reach its potential in meeting the needs of developing Asia's populations and allow for continued, sustained development. Major problems in most of the developing countries need to be resolved. Some of these include a rational and transparent policy on private power, a pricing policy consistent with the market, fuel and environment policy. Another important area that needs to be addressed simultaneously is how to achieve social objectives within the free market environment. A related issue that is often referred to is: who bears the social responsibility for rural electrification or for providing power for the rural and urban poor?

Until such time when the public in general and all major players of the power sector achieve a greater degree of confidence in private power, it is likely that governments in most of the developing economies will continue to keep a significant control over the power sector. Even in countries where the IPP’s are already very active, governments play a crucial role in creating a conducive atmosphere through proper regulation including pricing and environmental standards.

With the rapid change in the power industry the utilities are also reforming or adjusting to live with it. The power industry is being unbundled from its bundled or integrated system to components like generation, transmission and distribution. Generation and distribution components are already up for the participation of the private sector or ‘threatened' to be taken over altogether from the utilities. It is now expected that the present utilities will transform into facilitators in the future, perhaps ultimately keeping control over the transmission grid system to retain its roles of coordinator and dispatcher. The commonly mentioned grid code is perhaps moving in that direction. The role of government as a regulator is likely to be maintained at all levels of privatisation.

Risk sharing

If everything is in order, why are things not moving as fast as one would expect? The challenge for the market players is how to accelerate market acceptance? There are a number of barriers that need to be removed. The main concern of the investors is how much risk they have to share and with what costs. Exposure to risks has recently even risen in respect of financial and political risks. The credit ratings of some countries have been lowered as a result of the current economic crisis. One of the major areas is the pricing or tariff policy, particularly in the case where power or the excess power needs to be marketed. Often the only market is the utility. Therefore a clear power purchase policy should be in place. Another important issue is the provision of back-up power from the utilities in emergency and during the scheduled maintenance. Government regulators have a critical role to play to set things right so that a partnership is developed between the utility and small scale generator(s); unfortunately this is not the case, at least as yet. What is needed most is a change in attitude to the whole concept to work together for the greater benefit of the society. All market players, including the utilities, should accept fair play; let the market forces determine what is acceptable and what is not. We cannot and should not ignore the potential role of small-scale generation, particularly when society stands to gain. We should rather work together to create a conducive atmosphere to further the development and acceptance of such entities. Countries should have their own strategy befitting their own need and priority.

Another risk or uncertainty relates to environmental standards. As one of the largest commercial energy-consuming sectors, the electric power industry has environmental and health impacts, particularly in relation to the production of electricity, which has emerged as one of the significant issues in the development and management of the power system. One of the reasons for environmental concern is the dominance of fossil fuel use in power generation. A growing concern of both the utility planners and the IPP's is the degree of uncertainty in the national environmental policy. This has a direct consequence on the fuel options for power generation. Although the choice of fuels is influenced by the national fuel policy, depending on the target level of environmental standards on emissions, fuel substitutions are likely to take place. If more stringent environmental standards on emissions are stipulated, primary electricity is likely to play a bigger role in the future than today.

Fuel supply policy is another potential risk area. Energy sources used for electricity generation include coal, oil, natural gas, hydropower, nuclear and to a lesser degree other forms of new and renewable energy, such as geothermal, biomass, solar and wind energy. Traditional sources of energy play a significant role in energy supply in a number of developing countries but most of these energy sources are used inefficiently with old technologies. If the state-of-the-art technologies could be applied to harness some of these resources, not only could energy services be improved but so could the environmental quality. Modern and medium-to-large scale biomass conversion technologies, for example, have the potential of meeting a part of the fuel need for power generation. In particular, where there is a shortage of infrastructure to bring in fossil-based power through grid extension, decentralised power generation through efficient uses of biomass can meet energy needs and bring social and economic benefits to the rural population with access to income generation activities.

2.8 REGIONAL/SUB-REGIONAL COOPERATION

Power sector investment is and will remain a major concern of the developing economies of the Asian sub-region. Independent power producers are likely to play an increasingly bigger role in mobilising resources for the power industry. It may be worthwhile for the regional countries to share each other’s experience in this respect.

Sub-regional studies may be undertaken by countries in the development of renewable resources, such as biomass, solar and wind. Collective efforts in addressing other issues including the transfer of technology may be a good option both in terms of cost effectiveness and enhancing capability including human resource development. Countries may share their resources in common research, development and demonstration of emerging technologies.

2.9 CONCLUSIONS

The energy/electricity demand in the ESCAP region, particularly in the developing economies, will increase at a high rate until well into the next century though at a gradually diminishing rate. While financing remains a major issue for countries and utilities, the recent trend of opening up of markets has created an opportunity for investment by the private sector.

It is evident that the power industry will continue to use a high proportion of fossil fuel for electricity production and the environmental impacts of fossil fuel burning in the region will therefore increase. Alternative fuel options should be explored to make use of renewable sources of energy, including biomass, solar and wind with possible adaptation of modern technologies.

Taking into account changes in the ownership pattern of energy/electricity industry in the region, regional co-operation in sharing information, experience and technology may bring mutual benefits to the participating countries. The issue of transfer of technology and funding support should be addressed by all parties concerned, including the developer of the technology and the potential users. The international community can play a facilitator's role.

It is desirable to set environmental standards and take appropriate measures to control pollution. On regional and global environmental issues, regional co-operation in taking concerted steps is needed.

3. DENDRO-POWER IN INDIA

by

N.P. Singh
Director ,Ministry of Non-Conventional Energy Sources
Government of India, New Delhi

3.1 INTRODUCTION

India is a large country (its total land area is 328.8 million hectares) having an estimated human population of 911 million, most of whom live in about 587,000 villages. The annual production of foodgrain is about 130 million tonnes. Although no data is collected on the quantity of agricultural and agro-industrial residues, it is estimated to be about 320 million tonnes per annum. It is also estimated that the total amount of cattle dung, produced by the 450 million cattle is about 240 million tonnes per year. About 20 per cent of the total land area is under forest cover which produces about 40 million tonnes of fuelwood and 4 million tonnes of sawdust.

3.2 ENERGY SCENARIO

In India energy is generated by a mix of commercial and non-commercial sources. The production of coal and lignite has increased from about 32 million tonnes in 1950-51 to about 320 million tonnes in 1996-97. The production of crude oil has increased from 0.3 million tonnes (1950-51) to about 37 million tonnes (1996-97), whereas the consumption of petrol and petroleum products has increased from 33 million tonnes (1950-51) to about 90 million tonnes (1994-95). The installed electric power generating capacity increased from 1713 MW in 1950-51 to 87,000 MW by the end of 1996-97. Despite such increases only about 30 per cent of households have access to electricity and about 80,000 villages have no electricity at all. The urban and semi-urban population utilises commercial energy. The rural population, which is about 75 per cent of total population, still depends upon non-commercial sources of energy, mainly biomass. Fuelwood and biomass contributes about 40 percent to the total energy consumption of the country.

3.3 BIOMASS RESOURCES ASSESSMENT

Biomass is available in large quantities in the form of fuel wood and logging waste, agro-residues and human wastes. Fuelwood originates mainly from forests, farms, shrub lands and commercial fuelwood plantations. Annually, some 320 million tonnes of agro-residues are generated (mainly rice-husks, groundnuts, coconut shells and bagasse).

Systematic data on the availability of various biomass sources for sustained energy generation have been collected in about 100 studies covering 100 *talukas*. On the basis of this data, biomass energy projects are planned and commissioned for energy generation and environmental enhancement.

3.4 BIOMASS PRODUCTION AND IMPROVEMENT PRACTICES

In India, about 93 million hectares of non-forest lands and about 30 million ha of forest lands are classified as degraded lands, i.e. land not suitable for agricultural production. Such lands are located in 14 different agro-climatic zones. On the other hand, there is a fuelwood shortage of about 166 million tonnes per year. This fuelwood shortage is normally met using agricultural residues and cattle dung that could otherwise be used for efficient energy production and industrial uses.
For these reasons, experience is being gained in fast growing, short rotation, high coppicing fuelwood species suitable for degraded lands. Research, development and field trial experiments are in progress for 70 fuelwood species. The knowledge is translated into 'Packages of practices' which will include standardisation of nursery technology, application of bio-fertilisers and pest and disease control for commercial plantations. Packages of practices for 35 species have already been prepared with a yield of about 15-20 tonnes of biomass per hectare per year of a 5 or 6-year rotation cycle.

3.5 TECHNOLOGICAL ASPECTS

A dendropower system is an integrated wood or biomass fuel based electric power generation system. It includes a fuelwood plantation, fuelwood transportation and storage, generation of electricity using a steam cycle or gasification route and transmission and distribution of electricity to the consumers. Technical progress has been achieved in raising energy crops on degraded lands that are unsuitable for agriculture crops, and in conversion technologies such as direct combustion (fixed and fluidised bed) and gasification.

In India, technological advancement has been achieved in gasification of woody and non-woody biomass up to the MW level and in the combustion route up to the 5 MW level. For the last two decades, R&D in both the public and private sectors has been actively pursuing these technologies. Biomass based power generation is considered carbon neutral since the carbon dioxide observed during the biomass growth is about equal to the carbon emitted during the combustion/gasification process. Studies on the environmentally benign disposal of ash and other effluents from biomass power systems are underway.

3.6 INSTITUTIONAL AND ORGANISATIONAL ASPECTS

The Ministry of Non-Conventional Energy Sources (MNES) was established in 1992 by upgrading the then Department of Non Conventional Energy Sources (DNES) into a full fledged Ministry. MNES is responsible for the planning, development and commercialisation of new and renewable energy, including biomass energy. At the state level, the departments or nodal agencies implement programs for planning and implementation of NRSE schemes. In addition, public and private industries are engaged in R&D and manufacturing of renewable energy devices and systems. A large number of Non-Governmental Organisations (NGO's) are also actively involved in preparing survey reports, feasibility studies and the implementation of renewable energy including biomass energy projects.

The Indian Renewable Energy Development Agency (IREDA) is a public sector body under administrative control of MNES. It provides loans at confessional rates for the manufacturing and utilisation of new and renewable energy systems. Through soft loans, IREDA has supported a large number of projects in the area of solar, wind and biomass energy. IDBI and other commercial banks have also been providing loans to bio-energy and other renewable energy projects.

3.7 FISCAL AND FINANCIAL ASPECTS

The power generation sector was opened to private companies in 1991 to augment India's installed power generation capacity. A number of fiscal and financial incentives are available to manufacturers and users of renewable energy technologies. Many barriers have been removed to facilitate the participation of the private sector or international manufacturers in the setting up of manufacturing facilities or the supply of equipment, materials and products. Financial and technical collaborations are encouraged. Some of the many benefits available to manufacturers and users of renewable energy systems are:

- 100% depreciation for tax purposes in the first year of the installation of the systems;
- no excise duty on finished products;
- low import tariffs for capital equipment and most materials and components;
- soft loans to manufacturers and users by Indian Renewable Energy Development Agency (IREDA);
- wheeling and banking is facilitated by the State Electricity Boards; and
- remunerative price for the power generated through renewable energy systems, fed to the grid, by State Electricity Boards.

3.8 DENDRO POWER PROJECTS

Under the various programs of MNES, viz. gasification, combustion and cogeneration, a large number of power generation projects (both captive and grid connected) have been taken up during the last 10 years. The salient features of some of these projects are described below.

The Kutch Plant

Kutch, a desert district in the state of Gujarat, is less developed and thinly populated. The average annual rainfall in the locality is only 250 mm. The rainfall pattern is very erratic and dry spells of long duration are common. There is little industrialisation in the locality. Electricity supply has the potential to change the pace of development in the region. In 1987, MNES supported the establishment of an energy plantation on 1,000 hectares of wasteland in Moti Sindhodi village in Abdasa, Kutch. The plantation, completed in 1990, is estimated to yield 8-10 tons/ha/year wood under very difficult soil conditions and inadequate irrigation. In 1995, a 500 kW grid-connected gasifier cum diesel electricity generator was installed near the energy plantation site. The technical specifications of the gasifier and power generator and the cost-economic aspects are shown in the accompanying box. The project, to be commissioned in early 1997, is expected to generate electricity at Rs.2.25 per kWh (6.3

0.5 MW Biomass Gasifier in Kutch,R&D Project

Capacity	0.5 MW
Total cost	1.87 Crores
MNES subsidy	1.20 Crores (hardware costs)
Balance	GEDA
Main fuel	Prosopis Juliflora energy plantation, 750 hectare
Location	Kothara village, Kutch district, Gujarat
Progress	civil works like foundation of dg set, gasifier, diesel tank, transformer room completed, erection of plant machinery in progress, likely commissioning March 1998

cents per kWh). Since the plantation is sufficient to support a 3-4 MW power system, new gasifier units will be added later.

The Gosaba Plant

Gosaba, an unelectrified remote island village with a population of 16,000, is located in the Sunderbans area of West Bengal State. The village is approachable only by boat/barge from Sonakhali, located 100 kilometres from Calcutta. There is an abundant biomass potential in the region. The availability of electricity can change the development pattern in the region through myriad means such as improving:

- the quality of domestic life;
- the productivity of agriculture (irrigation and dewatering of low lying areas);
- the development of agro-based and small scale industries; and
- the preservation of fish for transportation to the mainland.

There is an existing state owned forest of 10,000 hectares. On a 1,000 hectares of land available near the village, a successful captive plantation is being promoted with standardised systems. While a quarter of the plantation yield is presently committed for local consumption, the remainder is sold elsewhere at a price of Rs.300-400 per ton. The site is ideal for a biomass electricity project. A 500 kW (5x100 kW) gasifier project costing Rs. 9 million has been installed with full financial support from MNES and the state government. The state forest department has initially guaranteed fuel wood supply. The project has been in operation since June 1997 and provides electricity to about 300 families and commercial establishments. The cost of electricity production is Rs. 2 per kWh (5.6 cents per kWh).

The M/S HCL Agro Power Plant

M/s HCL Agro Ltd., a private company based in Hyderabad, capital of Andhra Pradesh State submitted a proposal to establish a 6 MW dendro power plant in 1995 with financial support of Rs.4.2 Crores from MNES. *Prosopis Juliflora* and other fuelwood species, grown nearby are the proposed feedstock for the power plant. The plant is to be located about 250 km from Hyderabad. The company has already acquired 10 hectares for the plant. The total plant cost is estimated to about Rs.18 crores. The major equipment like the boiler and turbine generator set has been procured from China through M/s Investtech, USA. The erection and commissioning of the plant is being looked after by the Nanjing Design Institute, China. The power generated will be fed to a nearby 33 kV line of Andhra Pradesh Electricity Board (APSEB) who will buy the power. Major indigenous equipment includes water treatment plant, cooling water, water circulating pumps, belt conveyor and overhead crane etc.

6 MW biomass power project, HCL Agro Power Ltd	
Capacity	6 MW
Total cost	Rs. 18.00 Crores
MNES subsidy	Rs. 4.2 Crores
Balance	IDBI, IREDA & proposers
Main fuel	Prosopis Juliflora
Location	Vedadri village, Krishna district Andra Pradesh
Type of boiler	spreader stoker, travelling grate, 35 tph,39 Bar, 380 °C
Storage provision	2 months
Fuel preparation	chopping to less than 3 inch size
Annual fuel requirement	45,000 tonnes
Back-up fuel	coal
Alternative biomass	bagasse, pulp mill rejects

The total fuelwood requirement for the plant is expected to about 7 tons/hr. The collection, transportation and handling of fuelwood are critical for the successful operation of the plant. The company proposes to have 3 collection and chipping centres at Nalagonda (150 km), Prakashan (250 km) and Krishna. The fuelwood is to be transported using trucks from a cement company that otherwise come empty to load cement. The power plant is expected to be commissioned by June 1998. The salient features of the plant are given in the accompanying box.

The M/s Indo Lahari Biopower Plant

M/s Indo Lahari Biopower Ltd., Raipur (Madhya Pradesh) proposed the building of a 5.5 MW rice husk based power plant at Jauroda village in Raipur district of Madhya Pradesh in 1996. There are a large number of rice mills around the location of power plant (the area is known as "Bowl of Rice"). The total plant cost is estimated to about Rs.22 crores which includes a subsidy of Rs.3.5 crores from MNES. While the promoters' equity is Rs.6.6 crores, the balance amount of Rs.11.9 crores is proposed to be raised by loans from IREDA, IDBI and public issue. The boiler and turbine have been supplied by M/s Thermax and M/s Triveni, both Indian Companies. The civil works for the boiler and turbine house have been completed. A fuel storage facility measuring 660 m^2 has been built. The power generated from the plant will be fed into the 30 kV grid of the Madhya Pradesh State Electricity Board (MPEB). The power purchase agreement with MPEB has been finalised, and the power plant is expected to be operational by March 1999. The specifications of the plant are given in the accompanying box.

5.5 MW demonstration biomass power project Indo Lahiri Bio Power Limited

Capacity	5.5 MW
Total cost	Rs. 22.00 Crores
MNES subsidy	Rs. 3.5 Crores
Balance	IDBI, IREDA & proposers & public issue
Main fuel	rice husk
Location	Jharouda village, Raipur district, Madhya Pradesh
Type of boiler	atmospheric fluidised bed, 2.5 tph, 64 Bar, 485 ° C
Storage provision	3 - 4 months
Fuel preparation	fired as it is
Annual fuel requirement	50,000 tonnes
Back-up fuel	coal
Alternative biomass	nil

3.9 DENDRO POWER PLANTS IN THE PIPELINE

The central and state governments offer excellent promotional incentives in the forms of direct subsidy, interest subsidy and other fiscal incentives for the generation of power from renewables by the private sector. As a result, several proposals have already been prepared in the states of Andhra Pradesh, Tamil Nadu and Karnataka. These proposals are based on both biomass combustion and gasification routes. The detailed feasibility reports for these projects have been prepared and submitted to various financing bodies in order to raise loans. Negotiations with State Electricity Boards are in progress for purchasing power generated by these plants. A consolidated list of power plants in India is given in Table 2.1.

Table 2.1: Biomass power generation projects in India (exceeding 1 MW)

Name of project / implementing agency	**Location**	**Technology**	**Cap (MW)**
M/s R.R. Bio Energies Ltd.*, Doobakasala, West Godavari	Andhra Pradesh	IGCC	8
M/s Harsha Power Projects Pvt., Siddipet, Medak	Andhra Pradesh	Gasification	1
M/s Alpha Energy Systems Ltd.*, Pasha Mailaram, Medak	Andhra Pradesh	Combustion	40
M/s Sharp Power Projects Ltd.*, Beechupally, Mahaboob Nagar	Andhra Pradesh	Combustion	10.2
M/s Clarion Power Corporation Ltd.*, Singarayakonda, Prakasharn	Andhra Pradesh	Combustion	12
M/s Gautami Solvent Ltd., Tanuku, East Godawari	Andhra Pradesh	Combustion	2.75
M/s HCL Agro Power Ltd., Vedadri, Krishna	Andhra Pradesh	Combustion	6
M/s Nuchern Ltd., Tauhaua, Gurgaon dist.,	Haryana	Combustion	5
M/s Indo-Lahari Bio-Power Ltd., Jauroda, Raipur	Madhya Pradesh	Combustion	5

***Under finalization**

Cogeneration in Sugar Mills

India is the largest producer of sugarcane in the world. The generation of electricity from bagasse in sugar mills is universally accepted and desirable both economically and environmentally. In India, a potential 3,500 MW of additional power has been estimated in the country's 430 sugar mills through modern cogeneration techniques. The actual status of cogeneration in sugar mills is given below.

Table 2.2: List of commissioned bagasse cogeneration power projects

Name of project / implementing agency		**Cap (MW)**
M/S Ugar Sugar Works Ltd.	Karnataka	1.0
Datta S.S.K. Ltd., Shirol, Kolhapur	Maharashtra	1.5
Jawahar S.S.K, Hapuri, Kolhapur	Maharashtra	1.5
Deogiri S.S.K., Pulambari,Aurangabad	Maharashtra	1.5
Mazalgaon S.S.K., Distt.Beed	Maharashtra	1.5
Adinath S.S.K. Ltd., Distt.Sholapur	Maharashtra	1.5
Chopda S.S.K., Chopda, Jalgoan	Maharashtra	1.5
M.R.Krishnamurthy Coop.Sugar Nulls Ltd, Chidambaram	Tamil Nadu	3.0
Cheyyar Coop.Sugar Mills Ltd.Cheyyar, T.S.District	Tamil Nadu	3.0
Thiruarooran Sugars Limited, Thrumandandkudi	Tamil Nadu	9.0
M/s Rajashree Sugars, Madurai District	Tamil Nadu	8.0
M/S Kothari Sugars & Chemicals Kattur	Tamil Nadu	7.0
M/S Dharani Sugars & Chemicals Limited, Thirunelvelli District	Tamil Nadu	8.0
Parry (1) Ltd., Allikupppam, Sarth Arcot District	Tamil Nadu	10.5
Thiru Arooran Sugars Limited, Papanasam Taluka	Tamil Nadu	9.0
Dhampur Sugar Mills, Dhampur (Unit-1)	Uttar Pradesh	3.0
Aguata Sugar Mills, Bulandshahar	Uttar Pradesh	3.5
M/S Dhampur Sugars Ltd, Rozagaon Distt. Muradabad	Uttar Pradesh	4.0
J.K.Sugars Limited, Shahjahanpur	Uttar Pradesh	4.0
Total installed capacity for cogeneration		82.6

Table 2.3: List of bagasse cogeneration projects under implementation

Name of Project/ Implementing Agency		**Cap (MW)**
M/S Sudalagunta Sugars Limited Chittor District	Andhra Pradesh	4.5
Ugar Sugar Works Ltd., Ugar-Khurd, Belgaum	Karnataka	18.0
Shamanur Sugars Davangere	Karnataka	9.0
Ryatar Sugars, Hubli	Karnataka	4.0
Prabhulingeshwar Sugars, Belgaum	Karnataka	9.0
Godavari Sugar Samirwadi	Karnataka	10.0
Faridkot Coop.Sugar Mills Ltd., Faridkot	Punjab	2.0
Rana Sugars, Amritsar	Punjab	10.0
S.V.Sugars, Near Kanjipuram	Tamil Nadu	2.0
M/S Kallakurichi Coop.Sugar Mills Ltd., Moongil,Thuraipattuvrp District,	Tamil Nadu	1.5
M/S Subramaniya Siva Coop.Sugar Mill Ltd.,Gopalpuram Dist.,	Tamil Nadu	1.5
N.P.K.R.R.Coop. Sugar Mills Ltd., Thalainayar Dist. Nagai,	Tamil Nadu	2.0
M/S Sbec Sugars Ltd., Malakpur, Dist. Meerut	Uttar Pradesh	7.0
M/S Dhampur Sug. Ltd., Rozagaon, Dist. Barabanki	Uttar Pradesh	19.0
M/S Bajaj Hindustan Ltd., Golagokarnath Dist., Lakhimpur Kheri	Uttar Pradesh	2.5
M/S Bajaj Hindustan Ltd., Palla District	Uttar Pradesh	3.0
M/S Ghagara Sugars Ltd.	Uttar Pradesh	3.0
Total installed capacity under implementation for cogeneration		108.0

Under its National Programme on Cogeneration, MNES has been providing financial support for the preparation of Detailed Project Reports (DPR's). It has also provided direct subsidies of Rs.2 crores per MW of surplus power generated in the co-operatives sugar mills. Further, the Programme provides interest subsidies for the capital grants of leading financial institutions of up to Rs.35 lakhs per MW for projects of more than 4 MW of surplus power capacity to enable institutions to reduce interest rates on their term loans for cogeneration projects. Lower rates of grants are also available for other similar cogeneration projects or those using second boiler co-turbines.

In the last four years, a large number of sugar mills have taken initial steps towards preparing DPR's and commissioning projects. About 110 MW of cogeneration projects have already been installed and 120 MW is currently being installed. For every 2500 TCD capacity, some 9 MW of power can be exported in an existing mill, with a capital cost of around Rs.36 crores (4 Rs. crores/MW_e). For new mills this will be much lower at around Rs.2.5 crores per MW_e.

3.10 CONCLUSIONS

Taking into account the various techno-economic and social aspects of dendro power the following may be concluded:

- Dendro power plants are environmentally benign compared to coal and lignite based power plants.
- Research, development and commercialisation capabilities and other institutional mechanism exist in India.
- Excellent opportunities in the field of dendro power exist for entrepreneurs. These include fiscal and financial incentives, wheeling and banking and purchase of power by State Electricity Boards.
- Dendro power plants provide excellent opportunities for generating employment in rural areas and improving their socio-economic conditions.

4. RUBBER PLANTATIONS: AN OVERLOOKED DENDROPOWER OPTION

by

S. Prasertsan, Rubber Wood Research Program
Thailand Research Fund, c/o Department of Mechanical Engineering
Prince of Songkla University, Hat Yai, Thailand 90110
P. Vanapruk, Yala Power Producer Co., Ltd., Yala, Thailand 95000

Abstract

The failure of the dendrothermal power program in the Philippines was primarily caused by mismanagement at both the conceptual design and implementation stages. Growing energy crops by inexperienced farmers led to the inadequate supply of woodfuel. Despite this negative experience, the rubber plantation is proposed as an alternative candidate. The rotation period of rubber trees is 25 - 30 years, the time when rubber trees are cut down for replanting. Thailand, as the world's leading rubber producer is in the position to initiate rubber wood dendropower projects. The rubber-related industry includes rubber producers (farmers and rubber factories) and rubber wood product manufacturers. These two parties generate a substantial amount of biomass wastes such as small chunks and branches in the field and residues (sawdust and wood off-cuts) in the factories. The rubber wood fuel for dendrothermal power plants is, therefore, available as a downstream process of the well established upstream industries. Data on rubber wood residues in Thailand were analysed and it was estimated that a total of some 950 MW_e can be generated at 200 sites. The potential future supply of biomass was determined from the age distribution of rubber trees. Thailand will continue to enjoy biomass energy from the rubber industry as long as the world consumes rubber.

4.1 INTRODUCTION

A dendrothermal power system is defined as an integrated wood based electric power generation system, but it is often synonymously used for any biomass based electricity power generation system (FAO, 1997). The system includes energy plantations, transportation of wood, generation of electricity and a system for transmission and distribution of electricity to the consumers

It has long been believed that dendrothermal projects may not be practical. This may stem from failure in the Philippines. Obviously, there were many crucial factors that were overlooked during the development and design of the program. The Philippines program was a single-purpose plantation exclusively devoted to wood for energy. A major problem was the inability to secure the supply of fuel at an economically acceptable price (Durst, 1986). However, the failure of the Philippines' case does not mean that dendropower is not practical. It just means that a different approach should be tried.

At present, growing rubber trees is a multi-purpose activity. Apart from harvesting latex, the biomass collected after the end of the rotation period can be transformed into wood-based products and energy. The economic life cycle of the rubber trees is 25-30 years after which the trees are cut down for replanting. Rubber wood usually does not last long because it contains carbohydrate, which induces insect (woodborers) and mould attacks. In the past, the trees were burnt down in the plantation. It was not until a decade ago that rubber wood found its way out of the plantation when rubber wood-based industries were set up in the region. Now, the wood is treated chemically for insect resistance and is rapidly dried to avoid mould growing. Various rubber wood products such as particleboard, solid wood furniture, educational toys and kitchenware have successfully penetrated the world market. Large quantities of wood waste in various forms like sawdust and wood off-cuts are generated in the wood processing factories. The supply of these wood wastes overwhelms the demand (i.e. brick making and rubber sheet smoking industries) and factories often face disposal difficulties).

The rubber industry consists of rubber producers, wood based-product manufacturers and energy suppliers. Dendrothermal power in this case, is therefore, a downstream industry of two well established upstream industries. This paper presents an integrated viewpoint of the three rubber-related industries. However, energy production from rubber wood waste is emphasised.

4.2 RUBBER PLANTATION FOR SUSTAINABLE DENDROPOWER

As a response to the oil crisis, in 1979 the Philippines Government launched a program for 217 decentralized dendrothermal power plants of 3 MW_e each. The program aimed for large scale, grid based biomass electricity generation, dedicated biomass energy plantations, decentralised and co-operative ownership, national co-ordination by the centralised administration and integration of social and environmental benefits within the program design (Durst 1987a, Durst 1987b). Since mid 1983 the permission to build new power plants, except for 17 for which the equipment had already been purchased, was indefinitely postponed and plantation development was sharply curtailed (Durst 1986). Tree planting declined after the first two years of the program, this led to fuel shortages and only 2 out of 9 operational power plants could receive an adequate supply of wood The causes of failure are summarised below.

1. The program was designed with a top-down approach, and depended totally on government support for finance, administration and technology. It was pushed by the Government, not pulled by the market. The planning and implementation were too centralised and could not respond to the specific problems of decentralised power plants.
2. The program depended solely on the energy plantations, which proved to be very risky. Furthermore, the plantations were mainly in the mountainous areas and one single tree species (Leucaena Leucocephala or Ipil-Ipil) which did not suit all sites was used. In some locations, the trees were attacked by insects. The actual yield in some places was only 25% of the projected yield.
3. Poor management and planning also contributed to the failure. At the time this large program was launched, knowledge and experience related to plantations for energy were very limited. The centralised decision making was not responsive to the decentralised implementation and operation. The inexperience of the farmers aggravated the problems socially and economically.
4. The inadequate and uneconomical supply of biomass fuel was the most important cause of the failure. The low yield led to competing needs and price increases. Transporting the wood in the mountainous areas using the installed aerial mono-cable system was so costly that it had to be substituted by manual labour.

The failure of the Philippines' initiative actually indicated the complexities of managing a dendropower system as an integrated operation. It was concluded that the de-linking of biomass supply and electricity generation through a well-developed biomass market can be one important step in improving the performance of dendrothermal plants (FAO, 1997). Alternatively, a reliable feedstock supply can be obtained from a strong, planned, efficiently managed and dedicated biomass plantation system. In developing countries these conditions are difficult to achieve. Unless the market and other institutional infrastructure are in place, dendrothermal programs in developing countries are likely to fail (FAO, 1997).

Despite the above comment, it is suggested that rubber plantations and downstream industries could provide enough wood for a dendropower project. Moreover, there is a well-established institutional infrastructure in the rubber industry. With an annual production of almost 2 million tons, Thailand is the world's largest natural rubber producer. Rubber plantations cover an area of 1.9 million ha. The steady supply of wood from rubber tree replanting schemes makes rubber wood fired power generation a promising concept. Some dendrothermal activities such as growing trees and transportation of fuel are shared by the rubber producing industry and the wood-based industry, respectively. Plantation-grown fuel in the Philippines costs 15.4 $/dry ton/ha/year which gives a delivered feedstock cost of 0.42-1.18 $/GJ (Perlack et.al., 1995). Those costs are definitely lower for rubber wood fuel. The existence of the biomass-fired power plants can make use of the wastes and finish the biomass chain in a beneficial way, environmentally and economically. The failure of the dendrothermal project as experienced in the Philippines is unlikely to be repeated if rubber wood is used.

4.3 ECONOMICS OF THE INTEGRATED APPROACH OF THE RUBBER INDUSTRY

Thailand earns 80,000 million baht a year from rubber exports. About 6 million workers are employed in this sector. A mechanism was set up to determine the actual production cost, which is used by the Government for pricing policy and market interference. The per kilogram production cost is calculated for the life cycle of the rubber trees. At present (1998), the figure is 22.75 baht/kg. Thailand produces 1.987 million tons of rubber a year and 92% is exported. Thus, the annual production cost is 45,000 million baht. The difference between the export value and the production cost is 35,000 million baht. By analysing the cost structure, it was found that only 8.5% of the production cost is for imported chemicals (fertiliser, pesticide, etc). In other words, 41,200 million baht of the production cost are circulated in the country, mainly through labourers and support industries such as latex containers, processing equipment, and etc. The monetary flow is depicted in Figure 4.1. The net in-country cash flow is 76,200 million baht per year.

Data retrieved from the Ministry of Industry revealed that in 1997 there were over 600 rubber wood-based factories in Thailand which provide at least 35,000 jobs. The export of Thailand's rubber wood products amounted to 15,000 million baht in that year and is increasing. With the total plantation area of 12 million rais and the life cycle of 25-30 years, biomass from 3.5% of the planting area is available every year. Biomass yield was measured as 281 m^3/ha (or 393 ton of green wood per ha). Therefore, the annual replanting area of 56,000 ha easily yields 15.75×10^6 m^3 of biomass. The composition of biomass and its usage is illustrated in Figure 4.2.

Figure 4.1: Cash flow of the rubber industry

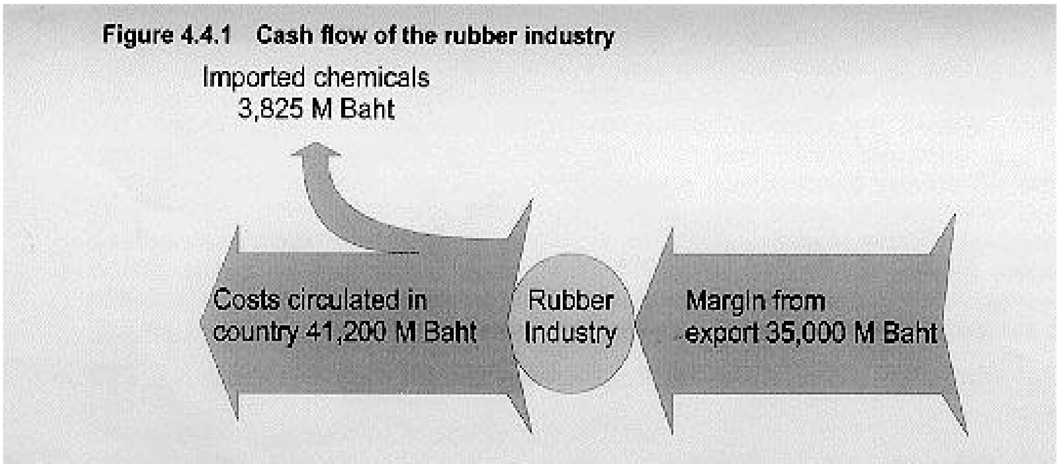
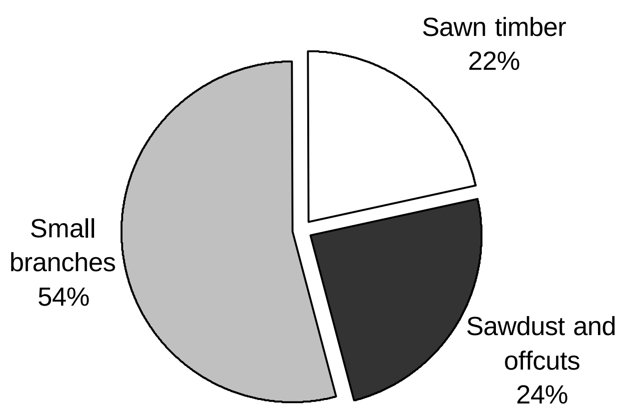


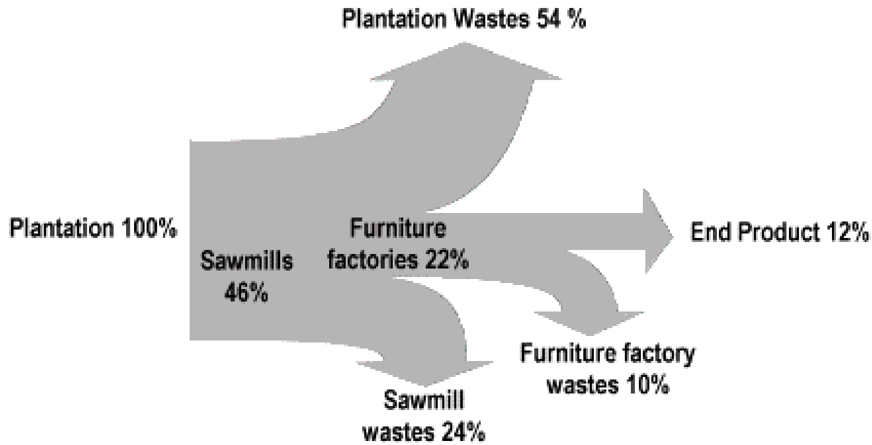
Figure 4.2 Composition and usage of rubber wood



Source: Royal Forestry Department

Small chunks and branches of diameter less than 6 inches representing 54% of the total biomass are, at present, burned in the field. Only 46% are transported to saw mills. Because of relatively small logs, the sawing yields only 22%. Wood flow is given in Figure 4.3.

Figure 4.3: Wood flow from plantation to products



It was estimated that 83% of the felled rubber trees are utilised (ITC, 1993). Consequently, $9.68x10^6$, $3.14x10^6$ and $1.31x10^6$ m^3 of wood waste are located at the plantations, sawmills and wood-based factories, respectively. Dry rubber wood has a volumetric shrinkage of 10%, a density of 630 kg/m^3 and a heating value of 17.9 MJ/kg. That is, the energy potentials at the corresponding sources are $98.18x10^6$, $31.86x10^6$ and $13.29x10^6$ GJ. Wastes at the sawmills and wood-based factories are available at no transportation cost if the power plants are to be set up in the same premise. If the thermal efficiency of the power plant is assumed to be 30%, the electrical energy of $2.66x10^9$ and $1.11x10^9$ kWh/year can be obtained from the saw mills and wood-based factories, respectively. However, this collective potential does not reflect practicality, since the power plants are suitable for sawmills and factories of a certain size only, i.e where the waste quantity is sufficient to feed the plants continuously.

If, as in the Philippines, 3 MW_e power plant is a goal, it must be attached to a factory that generates at least 48 tons of dry waste a day. Such an amount of waste can be acquired from a sawmill having a production capacity of 42 tons of dry timber a day or a wood-based product factory consuming 100 tons of sawn (and dry) timber per day. By looking through the list of factories registered with the Ministry of Industry, we can identify the saw mills and wood product factories having enough wastes to produce electricity (Table 4.1).

Table 4.1 suggests that approximately 950 MW_e is obtainable from about 200 sites. The energy produced in small plants is suitable for captive consumption like in the palm oil mills, where the generation capacity is about 500 kW_e. The plants that sell electricity to the grid should have a higher capacity to justify economic feasibility. In one case in Thailand, a plant was designed and partly commissioned only later to be abandoned by the owner because it was found that a plant of 2.5 MW_e is not feasible. After this it was recommended that the minimum feasible size for cogeneration in Thailand is 6 MW_e.

Table 4.1: Potential rubber wood waste power generation in Thailand (1997)

Provinces	number of saw mills (wood product factories)				
	0.5 -1 MW_e	1 - 3 MW_e	3 - 6 MW_e	6 - 10 MW_e	> 10 MW_e
Chumporn	2				
Surattani	7(1)	21 (1)	5	1 (1)	1 [73MW_e]
Krabi	1	2	1		
Satoon	1	3			
Ranong	1	1		1	
Pangna	2 (1)	1	1		
Pattalung		1			
Trang	8	9	5	1	
Pattani	2	4		1	
Yala	10 (1)	6 (1)	4 (1)	2	
Nakornsri	11 (1)	3	3	4	1 [44MW_e]
Songkhla	9 (2)	9 (1)	5 (1)	4	1 [52MW_e]
Narathiwas	3	2	1		1 [41MW_e]
Chonburi	(3)	1		(2)	1[254MW_e]
Rayong	4 (2)	6	3		1 [17MW_e]
Chantaburi	1	1 (1)			
Total	62 (11)	70 (4)	28 (2)	14 (3)	6

Biomass remaining in the plantation can be another fuel source if the transportation cost allows. In Thailand, it was estimated that the transportation cost is 2 baht/ton/km. A 6 MW_e power plant consumes 96 ton of dry wood a day, which is equivalent to 202 tons of green wood. A wood supply of 202 tons is obtainable from a 1 ha plantation (calculated from small chunks and branches, which account for 54% of total wood). Thus, the power plant must be located in an area having a replanting area of 368 ha/year. Since the replanting area accounts for 3.5% of the total plantation area, the sustainable plantation area for a 6 MW_e power plant is 10,500 ha or a circular area with a radius of 5.8 km. The maximum transportation cost is then 11.5 baht/ton (green wood) or 0.016 baht/kWh which is about 1% of the electricity buy back tariff. Therefore, based on this assumption (i.e., no other cost except for transportation) it is possible that the residues in the plantation can be economically used for power generation.

Normally, the saw mills require steam for their drying kilns. As two forms of energy are used in the sawmills, combined heat and power (CHP) generation, or in short cogeneration, is of interest. The thermal efficiency can be as high as 85%. At present, wood off-cuts are fed into low-pressure boilers producing steam for the kilns only. To be self sufficient in energy, a capacity of 500 kW is required for a relatively large saw mill. Similar systems with 20 bar, 350°C boiler and backpressure steam turbines have in the past been installed in palm oil mills. The turbine exhaust steam at 4 bar, 145 °C is then used in the sterilisers and digesters. Palm oil mills have a relatively high heat-to-power (HP) ratio. For sawmills, the HP ratio is much lower and condensing steam turbines are usually recommended to increase the power output. A study in one medium scale saw mill found that the HP ratio was 17.7:1 while in another factory, which has both sawing and furniture manufacturing, the HP ratio was 2.36:1. With such a varying HP ratio, case-to-case design of the cogeneration system is essential.

Uncertain fuel characteristics are another critical factor. Unlike coal or gas-fired power plants, biomass-fired power plants have to cope with fuel variation in form, size, moisture content (and hence heating value), combustion control, and fuel preparation and handling.

For example, in Yala province, a rubber wood processing company owning a sawmill and a plywood factory wants to establish a woodwaste fired power plant. A cogeneration power plant was designed to cope with the fuel variation and energy (heat and electricity) consumed by the company. The company also plans to sell excess electricity to the grid. The operation is complicated since the heat consumed by the saw mill and the plywood processing lines varies according to the production capacity while the electricity sale must be guaranteed at 15 MW_e.

The boiler thermal load is 87 MW, with a net output of about 19 MW_e and a process heat supply of about 30 t/h for the plywood factory and saw mill works. The power export is a firm 15 MW_e base load to the national grid. The extra 4 MW_e is for the plywood and sawmill works (2 MW_e) and a reserve for future expansion of the plywood factory (2MW_e). The 19 MW_e net power production must be achieved in all process steam consumption values between 0 and 30 t/h. The process steam extraction is dimensioned so that the consumption of 40 t/h will be possible in the future.

Under normal conditions, the process steam requirements for the plywood factory and the saw mill are 32 t/h at peak and 27 t/h on average. The steam pressure is 4-6 bars and the temperature is 150-165°C. The consumption of steam is seasonal. During January to October and November to December the demands are 80-100% and 30-40% of the maximum demand, respectively. Approximately 80% of the steam sent to the end-uses returns as condensate (80-90°C).

The power plant uses rubber wood residues from the plywood factory and the sawmill as fuel. Fuel appears in 5 forms as rubber wood chunks, branches, sawdust, fresh veneer crush, dry veneer crush and plywood residues (with urea formaldehyde glue). The fresh residue has a moisture content of 50% and a heating value of 7.8 MJ/kg. The corresponding figures for the dry residue are 8-12% and 16 MJ/kg (an optimistic estimation for design purposes). The boiler was designed to receive various fuel mixtures. The maximum shares of rubber wood chunks, saw dust, fresh veneer, dry veneer and plywood residues in the fuel composition are 100%, 30%, 30%, 20% and 20%, respectively. It was reported that refuse-derived fuel (RDF) can be added into the boiler up to 30% of the total calorific load without adverse effects on the emissions (Aittola and Kassi, 1997). The Yala project was designed for a maximum of 10% RDF boiler feed.

4.4 FUTURE POTENTIAL OF RUBBER WOOD AS AN ENERGY SOURCE

The supply of rubber wood fuel in the future is determined from the age distribution grouping in 6 year intervals, and hence the projection of the wood supply is as appears in Table 4.2.

The wood waste supply figures in Table 4.2. are based on 88% of the total biomass (12% end product as given in Figure 4.3). By assuming that the rotation period is 25 years, the peak fuel wood supply will be 75.62 million tons in the period 2005-2010 or 12.6 million tons a year. If all the wastes are used for electricity generation (efficiency 30%), the dry wood of 12.6 million tons a year can feed a total power plant capacity of 2,145 MW_e.

Table 4.2: Age distribution of rubber plantation and projection of wood supply (1991)

Age (year)	Total area		Projected wood supply		Projected waste supply	
	year	10^3 ha	%	$x10^6$ m^3	$x10^6$ dry ton	$x10^6$ GJ
0-5	2011-2016	366	20.6	103	51.3	919
6-11	2005-2010	539	30.3	152	75.6	1,354
12-17	1999-2004	453	25.5	127	63.6	1,138
18-23	1993-1998	324	18.2	91	45.5	814
over 24		97	5.4			

With the many CO_2 mitigation initiatives that are emerging globally, research work should be aimed at efficient and effective energy use of rubber wood. In Thailand, a lot of research has been done on atmospheric gasification. Gasification systems operating on various agricultural residues were used for water pumping, generating electricity and producing process heat (Coovattanachai, 1985). Diesel engines were modified to be operated on producer gas. The future trend of biomass energy research is in the field of highly efficient power generation cycles. Pressurised biomass gasification coupled with a gas turbine offers high efficiency and low unit capital cost at modest scale. Improvements in jet engine and biomass gasification technologies are expected to lead to improved performance of the biomass power generation system over the next couple of decades (Williams and Larson, 1993). Technology development indicates that a 40 MW_e combined cycle gasification plant with an efficiency of 42% will be available soon at a cost of 1.6-1.7 million US dollars having a generation cost of 4 cents/kWh (Frisch,1993).

4.5 CONCLUSION

Dendrothermal power using rubber wood waste is a promising and environmentally sound future option that should not be overlooked by policy makers and power investors. Wood residues from plantations and factories have been pointed out as sustainable sources of energy. It has social and economic values by providing energy and jobs for local people. However, the success of a dendropower project strongly depends on the ability to supply sufficient woodfuel at a competitive price. Since all sectors are interdependent, failure in one sector is fatal to the whole system. The rubber industry in Thailand consists of two well-established industries (the rubber producers and the rubber wood product manufacturers). Consequently, a rubber wood based power plant can be established relatively easily.

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5. IMPLEMENTING CLEAN AND EFFICIENT ENERGY PROJECTS WITHIN THE WOOD SECTOR OF ASEAN

by

Michael Pennington, Ludovic Lacrosse and Alan Dale Gonzales
EC-ASEAN COGEN Programme, Asian Institute of Technology, Pathumthani, Thailand

5.1 INTRODUCTION

Gone are the days when wood industries could get rid of their residues by dumping or incinerating them without facing any problems with local authorities.

Several coincident factors contributed to that dramatic change of attitude from the wood industrialists: environmental regulations have been established recently and are now enforced by local governments. The high growth rate in power consumption in ASEAN countries and consequently, the increase in the energy prices, made it more and more economically viable for wood industries to invest in technologies that allow them to cover most, if not all, their energy requirements, by using their own residues. Reliable and highly efficient technologies for energy conversion from wood residues have been developed, particularly in Europe.

The scope of this paper is limited to combustion, as other technologies are rather marginal and/or still at a development stage. Different applications of the combustion technologies in different wood industries will be presented.

5.2 TECHNOLOGIES AND APPLICATIONS

Technologies for energy conversion of wood residues have been developed and implemented all over the world. Depending on the needs of the factory, a steam-producing plant can generate only heat, only power, or both heat and power. Combined production of heat and power constitutes cogeneration. Steam is generated by a boiler, which consists of a furnace where combustion takes place and a heat exchanger that transforms water into steam. When only process steam is required (for drying, hot presses,.etc.), low pressure boilers are generally used. When power is needed, higher pressure boilers are required. Steam is then expanded in a steam turbine, which is coupled to an electricity generator.

The high-pressure steam, after expanding through the turbine, is exhausted at low pressure or at vacuum conditions. Turbines with exhaust steam at lower atmospheric pressure are called backpressure turbines, while the turbines using the vacuum area are called condensing turbines. The choice of the model will mostly depend on the heat-to-power demand ratio of the factory.

Fully condensing turbines are the best option when:

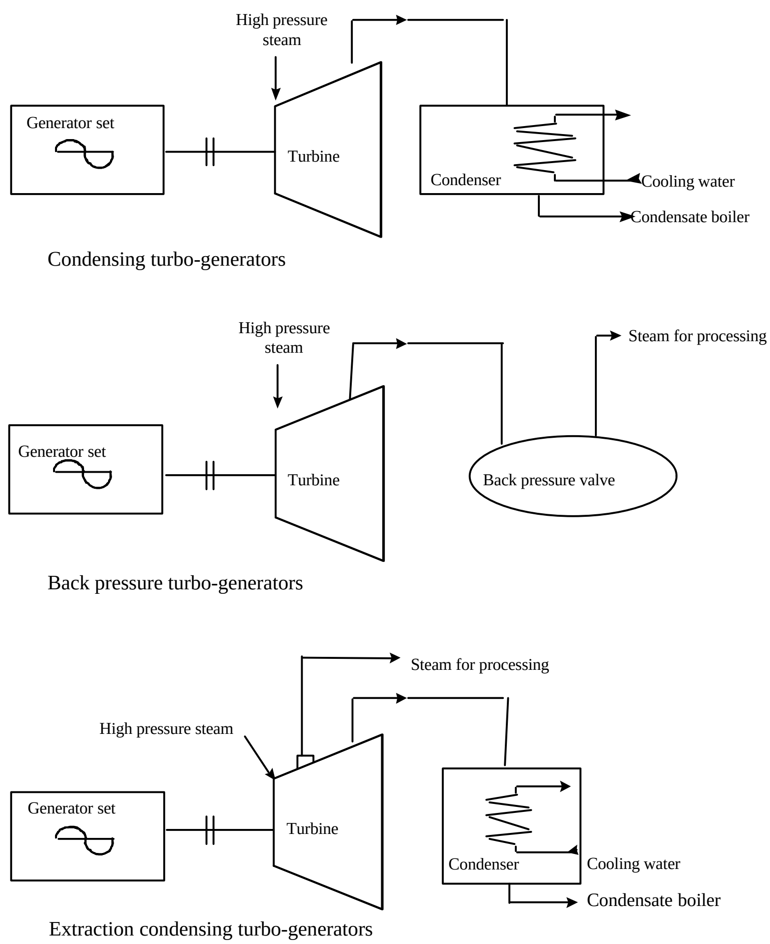
- only power is required;
- excess steam is available;
- steam used for process or power production is generated by separate boilers.

Non-condensing or back pressure turbines are more appropriate when:

- cogeneration is chosen and most of the steam is directed to the process;
- additional power requirements can be met through other sources such as utilities, stand-by gensets, etc.

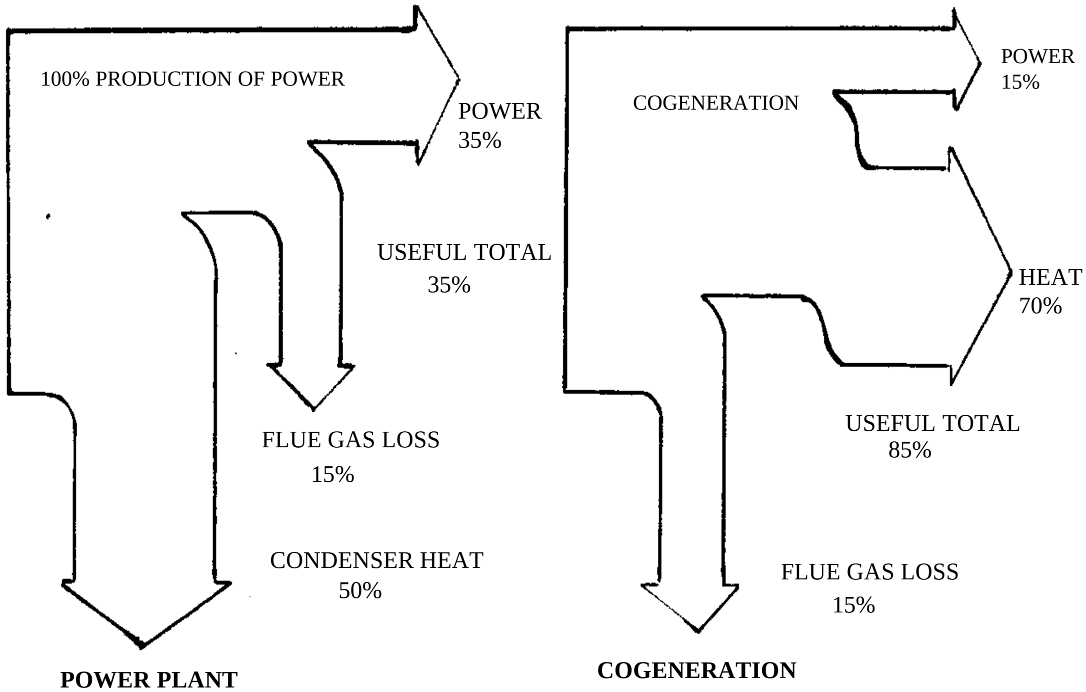
The benefits of both condensing and back pressure systems can be combined via a special system allowing the extraction of steam directly from the turbine, and not after it. The main advantage of an extraction turbine is that the extraction of steam can be regulated, which is very useful in the case of cogeneration operations. The different types of steam turbo-generators are illustrated in Figure 5.1.

Figure 5.1: Different types of steam turbines



From an energy viewpoint, cogeneration is much more attractive than power generation only. Indeed, as shown in Figure 5.2, the global efficiency of a cogeneration installation can reach 85% and up, compared to 30 to 35% in case of electricity production only.

Figure 5.2: Energy conversion in conventional and cogeneration plants



The following examples constitute a non-exhaustive list of energy related applications in the wood-based industries:

- Heat for kiln drying:

Heat is supplied to the kiln dryer through hot water, hot oil, or low pressure steam produced by a simple and cheap wood waste boiler.

- Heat for plywood, veneer and particle board plants:

Almost all plymills, veneer factories and particle board plants, can burn their dry wood residues in order to produce steam for drying and hot pressing. However, most of them use diesel gensets to cover their electricity needs. Only large units invest in cogeneration installations.

- Power from a fully condensing turbine:

Steam enters the turbine at high pressure. The exhaust steam which is at low or vacuum pressure proceeds toward a condenser. No steam is sent to the process. The energy of the steam is fully utilised for power generation. That is what can, for example, be implemented in sawmills without drying facilities.

- Cogeneration with a fully condensing turbine:

Before going into the turbine, part of the steam is diverted to the process and, when necessary, passes through a pressure reducer. Despite the fact that it is far from being optimal in terms of energy efficiency, this set up can be found in sawmills equipped with kiln dryers.

- Cogeneration with a back pressure turbine:

Back pressure turbines are the most appropriate when there is a significant need for low pressure steam. While power is generated by the expansion of the steam inside the turbine, low pressure steam for the process is recovered at the exhaust of the turbine.

- Combination of fully condensing and back pressure turbines:

Back pressure and condensing turbines can be coupled either in series or in parallel. In series, the excess steam produced by the back pressure turbine is taken over by a condensing turbine. In parallel, steam coming from the boiler is divided into two streams for the two turbines.

- Cogeneration with an extraction turbine:

The benefits of both condensing and back pressure systems can also be combined via a special system allowing the extraction of steam directly from the turbine. In an extraction turbine, steam is extracted in the upper part of the turbine, when steam is still at high pressure. The extracted steam can be used in the mill process while the rest of the steam is released in the lower part of the turbine. Extraction turbines are generally the condensing turbine type, but can also be back-pressure turbines.

5.3 EXAMPLES FROM THE REAL WORLD

One of the main purposes of the EC-ASEAN COGEN Programme over the last few years has been to demonstrate the technical reliability and the economic viability of technologies using biomass residues as fuel in wood and agro-industries. As a result, sixteen Full Scale Demonstration Projects (FSDPs) involving European and ASEAN Industrialists were selected. Most of these have already been implemented. Ten, out of these sixteen projects, are in the wood sector, and are summarized in Table 5.1.

Table 5.1: FSDPs implemented by the EC-ASEAN COGEN Programme in the wood sector in ASEAN

Project no.	Industry	Country	Equipment	Capacity
1	Parquet	Thailand	Hot water boiler	1,250,000 kcal/h
2	Sawmill	Malaysia	Steam boiler	5 tph; 12 bar
3	Wood Frame	Thailand	Hot water boiler	400,000 kcal/h
4	Plymill	Indonesia	Steam boiler	35 tph; 35 bar
5	Wood complex	Malaysia	Cogen plant	1.5 MW
6	Wood complex	Malaysia	Cogen plant	1.65 MW
7	Rubberwood	Thailand	Cogen plant	2.5 MW
8	Wood complex	Indonesia	Power plant	5.55 MW
9	MDF plant	Malaysia	Thermal oil heater	22 Gcal/h
10	Wood complex	Malaysia	Power plant	10 MW

A brief description of these ten projects as well as some of their economics (cost, pay back period) follows.

Project no. 1:	**Parquet flooring factory in Thailand**
Brief description:	Sawdust and wood shavings are sucked by a pneumatic collection system to be used as a source of energy in the boiler supplying hot water to the kiln dryers.
Location:	Srakaew
End User:	Areechai Woodtech Co., Ltd.
Main Supplier:	From Italy
Cost:	US$ 180,000
Pay back period:	2.9 years

Project no. 2:	**Sawmill in Malaysia**
Brief description:	Equipped with an automatic feeding system, the wood waste-fired steam boiler produces steam for the kiln drying plant. As part of the supply, there is also a wood dust extraction system from the wood moulding plant.
Location:	Gemas, Negeri Sembilan
End User:	Bekok Kiln Drying and Moulding Sdn. Bhd.
Main Supplier:	From Denmark
Cost:	US$ 274,800
Pay back period:	2.9 years

Project no. 3:	**Wood frame factory in Thailand**
Brief description:	Manufacturing top quality frames for export, the company decided to invest in a dust extraction and storage system and to use their wood residues as a source of energy for kiln drying. The residues are being combusted in a hot water boiler with a total capacity of 400,000 kcal/hr.
Location:	Laem Chabang, Chonburi
End User:	Laem Chabang Industry Co., Ltd.
Main Suppliers:	From Italy and Belgium
Cost:	US$ 342,000
Pay back period:	2.7 years

Project no. 4:	**Plywood in Indonesia**
Brief description:	The steam produced by the wood waste-fired boiler is used for the process as well as to run an existing turbo-generator with a net output of 3200 kW. The boiler replaces two old boilers, which are not able to provide sufficient steam for the turbine.
Location:	Palembang, South Sumatra
End User:	P.T. Kurnia Musi Plywood Industries
Main Supplier:	From Denmark
Cost:	US$ 1,600,000
Pay back period:	2.4 years

Project no. 5:	**Wood complex in Malaysia**
Brief description:	The 1.5 MW cogeneration plant (one boiler, one back pressure turbo-generator and one fully condensing turbine) supplies all the electricity needed for the complete factory (sawmill and moulding), as well as 4 tonnes of steam for the kiln drying operation.
Location:	Bentong, Pahang
End User:	IB Timber Industries Sdn. Bhd.
Main Suppliers:	From Belgium and Germany
Cost:	US$ 1,611,000
Pay back period:	3.5 years

Project no. 6:	**Wood complex in Malaysia**
Brief description:	The 1.65 MW wood waste-fired power plant consists of a boiler supplying steam to a fully condensing turbine. Power is being supplied to the sawmill, while part of the steam is used for kiln drying.
Location:	Sarikei, Sarawak
End User:	Homet Raya Sdn. Bhd.
Main Suppliers:	From Denmark and Germany
Cost:	US$ 1,994,000
Pay back period:	3.1 years

Project no. 7:	**Rubberwood complex in Thailand**
Brief description:	The 2.5 MW cogeneration plant consists of a boiler supplying steam to a 5-stage extraction/condensing turbo-generator. Part of the steam is to be used for kiln-drying operation (Project under implementation)
Location:	Surat Thani
End User:	TRT Parawood Co., Ltd.
Main Suppliers:	From Belgium and Germany
Cost:	US$ 2,187,000
Pay back period:	2.9 years

Project no. 8:	**Wood complex in Indonesia**
Brief description:	The 5.5 MW wood waste-fired power plant consists of a steam boiler and a fully condensing steam turbine. The electrical power output of the plant will be utilised by the wood processing plant within the complex while excess electricity will be sold to a neighbouring subsidiary. (Project under implementation)
Location:	Pekenbaru, Riau
End User:	PT Siak Raya Timber
Main Suppliers:	From Germany and UK
Cost:	US$ 4,488,000
Pay back period:	3.6 years

Project no. 9:	**MDF factory in Malaysia**
Brief description:	The 22 Gcal/h energy plant burns wood wastes to heat thermal oil up to 280 °C. The heated oil is then used for heating the continuous press, for generating 10 tonnes of steam/hr in a separate boiler and for preheating the primary combustion air. The flue gas from the combustion chamber is cleansed in the dust cyclones and then used for drying the fibres before manufacturing the board.
Location:	Kulim, Kedah
End User:	Kumpulan Guthrie Bhd.
Main Supplier:	from Denmark
Cost:	US$ 5,630,000
Pay back period:	3.5 years

Project no. 10:	**Wood complex in Malaysia**
Brief description:	The 10 MW wood waste-fired power plant supplies two-thirds of the existing power requirement of the wood complex, replacing existing diesel gensets.
Location:	Keningau, Sabah
End User:	Pembangunan Papan Lapis (S) Sdn. Bhd.
Main Suppliers:	From UK and Germany
Cost:	US$ 7,045,000
Pay back period:	3.1 years

5.4 CONCLUSIONS

More and more wood millers find it economically viable to satisfy their energy demand by using their wood wastes.

Moreover, current situations including governments' desires to promote 'green' or non-polluting technologies, the on-going threat to the security of supply of conventional fuels, and financial incapability of governments to provide added capacities for power generation, support governments' decisions to provide better conditions for private power using renewable energy technologies. All these factors should give cause for some optimism that biomass energy projects could take off within the next few years, particularly in the wood industry in ASEAN, and especially in Malaysia and Indonesia.

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6. THE GEF CLIMATE CHANGE OPERATIONAL PROGRAMS

by

Matthew S. Mendis
President, Alternative Energy Development, Inc.
8455 Colesville Road, Ste. 1225, Silver Spring, MD 20910, USA

The three GEF operational programs in the climate change focal area are:

1. Removal of barriers to energy conservation and energy efficiency;
2. promoting the adoption of renewable energy by removing barriers and reducing implementation costs; and
3. reducing the long-term costs of low GHG emitting energy technologies.

The emphasis of these programs is to remove barriers to the implementation of climate-friendly, commercially viable technologies; and to reduce the costs of prospective technologies to enhance their commercial viability. However, "enabling activities" receive emphasis during the initial GEF periods. These include:

- Preparation of national GHG inventories;
- identification of GHG mitigation options and CC adaptation options;
- preparation of National Action Plans to FCCC objectives; and
- preparation of the FCCC National Communication.

6.1 REMOVAL OF BARRIERS TO ENERGY CONSERVATION AND ENERGY EFFICIENCY

The primary objective of this first GEF operational program area is to:

- Remove existing barriers to the wide-scale application, implementation and dissemination of "least-economic-costs" commercially established, or newly developed, energy-efficient technologies;
- promote more efficient energy use where a reduction in GHG emissions would result;
- help ensure the sustainability of "win-win" projects by demonstrating cost-recovery and facilitating mainstream financial support; and
- facilitate the learning process for widespread applications of energy conservation and energy efficiency projects in developing countries.

Examples of energy efficiency applications where barriers need to be removed for wider implementation include:

- Energy efficiency in industry (variable speed motors, cogeneration, use of energy intensive materials, preventive maintenance, etc.);
- manufacture of more energy efficient equipment and appliances (refrigerators, industrial motors, automobiles);
- designing and building more energy efficient structures;

- efficient household cook-stoves;
- efficient irrigation pump-sets; and
- efficient electricity production and distribution.

The incremental costs are the costs of removing barriers to these "least-economic costs" energy-efficient technologies. Some universal barriers are given below, together with possible measures to overcome them.

Generic Barrier	**Possible Measures**
Lack of information	Appliance labelling, public information campaigns, information centres
Lack of trained personnel	Technical and energy management training programs
Price distortions	Price/policy reform
Regulatory biases or absence	Standards
High transaction costs	Market development and commercialisation; DSM programs and Energy Servicing Companies (ESCOs)
High initial capital costs, lack of access to credit	Innovative financing mechanisms
High user discount rates	ESCOs
Mismatch in the flow of investment costs and energy savings	Institutional matching of costs and benefits; ESCOs
Perception of risks	Information and demonstration

6.2 Promoting the Adoption of Renewable Energy by Removing Barriers and Reducing Implementation Costs

This second operational program is to remove barriers to the use of commercial or near commercial renewable energy technologies (RETs). It should reduce the high implementation and transaction costs due to low-volume or dispersed applications of RETs, such as:

- Solar photovoltaics (both on-grid and off-grid);
- combustion/cogeneration with agricultural/biomass residues;
- other biofuel technologies;
- methane-control technologies from urban and industrial waste disposal;
- wind power for electricity and water pumping;
- solar derived building heating, cooling and hot-water; and
- biogas digesters for lighting and water pumping.

Some generic and specific barriers that exist for the introduction of renewable energy technologies are given below.

Generic barriers

- Subsidised or average-costs prices
- Lack of information
- High transaction costs
- High front-end capital costs
- Lack of credit
- High user discount rate
- High uncertainty or risk about technology performance
- Institutional mismatch between energy costs and infrastructure costs
- Shortage of trained personnel

Specific Barriers

- Reluctance to accept unfamiliar technologies
- Low dispatch ability
- Simultaneous adaptations to energy end-use infrastructure
- Technical limits to utility integration of intermittent sources
- Competition for access to resources
- Urban siting and building restrictions or permitting risks
- Lack of grid access to remote sites
- Difficulty of fuel-price risk assessment
- Institutional structure of fuel-price risks
- Difficulty in quantifying environmental costs/benefits
- Technology prejudice and acceptance
- Low government priority or existing interests groups
- Existing infrastructure and market institutions

The GEF program aims to tackle these issues through:

- National, regional and local least-cost energy strategy planning;
- electric power utility regulation;
- RET information and service centres;
- renewable energy resource assessments;
- financing mechanisms and guarantee innovations;
- technology research and demonstrations; and involvement of local development organisations;
- establishment of renewable energy ESCOs;
- technical training and capacity building;
- joint ventures & public/private partnerships.

6.3 Reducing the long-term Costs of Low GHG Emitting Technologies

The objective of this third climate change operational program is designed to reduce the costs of prospective technologies that are technically sound, but have not yet become widespread least-cost alternatives.

The intent of this operational program is to promote the application of specified "back-stop" technologies so that through learning and economies of scale, the costs of manufacture and implementation will tend to become commercially competitive.
Technologies likely to fit these conditions include:

- Solar thermal power generation for high insolation regions;
- grid connected SPV for bulk power applications;
- advanced biomass power generation through gasification and gas turbines;

- advanced biomass to liquid fuel conversion technologies;
- fuel cells
- advanced/high-efficiency fossil fuel gasification and power generation technologies.

6.4 GLOBAL ENVIRONMENT FACILITY BIOMASS ENERGY PROJECTS

Below, some recent biomass power projects that have been supported by GEF are presented.

Project Title:	Biomass Power Commercial Demonstration *(Pilot Biomass Power Project)*
Country:	Brazil
GEF Inputs:	US $ 40.00 million
Cofinancing:	US $ 82.00 million
Total Costs:	US $ 122.00 million
GEF Agency:	World Bank
Executing Agencies:	Ministry of Science and Technology, and Companhia Hydroelectrica do Sao Fransisco
Project Description:	A follow-on project to the UNDP-GEF Pilot Phase project - *Biomass Integrated GasificationlGas Turbine.* The project, a 30 MW commercial scale co-generation demonstration project using biomass integrated gasification/gas turbine technology, is financed by a public-private consortium, and will utilise wood chip fuel from plantation forests.

Project Title:	Biomass Integrated Gasification/Gas Turbine Project
Country:	Brazil
GEF Inputs:	US $ 8.12 million *(GEF Pilot Phase)*
Total Costs:	US $ 8.12 million
GEF Agency:	UNDP
Executing Agency:	Ministry of Science and Technology
Project Description:	Assessment of commercial feasibility and environmental compatibility of a biomass integrated gasification/gas turbine demonstration project including engineering, economic, and financial issues. Plantation grown wood fuel will be utilised in the co-generation power project.

Project Title:	Sugar Bio-Energy Technology *(Sugar Energy Development Project)*
Country:	Mauritius
GEF Inputs:	US $ 3.30 million *(GEF Pilot Phase)*
Cofinancing:	US $ 51.80 million
Total Costs:	US $ 55.10 million
GEF Agency:	World Bank
Executing Agencies:	Central Electricity Board, Mauritius Sugar Authority, and Union St. Aubin Sugar Company
Project Description:	Technical assistance to the Mauritius Sugar Authority's Bagasse Energy Development Program for development of a program to utilise sugar cane waste for power generation. Development and testing of technologies for gathering, storing, and using sugar cane residues as fuel to increase power generation at existing sugar mills.

Project Title:	Development of Electric Energy from Sugarcane Biomass for Displacing Fossil Fuel Consumption
Country:	Cuba
GEF Inputs:	US $ 0.35 million *(PDF Block B Grant)*
Total Costs:	US $ 0.35 million
GEF Agency:	UNDP
Project Description:	Pre-feasibility/feasibility studies on opportunities for development, demonstration, and commercialisation of site-specific sugarcane biomass electricity generation technologies.

Project Title:	Carbon Emission Reduction through Biomass Energy for Rural India
Country:	India
GEF Inputs:	US $ 0.196 million *(PDF Block B Grant)*
Total Costs:	US $ 0.196 million
GEF Agency:	UNDP
Project Description:	To establish the commercial viability of various bio-energy options and their potential for widespread adoption at the village level in India. The adoption of the technologies will meet the energy needs of domestic, farm, and commercial sectors in rural India.

7. Financing Renewable Energy Projects, Constraints and Opportunities

by

Matthew S. Mendis
President, Alternative Energy Development, Inc.
8455 Colesville Road, Ste. 1225, Silver Spring, MD 20910, USA

7.1 Financing Renewable Energy Projects

The financing of renewable energy (RE) projects cannot be accomplished with one basic project finance strategy in the way that many large-scale conventional energy projects are often financed. RE projects vary considerably in scale, capacity, energy resource characteristics, points of sale for output, status of technology and a host of other factors. For example, a biomass cogeneration project may need to rely on several sources for fuel supply and possibly one or two principal points for its energy sales: an industry for its steam and electricity and, if necessary, an electricity distribution company for its power outputs. Alternately, a solar photovoltaics (SPV) home systems project has no need for a fuel supply contract but will need to sell its power output to individual homeowners or sell the entire SPV system to the homeowner. It is clear from these two cases, that very different financing strategies are needed to address a biomass cogeneration project as opposed to a SPV project. Similar differences can be identified for other types of RE projects such as wind power, hydropower, solar thermal power, ocean thermal energy conversion (OTEC), wave-power and tidal-power, solar hot water heaters and wind pumps. For financing and other purposes, RE projects should not be aggregated into a single category but must be assessed independently.

Table1 presents some key characteristics of RE technologies that are important when considering the financing of RE projects. Briefly, these characteristics include:

- Scale: The scale or capacity of an RE project is important as it will determine the level of financing that is needed. Many RE projects are small-scale and therefore difficult to cost-effectively finance as the ratio of project development costs to total project costs are much higher than conventional projects. In the case of some RE projects, the total capacity can be as low as the kilowatt (kW) range. In such cases, RE projects have to be aggregated into a single, larger scale megawatt (MW) range project before presentation for financing.

- Point of Sale: The point of sale for an RE project is an important factor as it will determine the risks and difficulties associated with guaranteeing the revenue generation of the project. For many RE projects, there can be a large number of points of sale that are widely dispersed as opposed to a single point of sale which is common for most conventional projects. When securing financing for a project, points of sale must be shown to be "financially sound" and capable of meeting their "power purchase agreements". When points of sale cannot be demonstrated to be financially sound, project financing is more difficult to secure.

- Technology Status: Many RE technologies are perceived to be either recently commercialised or are still considered to be experimental. This misconception translates into a perception of higher or unknown project risks, especially as it relates to engineering, procurement and construction (EPQ costs for the project, operation and maintenance (O&M) costs, performance reliability and project life. In some cases, like windpower or solar thermal power, RE technologies have only recently been commercially applied on a wider scale. As a result, reference EPC, O&M and other cost data are only now available for these projects. In other cases, such as OTEC, wave-power and tidal-power, RE technologies are still considered to be experimental as no commercial projects are presently in operation. Alternately, RE technologies such as biomass combustion/cogeneration, geothermal and hydropower are all considered to be mature, low risk and commercially ready technologies which have a reasonably established cost basis. RE projects based on mature and commercially proven technologies are much easier to finance than those utilising experimental technologies.

Table 7.1: RE Technology vs. Characteristics

Re Project Type	Scale	Point of Sale	Status of Technology	Fuel Supply
Biomass	L/M/S	G/IG	M/NC/E	K/P
Geothermal	L/M	G	M/NC	K
Hydropower	L/M/S/Mi	G/IG/NG	M	P/U
Windpower	M/S/Mi	G/IG/NG	M/NC	P/U
Solar Th.P.	L/M	G	NC/E	P/U
SPV	S/Mi	G/IG/NG	NC/E	P/U
OTEC	L	G	E	P
Wave-power	L/M	G	E	P/U
Tidal-power	L/M	G	E	P

Scale: L = Large > 20 MW/M = Medium 1 – 20MW/S = Small 100 kW – 1MW/Mi = Micro <100 kW
Sale: G = Grid connected/IG = Isolated grid/NG = Non-grid
Status: M = Mature/NC = Newly commercial/E = Experimental
Fuel Supply: K = Known/ P = Predictable/ U = Uncertain

- Fuel Supply: The assurance of fuel supply is an extremely important factor in conventional power projects. The "fuel supply contract" along with the other contracts (EPIC and O&M) are necessary to demonstrate a limited risk of cost overruns. Furthermore, the fuel supply contract is a necessary assurance that the project will have the fuel to generate power. Many RE projects rely on nature for the supply of their fuel (e.g., solar, wind, hydro and wave energy). In these cases, there are no fuel supply contracts and therefore no recourse when projects fail because of a lack of fuel (e.g., a drought, no wind or extended cloud cover). With no guarantees on fuel supply, there can be no guarantees for power sales and similarly no guarantees for stable revenue generation. Of course, assessments of average conditions can help estimate the average revenue generation potential of the RE project. However, repayment of project financing must take into account that, in the short-term, there could be considerable variation from the average expected conditions and therefore a resulting variation in the average expected revenue stream of such RE projects.

7.2 PRIMARY BARRIERS TO FINANCING RE PROJECTS

High Capital to O&M Cost Ratio

Renewable energy systems tend to have little or no fuel, operation and maintenance (O&M) costs but their initial capital costs tend to be much higher than conventional systems. As a result, RE projects have higher capital to O&M cost ratios than conventional energy projects. For example, a SPV or windpower project typically can have a capital to O&M cost ratio above 20 as compared to a ratio of 6 to 10 for conventional energy projects. The higher ratios are significant because they' indicate that RE projects carry a disproportionately heavy initial cost burden that must be financed and amortised over the life of the project. While it is possible that RE projects can have a lower net present value (NPV) of all costs when compared to conventional systems, their high capital costs result in a perception that renewable energy is "more expensive" than conventional energy. Additionally, the high capital costs of RE projects are a major barrier to project financing.

High Project Development to Investment Cost Ratio

In addition to the relatively high capital cost, the ratio of project development costs to project investment is also higher in RE projects than conventional energy 'projects. This is primarily due to the fact that RE projects are dispersed, small in scale and lack established infrastructure and data to assist in the project development process. Legal, regulatory and engineering transaction costs are also generally higher, more complex and do not benefit from the economies of scale common to large conventional projects.

Small Total Investment Requirements

In addition to the challenging cost ratios, RE projects are generally smaller in scale and therefore require smaller total investments (even if the capital cost to capacity ratio is higher). For example, biomass cogeneration, mini-hydropower and windpower projects typically run in the range of $ 10 million to $30 million. Solar PV, micro-hydropower and biogas projects generally are considerably smaller than $1 million. The result is that most commercial banks, utilities and established independent power producers (IPPs) are not interested in pursuing these smaller investments. A primary reason again is that the time and costs required to undertake the "due diligence" on these projects are high, as are the perceived risks.

Longer-Term Debt Financing

Due to high initial capital costs, the RE project developer must usually seek longer-term debt finance agreements to minimise the annual debt service burden on the project. The high initial costs, when amortised over a shorter period will increase the project's annual revenue requirements and, in many cases, can make RE projects financially unattractive in comparison to less capital intensive conventional projects.

Difficulty Guaranteeing Project Cash Flow

Guaranteeing a project's cash flow is one of the most important elements necessary for securing project financing. Project cash flow is guaranteed when most of the project's annual O&M costs and revenues are secured by enforceable contracts. For costs, this usually includes long-term fuel supply contracts and also possibly a plant operating contract. For revenues, this includes a solid power (or energy services) purchase agreement. Conventional energy projects are much more likely to be able to secure fuel supply contracts and power purchase agreements as they are usually dealing with one fuel supplier and one power purchaser. RE projects on the other hand may have to deal with several fuel suppliers (as in the case of biomass) or no fuel suppliers (as in the case of solar, wind, hydro, etc.). However, in the latter case where there is no fuel supplier, there is also no guarantee that "fuel" will be available when needed as many of these renewable fuels are subject to environmental conditions. Additionally, RE projects such as solar PV tend to have multiple "power purchasers" most of which are not in financial positions to provide enforceable long-term guarantees to purchase the output of the project. Without these guarantees, it is difficult for RE projects to secure the necessary financing.

Weak Basis for Non-Recourse Financing

Small, independent and newly established RE project developers often lack the institutional track record and financial inputs necessary to secure non-recourse project financing. Non-recourse project financing is generally difficult to obtain even for well established energy project developers. This is primarily because non-recourse project financing requires minimisation of project risks. Conventional energy project developers generally have established track records and are capable of easily meeting the larger equity inputs also needed with non-recourse project financing. Additionally, the valuation of RE project assets are not readily accepted by financial institutions because of the limited marketability of these assets as opposed to conventional energy systems.

Inaccurate Perception of Risk

Many RE technologies are newly commercial and are, subsequently, not widely known or adopted by project developers or investors. Proven and reliable information on RE systems is not readily available and accessible to potential investors. In addition, RE systems are perceived to be appropriate only in limited circumstances and suffer from a "flower power" stigma of being a technology only promoted by "environmental radicals". The reality is that many RE technologies have been commercially successful for a long-time and new RE technologies are rapidly making commercial inroads in the marketplace.

Higher Financial Cost for RF, Services

Many conventional energy systems enjoy built-in or hidden subsidies that provide them with an insurmountable financial edge. For example, the costs of the numerous environmental impacts caused by conventional (fossil) energy production and use are generally not reflected in the price of these fuels and are not recovered from the users of these fuels. As such, society bears these costs. Additionally, fossil fuels enjoy a number of direct subsidies from reduced transport tariffs to resource depletion allowances. In many countries where fossil fuels are imported, they are exempt from import duties. Alternately, RE systems seldom enjoy direct or indirect subsidies as a result of their environmental benefits. Furthermore, many RE systems, if imported, are subjected to import duties and taxes. The net result is that RE systems face higher financial costs when compared to conventional energy systems.

Weak Project Developers

RE projects tend to be developed by smaller entities with weak financial positions. Due to the structural barriers outlined above, larger investors often do not consider financing RE projects. Smaller entities with weaker financial positions are not able to leverage the financial resources and as a result are unable to attract equity investors or secure debt financing.

7.3 INNOVATIVE STRATEGIES FOR RE PROJECT FINANCE

The financial barriers faced by small, medium and large scale RE projects vary considerably. Therefore, the strategies needed to effectively overcome them vary according to project scale. In general, **large and medium scale** RE projects need to:

- Operate within the same financing rules applied to conventional energy projects; and
- seek assistance to level the financial playing field.

Small-scale RE projects need to consider the following:

- Develop innovative financial mechanisms to cascade affordable financing to the end-users; and
- seek assistance for institutional, infrastructure and capacity building.

The sections below describe specific strategies for the primary RE project systems:

- Small Scale / Non-Grid,
- Medium Scale / Isolated Grid, and
- Large Scale / Grid Connected.

Small-scale / Non-Grid Systems

Small-scale/non-grid connected systems consist primarily of solar photovoltaic home systems, small windpower systems and hybrid solar/wind/diesel systems that have no associated distribution network. To date, most of these systems are sold directly to the end-user. The result is that only end-users that are relatively well off financially are able to afford the outright purchase of these systems. The primary financial barrier for these systems is the inability of most end-users to afford the up-front purchase of these systems. A number of innovative financing strategies are emerging to help overcome this primary financial barrier. These include:

- **Finance Leasing Programs**: This approach allows the end user to lease rather than purchase the RE systems. In this way, financing can be aggregated to more central and larger components that are more easily appraised and managed. Additionally, tax benefits from depreciation of equipment could accrue to the leasing company. At the same-time, end-users are relieved of the burden of up-front purchasing of the RE systems. The principal drawback to leasing programs are the additional costs assessed by leasing companies which result in higher financial costs to the end-user. This model is being tested by the Indian Renewable Energy Development Agency (IREDA) in the implementation of the SPV component of the Global Environment Facility (GEF) supported Indian Renewable Resources Project.

- **Finance Service Providers**: This approach encourages the creation of renewable energy "micro-utilities" which essentially sell energy services (such as electricity, or lighting, or refrigeration, etc.) for a price rather than hardware. Again, financing can be aggregated to the level of the "service provider" rather than the end-user and can be more easily appraised and managed. An additional benefit of this approach is that the end-user is relieved of the operation and maintenance responsibilities of the RE systems, which remain with the energy service provider. The end-user is required to make periodic payments based on the level of energy services received. This is similar to the conventional utility approach for providing energy services. This approach has been successfully demonstrated in the Dominican Republic and elsewhere and is now being implemented in a 10,000 solar home system program by a rural electric cooperative in Bolivia.

- **Mortgage the End-User**: This approach essentially allows homeowners to incorporate the costs of installing RE systems into the overall costs of their homes through mortgage financing. This recourse based financing allows the financing of RE systems to be aggregated and incorporated into a larger financing program. The primary drawback of this approach is that it excludes low-income and non-homeowner segments of the population. This approach is being tested out in a rural housing/electrification program in the Republic of South Africa.

Medium-scale / Isolated-Grid Systems

Medium-scale/isolated grid systems consist primarily of mini- and small hydropower, biomass gasifiers and cogeneration systems, wind/diesel/solar hybrids and other medium-scale RE systems in the range of 1-20 MW or less. The principal financial barriers facing these projects are that they are: still relatively small; isolated and therefore higher risk; more difficult to develop and implement; and more difficult to appraise. The positive aspect is that most of these projects are proposed by national or state utility companies, rural electric cooperatives or private sector companies that can be financially appraised and also held financially responsible. A number of medium scale/isolated grid connected RE projects are presently being implemented. The most notable is the World Bank financed "Renewable Energy Small Power Project in Indonesia - a component of which addresses medium-scale/isolated grid systems.

Large-Scale / Grid-Connected Systems

Large-scale energy projects are generally financed on a project by project basis where the project is the target of financing and the project developers, along with the financial institutions become partners in the development of the project. This is equally true for large-scale conventional energy projects and large-scale RE projects. Some of the largest power projects in the world are renewable energy hydropower projects. The principal barriers for financing of large-scale RE projects are, in many cases, the size of the investments required by these projects. In addition, for the newly emerging large-scale RE technologies such as solar thermal power, advanced biomass gasification, ocean thermal energy and others, the undefined risks associated with these projects in combination with the size of the investments needed make financing these projects particularly challenging. Financing of large-scale projects is done with a number of conventional and innovative instruments as the financial requirements and conditions dictate. In all cases, these projects will require backing of various investment and risk insurance, all of which add to the overall financing costs of the project.

7.4 Evolving Sources for RE Project Finance

Financial structuring (or financial engineering) is the means of allocating the risks and returns of a project among the various project participants. The basic principle is that the expected returns to a given investor should be commensurate with the risks the investor is willing to take. Risk averse investors are provided with low but more assured returns while risk taking investors are provided with the opportunity to earn higher but less assured returns. While a wide variety of instruments can be used to finance RE projects, these three categories characterize the majority of funding sources:

- **Equity** - High risk financing that expects high returns. An equity investment can be made in a project or in a company carrying out the project. Equity investors maintain the right to get involved in the decision making process of the project or company in order to protect their investment.

- **Debt** - Medium risk with medium expected returns. In contrast to equity investors, lenders who provide debt financing to a project do not own shares in the project. They provide capital for the purpose of earning interest. Because lenders must be repaid before distributions can be made to shareholders, they bear less risk. For this reason, potential returns to lenders are limited to risk-adjusted market interest rates.

- **Grant** - No expected returns. Governmental and international organizations offer grants to promote environmental and development policies. RE projects are often eligible for these funds.

Sources of Equity Financing

Sources of equity financing include project developers, venture capitalists, equity fund investors, equipment suppliers, multilateral development banks, and institutional and individual investors.

- **Project Developers** - A project developer initiates the project idea and usually invests the "up-front capital" that is necessary to develop a project from a concept to an actual project. The project developer usually leverages up-front capital inputs for a larger equity stake in the project.

- **Venture Capitalists** - The venture capitalist specialises in investing in new companies. Because venture capitalists join companies in their earliest and riskiest stages, they expect to earn unusually high returns.

- **Equity Fund Investors** - Equity funds provide investment capital in a project in return for a share of the equity of the project. The expected return on equity is generally two or more times greater than return on debt. In return for the higher expected yield, equity investors bear the greatest risks and have rights to distributions from the project only after all other financial and tax obligations are met.

- **Equipment Suppliers** - Reliable, experienced RE equipment supply companies often not only construct, install and operate RE systems but also offer equipment financing. In addition to turnkey system delivery and operation, the RE technology vendor may offer favourable financing terms.

- **Regional Development Banks** - These are regional development banks like the Asian Development Bank (ADB), Inter-American Development Bank (IDB) and International Finance Corporation (IFC). These institutions not only provide debt financing, but can also provide minority equity financing.

- **Institutional and Individual Investors** - These are organisations or individuals who are willing to invest in projects on an equity basis in the hopes of earning high returns on their investments.

Sources of Debt Financing

A principal source of debt financing is international and national commercial banks. Other sources of debt financing include multilateral development banks (MDBs) and IFC, international and national commercial banks, debt/equity investment funds, equipment suppliers, and private investors. These banks can play a major role by syndicating the debt financing of a major project amongst several banks so as to minimise their own risk exposure on a project. A description of the characteristics of most of these institutions was presented above.

Subordinated debt is another form of financing that falls between debt and equity. Principally, subordinated debt is provided by a "friendly investor" or project partner and is subordinated to other primary debt in case of project default. In return, subordinated debt usually commands a higher interest rate than normal debt to reflect the higher risks associated with this investment.

Sources of Grant Financing

Sources of grant financing include the World Bank's Global Environment Facility, international and bilateral agencies, foundations, and national and local agencies.

- **Global Environment Facility (GEF)** - The GEF has become an important source of grant financing especially for RE projects. One of the GEF's mandates is to support projects that help reduce greenhouse gas (GHG) emissions. As a result, many RE projects are targeted by the GEF for support to help ultimately improve the competitiveness of these projects in comparison to conventional fossil energy projects. The GEF is the interim financial mechanism of the United Nations Framework Convention on Climate Change (UNFCCC).

- **International and Bilateral Development Agencies** - Many international and bilateral development agencies such as the United Nations Development Programme (UNDP), the Netherlands Ministry of Development Cooperation (DGIS), Danish Development Assistance Agency (DANIDA); etc., can and do provide grant assistance for RE projects.

- **Foundations** - A number of philanthropic agencies such as the Ford Foundation and the Rockefeller Foundation have, on occasion, provided grant funds for RE projects to help advance these projects where they have demonstrated environmental and social benefits.

- **National and Local Agencies** - In a number of countries, support for RE projects is also available from national and local agencies. A specific example is India where there is a Federal Ministry for Non-Conventional Energy Sources as well as State Renewable Energy Development Agencies.

Evolving RE Project Finance Supporters

There are a number of multilateral, bilateral and private sector programs that are available or emerging that will help support RE projects. Specifically, the multilateral development banks (MDBs) are aware of and are taking action to direct their energy sector investments for more sustainable development. For example, the World Bank has established the Asia Alternative Energy Unit (ASTAE) which is chartered to develop only RE and energy efficiency projects.

Since its inception, ASTAE has helped the World Bank lend over US$500 million for RE projects in the Asia region. The International Finance Corporation (IFC) has recently launched a US$ 100 million Renewable Energy and Energy Efficiency Fund (REEF) which is designed to invest in private sector projects. The Asian Development Bank recently approved a US$100 million loan to the Indian Renewable Energy Development Agency (IREDA) for biomass cogeneration projects in India. Several other examples exist that clearly demonstrate that the MDBs are increasing their level of financial support for RE projects.

Bilateral development institutions (BDIs) have traditionally supported RE projects in developing countries because of the social and environmental benefits of these projects. BDIs have recently stepped up their support for RE projects especially since many of these projects have global environmental benefits and can be supported under the UNFCCC mandate for "Activities Jointly Implemented" (AIJ). A number of bilaterals such as the USA, the Netherlands, Canada, Japan, Norway and Germany have very active AIJ programs that include support for RE projects.

A number of "green banks" or "green funds" are also emerging which target support for RE projects. For example, the Triodos Bank in the Netherlands is specifically chartered to support only "green projects". The Global Environment Fund is a mutual fund that is designed to invest in companies or ventures that are beneficial for the global environment. Additionally, some national and private sector banks in developing countries have also established programs to specifically address RE projects. These include IREDA in India, Development Bank of the Philippines (DBP) - Window 111, and Grameen Shakti of the Grameen Bank in Bangladesh.

The types of support available for RE project development from multilateral development agencies and private sector investors is presented in Tables 7.2 and 7.3 below.

Table 7.2: Multilateral development agency support for RE projects

Type of Service	World Bank	IFC	MIGA	RDBS	UNDP
Feasibility studies / project devt. assistance	X	X		X	X
Equity investment		X		X	
Debt Financing	X	X		X	
Investment Co-Financing	X	X		X	
Loan Guarantees			X		
Lease Guarantees			X		
Political Risk Insurance			X		
Technical Assistance and Training	X	X		X	X

Table 7.3: Private sector investor support for RE projects

Type of Service	Comm. Banks	Venture Capitalists	Institutional Investors	Individual Investors	Equipment Suppliers
Equity Investments		X	X	X	X
Debt Investments	X		X	X	
Debt/Equity Swaps	X				
Project Co-Financing	X				
Equipment Financing	X				X

7.5 NEED FOR INNOVATIVE FINANCING MECHANISMS

RE projects must utilise innovative financing strategies when the project cannot be easily financed under "normal" project financing terms. The following is a list of conditions that indicate a need for innovative financing mechanisms:

- Inability to secure the project's net revenue stream;
- highly inconsistent and unpredictable project revenue stream,
- multiple and financially unsecured purchasers of the project services;
- small- or micro-scale RE technology project base;
- "newly commercial" or experimental RE technology;
- high capital to operating cost ratio;
- low initial demand for the technology which results in a high initial costs for the technology;
- high implementing costs due to lack of supporting infrastructure;
- incremental costs resulting from financially unrecognised environmental benefits in comparison to conventional options; and
- financially not competitive with the conventional option.

Emerging Innovative Financing Mechanisms

A number of innovative financing mechanisms are emerging to help meet the growing demand for the financing of RE projects. These innovative financing mechanisms are designed to overcome the principal barriers that RE projects face. A brief description of some of the emerging RE financing mechanisms is presented below:

- **RESCOs / Micro-utilities / Cooperatives** - Renewable Energy Service Companies or RESCOs along with concepts for micro-utilities or cooperatives are all designed to overcome two key barriers that small-scale RE projects face: high initial capital costs for end-users and aggregation to reach a critical mass that is attractive for financing. The RESCO concept is most suitable for small-scale RE systems like SPV home systems. Rather than selling the SPV home system to homeowners, the RESCO sells the service (e.g., lighting) that is produced by the SPV system and in turn collects a monthly fee. This is very similar to what utilities do with electricity from their power plant. In this approach, the RESCO is responsible for owning, operating and maintaining the SPV system while the consumer is only responsible for paying for the service. The RESCO, in turn, can aggregate a large number of consumers into a single project and seek financing for the project rather than for each individual SPV system. The consumer overcomes the high cost barrier by only having to make small monthly payments.

- **RE leasing companies** - The RE leasing company concept is very similar to the RESCO approach with one key exception: the leasing companies are usually not responsible for maintaining and operating the RE systems. 'The leasing company approach helps overcome the high first cost barrier as well as helps aggregate and target project financing to a few business oriented entities. This latter point is important for banks and investors. In addition, the leasing company approach provides certain tax benefits for a project that can help the financial attractiveness of the project.

- **RE vendor credits** - RE vendors are now recognizing what automobile and appliance vendors have known for a long time: providing credit to customers can help boost sales. RE vendors of both small and larger-scale RE systems are now extending supplier credits to RE consumers and projects to help close financing gaps and in the process to help secure their sales. RE vendor credits can help overcome some of the perceived technology risks associated with many RE technologies. Consumers and project financiers are more likely to reduce their perception of technology risks if the equipment vendors are willing to financially back their products.

- **Targeted project credits** - Multilateral development banks have recently used the approach of "targeted project credits" to supply financing through national and local banks for RE projects. In many cases, national and local banks may not be familiar or willing to enter new markets or have limited financial resources and therefore service their traditional clients first. By targeting credits for RE projects, the MDBs have encouraged the national and local banks to explore these new and emerging markets. This approach has helped the national and local banks develop the knowledge and expertise for assessing similar projects in the future, thereby expanding their market base to include RE project financing. Targeted project credits help overcome the "no track record" financial barrier often faced by new and emerging technologies.

- **Direct consumer credits** - Many low-income rural consumers do not have the ability to establish credit with which to purchase high capital cost RE systems. In these cases, the market potential for RE systems is severely limited. Attaching a consumer credit program to the RE project will help extend the reach of the RE systems to a larger percentage of the market, particularly those financially viable consumers who have no established credit or cash to purchase the RE systems outright.

- **Acceptance of equipment as collateral by suppliers** - Many commercial banks are unwilling to lend to RE projects because they do not consider the RE equipment as acceptable collateral against their loans. The primary reason is that they are unsure of the secondary market for the RE equipment. To overcome this barrier, RE equipment suppliers are beginning to indicate their willingness to repurchase their equipment at a prescribed discount in the event the project fails financially. In these cases, commercial banks are more willing to accept RE equipment as collateral when financing RE projects.

- **Support for project preparation/development** - One of the principal barriers identified for RE projects is the high project development costs to investment ratio. In recognition of this fact, a number of multilateral, bilateral and national sources have established funds or programs to help RE project developers overcome these high development costs. These are specifically technical assistance grants that, in some cases, are repayable when the project reaches financial closure. The eligibility and conditions for project preparation assistance vary considerably according to the objectives of the supplier of the funds.

- **Global Environment Facility (GEF)** - A major part of the GEF's climate change program is to help remove the financial, policy, institutional and technical barriers for projects that are beneficial for the global environment. RE technologies are extremely crucial for the eventual mitigation of greenhouse gases and are therefore a major target of assistance for the GEF. Specifically, the GEF resources are used to remove barriers to the commercialisation of RE technologies. As such, the GEF is a key resource for supporting RE projects that will help reduce or ultimately remove barriers to commercialisation.

- **Activities Implemented Jointly (AIJ)** - An emerging opportunity for extensive support of RE projects is the concept of "activities implemented jointly" to offset greenhouse gas emissions. This is the case where two countries work jointly to find least-cost options for reducing their combined GHG emissions to jointly meet a combined target of GHG emission reductions. This is a concept that derives from the UNFCCC and is presently being tested in a pilot phase. Under AIJ, RE projects that displace GHG emissions in one country (say a developing country) can receive financial support from the other partner country (say a developed country) if the resulting GHG emission credits are transferred to the partner country. In essence, AIJ allows for the trading of GHG emission credits. This concept helps overcome the barrier of not compensating RE projects for their global-environmental benefits. The concept can potentially have a very significant impact on the commercial acceptance of RE projects.

7.6 CONCLUSIONS

The financing of RE projects requires recognising that all RE projects do not have the same characteristics. Financing strategies for RE projects must be tailored to overcome the specific barriers faced by small, medium and large scale RE projects. As demonstrated in the previous sections, several sources for credit and finance exist to support good RE projects. Additional sources of RE project finance are emerging as a result of the recognition of the environmental, social and economic benefits associated with RE systems. Innovative financing mechanisms are useful tools for minimising transaction costs and risks normally associated with RE projects. However, one financing strategy will not fit all RE projects. If RE projects are to be more widely implemented, a broad range of financial instruments must be developed and utilised to help meet the various barriers that presently confront FE projects.

8. DENDROPOWER AND WOOD FUEL PRODUCTION SYSTEMS: ECONOMIC ANALYSIS AND IMPLEMENTATION STRATEGIES[1]

by

P.R. Shukla, Professor
Indian Institute of Management (IIM)
Vastrapur, Ahmedabad 380 015

8.1 INTRODUCTION

Biomass has been used as a fuel for millennia. Wood fuels are the most prominent biomass energy sources. Until the middle of the 19th century, biomass use dominated the global energy consumption. With the rapid increase in fossil fuel use, the share of biomass in total energy consumption declined steadily from substitution by fossil fuels - first by coal and then later by refined oil and gas. Despite a declining trend, biomass still contributes 14% of the global energy and 38% of the energy in developing countries (Woods and Hall, 1994). Globally, the energy content of biomass residues in agriculture based industries annually is estimated at 56 exajoules, nearly a quarter of the global primary energy use of 230 exajoules (WEC, 1994). The extent of biomass use in different continents is shown in Table 8.1.

Table 8.1: Global Biomass Energy Consumption and Growth

	Energy Consumption		Per Capita Energy Consumption	
	Petajoules 1993	% change since 1973	Mega Joules 1993	% change since 1973
Africa	4,815	76	6,991	0
Europe	552	-14	761	-21
North /Central America	1,825	106	4,130	53
South America	2,748	26	8,888	-17
Asia	9,009	47	2,690	1
Oceania	185	16	6,693	-14
World	19,926	47	3,594	4

Source: WRI (1996)

The importance of biomass energy use in some Asian countries, which are members of the Regional Wood Energy Development Programme (RWEDP) of the FAO, is evident from Table 8.2. Biomass share in energy in Malaysia and China declined in the past two decades following the massive substitution of traditional biomass by commercial fuels. In other Asian nations, the biomass share still remains substantial. In mountainous nations like Nepal and Bhutan as well as in wood rich countries like Cambodia and Laos, biomass contributes over 80% of the primary energy. Biomass contributes over 40 percent to energy consumption in all nations except Southern Africa where it contributes 14 percent. In Malawi and Mozambique, it contributes as much as 93 percent (Eleri, 1996).

[1] ***Study prepared for RWEDP, 1997***

Most biomass use in developing countries is in the traditional sectors. Due to population increases and shortages of commercial fuels, the urban areas in developing countries have also experienced rising fuel wood demands. In some places, excessive fuel wood extraction has contributed to land degradation (Ramana et al., 1997). Following rising incomes in developing nations, traditional biomass has been substituted by more efficient and cleaner fuels on the fuel ladder, thereby causing a steady decline in its share in the primary energy consumption. The modern biomass technologies and rising social and environmental problems associated with the conventional energy forms has now created conditions that may alter this trend.

Table 8.2: Shares of wood and biomass in the total energy consumption

Country	Year	Share of biomass (%)	Share of wood (%)	Biomass share in domestic energy (%)
Bangladesh	1992	73	13	89
Bhutan	1991	82		
Cambodia	1994	86	83	98
China	1992	10		25
India	1992	33		78
Indonesia	1992	39	31	73
Laos	1991	88		
Malaysia	1992	7	2	15
Maldives	1994			84
Myanmar	1991	74		
Nepal	1992-1993	92	68	97
Pakistan	1993-1994	47	27	83
Philippines	1992	44	26	66
Sri Lanka	1990	77		93
Thailand	1994	26	9	65
Vietnam	1991	50		

Source: FAO (1997)

8.2 RENEWED INTEREST IN BIOMASS ENERGY TECHNOLOGIES

Two decades ago, the oil crisis made the governments of oil poor countries look for energy alternatives. Brazil responded with the ethanol programme and the Philippines promoted the dendrothermal power (Box 1) programme. In recent years, the interest in biomass technologies has revived due to a multitude of factors, such as: i) improvement in biomass production systems, ii) advances in biomass based energy conversion technologies, and iii) rising awareness of the social and environmental shortcomings of conventional energy forms. For the past two decades, growing concerns about global climate change (Shukla, 1996), acid rain, the deterioration of urban air quality caused by fossil fuels, social and environmental hazards from large hydro dams and accidents at nuclear power plant sites have led to a search for alternative energy sources. Improved techno-economic performance of biomass based energy systems;

Box 1. Dendrothermal Power

Dendrothermal Power is an integrated wood (or bio-fuel) based electric power generation system. The dendrothermal power system includes energy plantation, transportation of wood, generation of electricity using the wood as a feedstock through a steam-electric generator route and a system for transmission and distribution of electricity to the consumers. The term dendropower is often synonymously used for any biomass based electricity power generation system.

combined with their inherent advantages such as renewability of biomass resources, decentralised supply, employment generation potential, and environmental soundnes, has made biomass a competitive and sustainable energy resource. In the developing countries, the shortage of centralised energy supply and lack of electrification in rural areas have contributed to the rising interest in biomass energy as a decentralised energy option.

In developing countries, biomass use is substantial but remains confined to traditional and rural sectors where commercial energy forms do not compete due to the absence of an energy market. The efficiency of biomass use in these applications is very low. In commercial applications, the improved characteristics of biomass systems made them competitive vis-à-vis conventional energy forms. Policy makers in developing countries have perceived additional benefits of commercial biomass, such as - i) energy supply to rural areas where commercial fuels and a centralised electric grid have not reached, ii) employment generation in energy plantations as well as rural industries, iii) saving of foreign exchange spent on oil imports (Shukla, 1997a) and, iv) restoration of deforested and degraded lands by energy plantations (Reddy et al, 1997). Another argument in favour of biomass energy is that it may help to tackle the problem of surplus agriculture production in the industrialised countries (Patterson, 1994). These advantages, together with more efficient electricity generation technology options which can accept a wider range of fuels, have led to the re-emergence of biomass as a competitive and sustainable energy option for the future.

8.3 TECHNOLOGICAL ADVANCEMENTS

Technological progress in biomass energy is derived from two distinct spheres - biomass energy production practices and energy conversion technologies. Biomass energy crops are intensively managed like agriculture crops. Energy plantations cover over 100 million hectares of land, most of which is in the tropical region and has been established since early last decade (FAO, 1992). A rich experience of managing commercial energy plantations in varied climatic conditions has emerged during the last two decades (Hall et al 1993). Improvements in soil preparation, planting, cultivation methods, species matching, bio-genetics and pest, disease and fire control have led to enhanced yields. Improvements in harvesting and post-harvesting technologies have also contributed to a reduction in the production cost of biomass energy.

Technological advancements in biomass energy conversion come from three sources - i) enhanced efficiency of biomass energy conversion technologies, ii) improved fuel processing technologies (such as for producing ethanol from sugar and maize) or fuel preparation technologies (such as briquetting), and iii) improved efficiency of energy end-use technologies. The capability of modern technologies to accept a variety of biomass feedstocks, such as in biogas plants, gasifiers and fluidized bed technologies, has enhanced the supply of bio-fuels. Besides, the technology penetration is enhanced by small scale applications with proven technologies such as gasifiers using rice husks that can economically operate at a capacity of 1 MW for thermal application and a capacity of 100-200 kW for electricity generation. Co-firing with other fuels has also opened up additional applications for biomass. The co-firing of producer gas (the product of biomass gasification) in a coal based power plant and gas turbine in the Netherlands has yielded efficiencies of 36 and 42 percent, respectively (BTG, 1994).

Rapid improvements in biomass power technologies are aided by the transfer of learning from conventional electricity generation technologies (Box 2). For instance, experience with coal integrated gasifier/combined cycle (CIG/CC) technology can be readily transferred to the biomass integrated gasifier/combined cycle (BIG/CC) technology. BIG/CC technology, although not as advanced as CIG/CC technology, has the potential to be competitive (Reddy et al, 1997; Johansson et al, 1996) since biomass as a feedstock is more promising than coal for gasification due to its low sulphur content and less reactive character. The biomass fuels are suitable for the highly efficient power generation cycles based on gasification and pyrolysis processes. The steady increase in the size of biomass technologies has contributed to declining fixed unit costs.

For electricity generation, direct combustion and gasification are the two most competitive technologies. Typical plant sizes range from 0.1 to 50 MW. Co-generation applications with combustion technology are highly efficient and economical. The efficiency of a combustion plant can be enhanced by fluidized bed combustion (FBC). Besides, FBC technologies are more flexible and can accept different fuel types and characteristics. Gasifiers first convert solid biomass into gaseous fuels which can then be used through a steam cycle or directly through a gas turbine/engine. Gas turbines are commercially available in sizes ranging from 20 to 50 MW. It is possible to reach an electricity generation efficiency of 40 percent with this technology. Technology development indicates that a 40 MW combined cycle gasification plant with an efficiency of 42 percent will be available soon at a capital cost of 1.6 to 1.7 million US dollars having a generation cost of 4 cents/ kWh (Frisch, 1993).

Box 2. Biomass Based Advanced Gasification Technologies for Power Generation

Production of electricity or the cogeneration of electricity and heat using gasified biomass with advanced conversion technologies is a strategy for modernising biomass. Advanced gasification technologies for biomass, adapted from coal gasification technologies, integrate the biomass gasifier with a gas turbine and offer high efficiency and low unit capital cost at modest scales as required for bioenergy systems. Electricity produced with biomass-integrated gasifier/ gas turbine (BIG/GT) technology offers major environmental benefits and is competitive with fossil and nuclear power under a wide range of circumstances. Initial applications of BIG/GT are developed with cheaper biomass residues from, for example, sugarcane, pulp and paper, and wood processing industries. Improvements in jet engine and biomass gasification technologies are expected to lead to the improved performance of BIG/GT systems over the next couple of decades.

Sources: Williams and Larson, 1993a; Johansson et al., 1996; Reddy et al., 1997.

8.4 TRANSITION FROM TRADITIONAL TO MODERN BIOMASS ENERGY

Biomass energy enjoys a significant share in energy consumption in developing nations. Most biomass here is consumed by rural households for domestic energy needs, traditional artisan industries and some small industries and service sector establishments. Since energy markets barely exist in rural areas, biomass fuels are not traded nor do they compete with commercial energy sources. Most biomass is home-grown or collected for own use by family labour. Where cheap or free labour is abundantly available, such as in rural areas of developing countries, the biomass acquires no market value so long as it is not scarce. In absence of an energy market, the traditional biomass fails to acquire exchange value. Biomass fuels get used very inefficiently in traditional applications. The incomplete combustion of biomass releases pollutants like carbon monoxide, methane, nitrogen oxides, benzene, formaldehyde, benzo(a)pyrene, aromatics and respirable particulate matter. These pollutants cause considerable damage to health, especially the health of women and children who are exposed to indoor pollution for long periods (Smith, 1987; Smith, 1993, Patel and Raiyani, 1997).

In traditional and rural sectors, the absence of a market acts as the vital barrier to penetration of efficient and clean technologies. Although widely prevalent, traditional biomass use survives as a historical relic and will continue to do so till development processes transforms the traditional economies into modern industrial economies. The renewed interest in biomass energy is solely due to its increasing commercial potential in a competitive market where social and environmental externalities of all competing fuels are internalised. The future of biomass is therefore along the commercial route. The policies to internalise the externalities of competing fuels will play a vital role in the future penetration trajectory of biomass energy. The modern technology and markets are set to transform biomass from an inefficient and unclean traditional fuel to an efficient and clean fuel that is produced and consumed through modern technologies and competes in a market.

8.5 MODERN USE OF BIOMASS ENERGY

The chief distinguishing feature of modern biomass energy, compared to the traditional biomass energy, is its competitive character. The modern biomass competes on the energy markets where energy consumers make their choices. The competitive dynamics are transforming the profile of biomass production and energy conversion technologies. Modern biomass technologies are now achieving energy efficiency, size and operating performance which are comparable to technologies using conventional fuels (Williams and Larson, 1993). Aided by policy thrust and increasing competitiveness, modern biomass technologies are penetrating many industrialised and developing nations in niche applications as well as in directly competitive applications.

8.6 MODERN BIOMASS ENERGY IN INDUSTRIALISED COUNTRIES

In some industrialised nations, biomass has already emerged as a competitive energy source. Some industrialised countries, like Sweden, have decided to phase out nuclear power plants and reduce fossil fuel energies in the next century. These nations have plans to dramatically increase the use of biomass energy. Sweden obtain 17% of their energy from biomass (Hillring, 1997). Some other industrialised nations where biomass contributes a significant share of energy are Finland (19%), Australia (13%), Denmark (7%), USA (4%) and Canada (4%) (Moreira et al, 1997) . The penetration of biomass energy technologies in the countries with economies in transition is marginal. In Poland, 30 million litres of ethanol was used to blend with 21 PJ of gasoline or 12 percent of total gasoline sales in 1994 (IEA, 1995).

8.7 MODERN BIOMASS ENERGY IN WESTERN EUROPE

In Austria, the biomass share increased from about below 3% to about 10% during the 1980s (Woods and Hall, 1994). Promoted by the supply and demand side incentives and regulations, biomass energy has penetrated district heating systems producing 100 PJ energy, equivalent to 10 percent of the total energy consumption. The use of biomass energy in Austria is expected to double by the year 2015, requiring an additional investment of 600 Million ECU (European Currency Unit) and creating up to 15000 new jobs (EC, 1995). In Denmark, biomass energy has received strong government support. In June 1993, the Danish Parliament decided to expand biomass power generation to 1.2 million tons of straw and 0.2 million tons of wood by the year 2000 (Nielson, 1995). Besides, since the mid-1980s, several centralised as well as single farm biogas plants with capacities of 1500 m^3 and used for combined heat and power generation have been established in Denmark. In UK, the renewable energy received a boost with the introduction of the Non-Fossil Fuel Obligation (NFFO), whereby minimum amounts of non-fossil fuel sources for electricity generation can be made mandatory by the government (Mitchell, 1995).

In Sweden, biomass energy is used in a variety of applications (Olerup, 1994; Hillring 1997) - heating in households, district heating and electricity generation. A short rotation willow plantation is grown for bio-energy in over 14000 hectares of land. Under the policy of balancing externalities, Sweden's 205 MW district heating biomass plant at Vaxjo has proved to be competitive (Lofstedt, 1996). The use of Circulating Fluidized Bed (CFB) Gasification technology has been reported in Sweden, Finland and Italy (IPCC, 1996a; AED, 1996). The applications range from a 2 MW pilot plant to larger plants of up to 40 MW.

The UK programme target is 1,500 MW of new renewable electricity capacity by the year 2000 (Barker, 1997). Combined heat and power biomass projects are included in the NFFO, which works by asking for bids from prospective electricity producers. Next to wind energy, which has grown rapidly under NFFO, biomass has been a close second favourite (Fulford, 1997). An important area where biomass energy application has attracted attention is the anaerobic fermentation of urban sewage to produce biogas. Under NFFO, 33 MW were contracted for generating electricity using sewage gas. Large scale incineration systems for burning municipal solid wastes are the largest biomass source in UK with 554 MW contracted under NFFO (Fulford, 1997).

8.8 MODERN BIOMASS ENERGY IN NORTH AMERICA

In the U.S.A, 7,000 MW of biomass power capacity was installed. The United States Department of Energy (USDOE) together with the private sector plans to double the biomass conversion efficiency to make biomass energy products competitive. The USDOE estimates that biomass power capacity in the U.S.A will reach between 22,000 MW to 50,000 MW adding 283,000 jobs) by the year 2010 (USDOE, 1993). Some other estimates are less optimistic, but still expect the biomass capacity in the USA to reach 13,000 MW with the addition of 170,000 jobs by 2010 (Klass, 1995). Next to Brazil, the USA is the world's second largest producer of ethanol with an annual capacity of 5.3 billion litres in 1994. The ethanol is produced in 21 states, contributes 10 percent of liquid fuel sales and is used in 100 million cars (GEC, 1995). The Canadian biomass programme has two decades of history. Biomass supplies 4.4 percent of primary energy and is used in diverse applications covering heating in 2.1 million homes and 550 industrial units such as paper and pulp mills and 40 cogeneration plants with 1,000 MW capacity (Klass, 1995).

8.9 MODERN BIOMASS ENERGY IN DEVELOPING COUNTRIES

Modern biomass energy technologies have penetrated numerous developing nations. Brazil leapfrogged the developed countries in large scale commercial use of ethanol produced from sugarcane. In many developing nations, the unavailability of centralised electricity transmission and distribution networks has created niches where local biomass based electricity generation is the most viable option. Also, the low labor cost and the decentralized character of biomass supply provides comparative advantage to biomass energy in developing countries.

8.10 BIOMASS IN LATIN AMERICA AND CARIBBEAN

Latin America and Caribbean nations have a very high potential to use biomass fuels (Table 8.3). The biomass use varies considerably across these nations. For instance in Haiti, the biomass makes up almost all of domestic energy, whereas in Argentina biomass makes up for only 5% of residential energy use. Small household scale biogas digesters exist in several countries (Ni et al., 1993) - notably in Brazil (8000), Cuba (550) and Guatemala (100). Over a hundred industrial biogas plants with large capacity exist in Brazil with a total capacity of 76,000 m^3 per day (Craveiro, 1991; Hiriart et al., 1988).

The largest plant using sewage has a pair of 3300 m^3 upflow anaerobic sludge blanket digesters in Bucuramanga, Colombia which have been in operation since 1990 (Schellingkhout and Collazos, 1991). Latin America is a leader of landfill gas applications among developing nations. The most complex landfill gas plant is operated in the Brazilian city of Belo Horizonte. The gas is purified in three stages until a 96% methane rich gas is obtained, which is then compressed for use as a transport fuel in garbage trucks and taxi cabs (Kessler, 1989). The total contribution of biogas to the energy supply of Latin America is, however, small. Advanced applications of biomass energy have barely penetrated the Latin American and Caribbean nations, except Brazil.

Table 8.3: Potential Biomass Resources of Latin American and Caribbean Countries - 1990 (Million Tons)

Country	Fuelwood	Bagasse	Residue
Argentina	37.5	4.8	427.3
Bolivia	25.5	0.8	63.2
Brazil	158.2	146.9	1773.1
Colombia	23.9	5.6	348.7
Costa Rica	10.3	0.7	31.3
Chile	15.0	0	174.6
Cuba	1.0	33.5	146.3
Dominican Rep.	0.1	3.8	68.6
Ecuador	6.1	1.5	96.0
El Salvador	-	0.9	47.3
Guatemala	4.9	1.5	518.4
Guyana	5.0	1.4	7.3
Haiti	-	0.4	34.1
Honduras	2.2	1.0	41.0
Jamaica	0.2	0.8	17.3
Mexico	47.5	14.4	933.0
Nicaragua	3.8	1.3	34.9
Panama	4.2	0.4	24.8
Paraguay	9.7	0.6	37.3
Peru	24.2	2.9	245.3
Surinam	5.7	0.1	4.1
Trinidad & Tobago	0.2	0.3	5.6
Uruguay	2.3	0.1	53.1
Venezuela	10.5	1.7	238.7
Total	398.0	225.7	5374.7

Source: Torra and Laborusse, 1993 Table 6

Brazil

Brazil is a major user of biomass for modern applications. The best known Brazilian initiative is the large scale commercial production of ethanol from sugarcane. Since 1975 when the ProAlcool programme was established about 180 billion litres of bioethanol valued at 25 billion dollars (at 1994$) have been produced replacing nearly 2000,000 barrels of oil per day of imported oil (Moreira et al, 1997). This has also saved 100 million tons of carbon emissions. The government of Brazil has invested 11.3 billion dollars in the ProAlcool programme. The programme has created 700,000 direct jobs and 3 to 4 times as many indirect jobs (Goldemberg et al, 1993). The relatively low price of oil during the past ten years (Ahmed, 1994) and the low administered price of ethanol set by the government in some periods has weakened the programme in recent years.

The large scale sugarcane processing in Brazil has generated substantial quantities of bagasse and this has been used more and more over the last decade to meet virtually all of the electricity consumption of the sugarcane processing industry. A potential of 2600 MW of power capacity by the year 2010 using bagasse with advanced biomass conversion technologies is estimated for Brazil (Goldemberg and Macedo, 1994). Biomass based electricity generation using plantation wood is also being promoted. A 30 MW wood fuelled CFB combined cycle plant has been set up under a GEF project and is expected to be operational in 1997-98 (IPCC, 1996b).

8.11 MODERN BIOMASS ENERGY IN MEXICO

Although a substantial potential to generate electricity from biomass was identified in Mexico, especially from the sugar cane residues, Mexico's energy policy has continued to ignore the development of biomass energy (Barkin, 1993; Bustani and Cobas, 1993) locking the economy into a dependence on fossil fuel (Klass, 1995). Institutional arrangements to connect sugar mills and the power utility were initiated in 1990. Under these arrangements the utility buys back cogenerated electricity at the prevailing industrial tariff. In South Mexico, where most sugar mills are located, the tariffs corresponded to 4.07 cents/kWh for base load and 6.51 cents/kWh for peak power (USAID, 1992). These rates were lower than marginal cost of electricity production from new power plants, since Mexican sugar mills are relatively small.

8.12 MODERN BIOMASS ENERGY IN AFRICA

Biomass based electricity generation is not widespread in Africa. In Mauritius, sugar cane is the primary crop occupying 88% of the cultivable area. Bagasse fired captive cogeneration plants meet all the steam and electricity requirements of the sugar industry and provide 10% of the total national energy requirement. The sugar industry contributes 17% of the national grid supply (Baguant, 1993). Zimbabwe, Kenya and Malawi produce ethanol from sugarcane. Ethanol is blended with gasoline to a concentration of 10 to 13%. In drought periods, such as 1991/92, the ethanol shortfall had to be met with imported gasoline. The Zimbabwean ethanol programme has helped to save considerable foreign exchange (Woods and Hall, 1994). In general, the ethanol programme has proved to be successful in Zimbabwe, but less so in Kenya.

8.13 MODERN BIOMASS ENERGY IN ASIA

Biomass is a most prominent fuel used in Asian developing countries (Table 8.2). The rapid industrialisation in many Asian countries has brought higher penetration of commercial fossil fuels, causing a decline in the share of biomass energy. However, the consumption of biomass energy has continued to increase unabated since the oil shock in 1973 (Table 8.4). Various factors such as the increase in population and shortages or unaffordability of commercial fuels in rural and traditional sectors of the economy have contributed to growing biomass use. The increasing pressure on existing forests is leading to considerable deforestation. Despite the efforts of many governments, the deforestation in tropics has far exceeded afforestation (ratio of 8.5:1) during the 1980's (Houghton, 1996). A sustained and enhanced use of biomass in Asia would require supplementing existing resources with modern plantations. In the present decade, many Asian countries have initiated afforestation programs and modern energy plantations for augmenting the supply and conversion of biomass energy by modern technologies.

Table 8.4: Biomass Energy Consumption and Growth in Asian Countries

Country	Energy Consumption		Per Capita Energy Consumption	
	Petajoules 1993	% change since 1973	Per Capita 1993	% change since 1973
Bangladesh	277	27	2,401	-20
Bhutan	12	79	7,345	21
Cambodia	54	21	5,560	-11
China	2,018	54	1,687	15
India	2,824	58	3,132	4
Indonesia	1,465	54	7,642	4
Lao PDR	39	35	8,366	-15
Malaysia	90	61	4,686	-3
Mongolia	13	0	5,689	-41
Myanmar	193	48	4,324	-4
Nepal	206	88	9,882	12
Pakistan	296	101	2,228	8
Philippines	382	44	5,892	-9
Sri Lanka	89	45	4,996	6
Thailand	526	75	9,141	19
Viet Nam	251	54	3,516	-1
Other	274	-	-	-
Total	9,009	47	2,690	1

Source: WRI, 1996

China

In the early 1980's, China initiated a nationwide programme to disseminate improved cookstoves and biogas technologies. The programme led to raising the energy efficiency of cookstoves to 20 percent, saving nearly a ton of wood fuel per household (Shuhua et al, 1997). The biogas programme also made notable achievements. At the end of 1995, 5.7 million biogas digesters were producing 1.47 billion m^3 gas annually (Baofen and Xiangjun, 1997).

Moreover, there are 600 centralised biogas plants that supply energy to 84,000 households on a commercial basis. Biogas is used for domestic cooking needs as well as for process heat for drying and processing agriculture products. Apart from energy supply, the biogas plants are regarded as effective means for converting human and animal excreta to safe fertiliser. There are 24,000 biogas purification digesters with a capacity of 1 million m^3 which treat waste water for 2 million urban inhabitants (Keyun, 1995). There are 190 small biogas based power plants with a capacity of 3.5 MW which produce 3 GWh of electricity annually.

Research and development activities related to the identification and conversion of suitable biomass to liquid fuels are common. A process for converting a high quality Chinese sorghum breed has been developed. Research is also being carried out on pyrolysis technology which can produce liquid fuel. The unfavourable economics have prevented the commercial production of liquid fuels (Baofen and Xiangjun, 1997). Considerable research has also been carried out on the gasification of agriculture residue and wood. Ten pilot plants, each supplying the gas to 100 - 200 households have been built in Shandong province and Beijing. The Ninth Five-year plan (1996-2000) envisages the standardisation and commercialisation of this technology and its extension throughout China (Baofen and Xiangjun, 1997).

Recently, modern biomass technologies for electricity generation have begun to penetrate China. Rice husk based power generation with gasification and diesel engine routes as well as a direct combustion route are being used. However, due to the low scale of operation of rice mills and collection and transportation difficulties, rice husk based power generation has not been economical and has declined (Baofen and Xiangjun, 1997). The largest share of biomass electricity is in the sugar industry. The bagasse based power generation capacity in two major sugar cane producing provinces Guandong and Guangxi is 483 MW and 323 MW respectively (Baofen and Xiangjun, 1997). The biomass electricity programme in China has received fiscal and administrative policy support. Despite notable achievements, as yet the modern biomass technologies in China contribute very little to the country's overall energy consumption.

India

Biomass is predominantly used in rural households and traditional artisan type crafts and industries. Biomass delivers the majority of energy for domestic use (rural - 90% and urban - 40%) in India (NCAER, 1985). Estimates of the share of biomass in total energy consumption in India varies from nearly a third (36%) to a half (46%) (Ravindranath and Hall, 1995). Wood fuels contribute 56 percent of total biomass energy consumption (Sinha et al, 1994). Estimates of biomass consumption remain highly variable (Ravindranath and Hall, 1995; Joshi et al, 1992) since most biomass is not transacted on the market. Supply-side estimates (Ravindranath and Hall, 1995) of biomass energy are reported as: fuelwood for domestic sector- 218.5 million tons (dry), crop residue- 96 million tons (estimate for 1985), and cattle dung cake- 37 million tons. A recent study (Rai and Chakrabarti, 1996) estimates demand in India for fuelwood at 201 million tons. The supply of biomass primarily consists of fuels that are home grown or collected by households to satisfy their own needs. The Government sponsored social forestry programme has added 40 million tons annually to the fuel-wood supply (Ravindranath and Hall, 1995).

The programs for promoting biogas and the improved cook-stoves began way back in the 1940s. Afforestation and rural electrification have been pursued since the 1950s. The national biomass policy originated two decades ago as a component of the country's rural and renewable energy technology policies. Since India has a large livestock population, animal dung is the most used feedstock in biogas plants. During the last two decades, under the push of rural energy programmes, efficient technologies for household energy use such as the improved cook-stoves (22.5 million) and family sized biogas plants of 2 to 4 cubic meters per day capacity (2.4 million) and community biogas plants (1623) have been added (till March 1996) to the technology stock (CMIE, 1996c).

Although the biogas and improved cook-stove programmes have been moderately successful, their overall impact on rural energy remains marginal (Ramana et al, 1997). Two deficiencies in policy perspectives contributed to the slow progress of biomass technology penetration. Firstly, the biomass was viewed solely as a traditional fuel for meeting the rural energy needs. Secondly, the policies primarily focused on the supply-side push. The market was allowed little role, in ensuring economic and sustainable biomass production or in promoting the efficient use of biomass. Since the early 1990s the policy has shifted towards market instruments and the enhanced role of the private sector. Now, biomass energy is treated as a clean competitive energy resource which will be pulled by the market if the social benefits of biomass and the social costs of conventional fuels are internalised. The new thrust is towards commercialisation of the energy supply and modernised technology applications - such as bagasse based co-generation, efficient combustion, densification, charcoal making and decentralised electricity generation.

The policy push on biomass based electric power in India is of recent origin. The programme on bagasse based co-generation, launched in 1994, provided subsidies for specific demonstration projects and support for R&D, training and awareness activities. The national programme for biomass combustion based power began in late 1994 as a pilot programme. It was launched with two 5 MW projects and an interest subsidy similar to the bagasse based co-generation and was extended in 1995. A grid-connected biomass gasification R&D-cum-demonstration project (500 kW) was initiated in 1995. The decentralised electricity generation programme provided support for a total of 10 to 15 MW of small decentralised projects aimed at local energy self sufficiency in electricity deficient rural areas.

The focus of the modern biomass programme is on cogeneration, especially in the sugar industry. A cogeneration potential of 17,000 MW power has been identified, with 6000 MW in the sugar industry alone (Rajan, 1995). Institutional arrangements have been strengthened with better co-ordination among the sugar industry, utilities, co-generation equipment manufacturers and financial institutions. A 42 MW surplus power capacity was installed in the sugar mills from 1994 to 1996 (Gupta, 1997).

Biomass gasifier technologies for small-scale motive power and electricity generation, have been promoted since the mid-1980’s. The programme aimed at developing and commercialising 5 horsepower (3.7 kW) engines for farm irrigation. Gasifier engines have also been used also for village electrification and for captive power generation in oil extraction, saw mill and chemical units. Small gasifier technology for process heat has found applications in plywood manufacturing, tea processing and coconut and rice milling. The gasifiers in these applications have penetrated where cheap processing waste, such as in rice mills and plywood units, is available as a feed-stock. In motive power applications, gasifier systems replace diesel whereas in process heat applications it replaces coal or fuel oil. The wood gasifier engines are commercially available for water pumping (5 to 10 horsepower) and power generation (3 to 100 kW). Seven manufacturers are marketing gasifiers for different applications viz. mechanical, thermal and power generation. Over 1600 gasifier systems are currently installed. The 16 MW capacity installed has generated 42 million Kilowatt hours (kWh) of electricity and replaces 8.8 million litres of oil annually (CMIE, 1996c).

Twelve small sized gasifier models, ranging from 3.5 to 100 kW have been developed for different applications. The large sized gasifier based power technologies are at R&D and pilot demonstration stage. The promotion of biomass combustion based power generation is of recent origin. Besides wood, the programme aims to utilise some of the 350 million tons of agricultural and agro-industrial residues produced annually. The recent thrust of the biomass power programme is on grid-connected megawatt scale power generation using a variety of biomass materials such as rice straw, rice husk, bagasse, wood waste, wood, wild bushes and paper mill waste. Power generation potential from biomass gasification is estimated at 17000 MW (MNES, 1993a) and another 3500 MW (MNES, 1993b) using sugarcane residues. Nearly 55 MW of grid connected biomass power capacity has been commissioned and another 90 MW capacity is under construction. Enhanced scale has improved both the economics and technology of biomass power generation. The technology has improved lately to global standards with the Indian companies entering into joint ventures with leading international manufacturers of turbines and electronic governors.

Guaranteeing biomass supply at competitive costs require highly efficient biomass production systems. Biomass productivity depends critically on agroclimatic factors. The government has established nine Biomass Research Centres (BRC's) in different agroclimatic zones to develop packages of practices for fast growing, high yielding and short rotation (5-6 years) fuelwood tree species for the degraded waste lands in these zones. Some centres have been in existence for over a decade. Packages of practices for 36 promising species have been prepared. Biomass yields of up to 36.8 tons per hectare per year have been reported (Chaturvedi, 1993) from some promising fuel-wood species. The dissemination of innovations is slow and the productivity of farm forestry nationally is very low at 4.2 tons per hectare per year (Ravindranath and Hall, 1995). Land supply for energy plantation has remained a controversial issue under the "food versus fuel" debate.

The ninth five year plan (April 1997 to March 2002) proposes an ambitious biomass programme. In addition to the existing nine biomass research centres, five new centres are proposed to cover all fourteen agroclimatic zones. Some important biomass related rural energy proposals include a gasifier demonstration system (100 kW), captive use, incentives for biomass briquetting, a village electrification pilot project through biomass gasifiers and biogas in an unelectrified remote village, and coverage of 200 villages under biomass electrification. Proposals for biomass based power generation are even more ambitious with a targeted capacity of 500 MW power during the plan period.

Philippines: The Dendrothermal Programme

Biomass contributed 44% of the energy consumed in the Philippines in 1992. While most biomass is consumed in the domestic sector, the Philippines was among the first nations to initiate a modern biomass programme. In the 1970's, three quarters of the electricity in the Philippines was generated from oil and diesel fired power plants. In 1979, nearly a third of the oil imported was used for electricity generation (Bawagan and Semana, 1980). As a response to the oil crisis, a large "dendrothermal" power programme was launched in 1979. The plan envisaged reducing the share of imported oil fired electricity plants to 30% (Durst, 1986a). The programme aimed to supply electricity to rural areas. The uniqueness of the Filipino initiative were - i) large scale, ii) grid based biomass electricity generation, iii) dedicated biomass energy plantations, iv) decentralised and co-operative ownership, v) national co-ordination by the centralised administration, and vi) integration of social and environmental benefits within the programme design (Durst, 1987a; Durst 1987b).

According to the programme plan the biomass supply was to be obtained from tree farmers on lands leased by the government. A typical dendrothermal plant was to be 3 MW size which can be fuelled by trees grown on a 1200 hectares plantation (Durst, 1986b). Each 3 MW dendrothermal plant was expected to generate electricity at a cost of 4 cents/kWh and save about 260,000 barrels of oil per year (Denton, 1981). A total of 217 plants of around 3 MW size (total capacity - 676 MW) were to be constructed in the 1980's. Plantations of 100 hectares size were to be managed by tree-farmers associations consisting of 10 to 15 families. Within the first few years, major efforts were made to grow the plantations and procure the equipment. By 1984, trees were planted on 17,827 hectares of land (BTG, 1990) and equipment was purchased for 17 plants. During that time, 338 tree-farmers association with 3,800 member families were registered with the programme (Durst, 1987a).

Since its inception, the dendrothermal programme faced serious difficulties caused by political and economic conditions in Philippines at the time and planning and implementation failures. At the time of launching the programme, little experience existed world-wide on wood plantations for energy. The tree planting and equipment purchases began early, whereas the supporting systems and infrastructure lagged behind. Although, the dendrothermal concept was suited essentially to decentralised management, the planning decisions remained centralised and a lack of institutional mechanisms led to failures in translating centralised decisions to decentralised implementation and operation. Many tree-farmers associations had inadequate cultivation experience. The growth and survival rates at many locations suffered as a result. The planning failure is visible in the decisions to allocate primarily mountainous sites for plantation and to use a single tree species (Leucaena leucocephala or ipil-ipil) which did not suit the conditions at several sites. While the feasibility studies had projected the annual yields as high as 75 to 100 m^3 per hectare (Bawagan and Semana, 1980), at some plantations the actual yield was only a quarter of that projected (BTG, 1990).

Major problems with the dendrothermal programme became visible in the mid-1980's This was the period of political instability in the Philippines. Except for 17 plants for which the equipment was already purchased, the permission to build new plants was then indefinitely postponed and plantation development was sharply curtailed (Durst, 1986a). The decline in oil prices since the mid-1980's aggravated the problems by reducing the comparative advantage of biomass energy. Planting activity declined after the first two years of the programme when the government curtailed the financial support to the plantation programme. The reduced plantation area and lower than expected productivity led to fuel shortages. The ipil-ipil plantations were affected at some locations by insect attacks and by 1985 only 2 out of 9 nine operational power plants could receive adequate wood supply from their planted stocks (Durst, 1987a). The competing needs for wood compounded the problem by periodic shortages and price increases. The institutional regime to avert such situations was not in place.

The cost of transportation was pushed upwards by the aerial mono-cable systems imported from Switzerland which needed a high investment. The cable system was inflexible and inappropriate for the administrative and physical settings of some sites (Laarman et al., 1986). At most sites, the cable system was found to be too expensive to install and maintain and the transport system had to be altered later on to labour intensive modes (BTG, 1990).

The failure of the dendrothermal programme in Philippines offers some valuable lessons. The primary reason for the failure was that the programme was designed with a top-down approach which depended primarily on government support for finances, administration and technology. Under this paradigm, the success would have required a stable policy regime, strong institutional support and dynamic processes for quick responses to problems at decentralised levels. The unstable government policy regime and changing priorities during the early years of the programme were sufficient to weaken the programme. The dendrothermal technology was pushed by the government policy and was not pulled by the market. The Philippines government policies did not use market based instruments to motivate the major players to make economically efficient decisions. The planning and implementation were too centralised for a system that needed decentralised responses. As a result the shortcomings of a centralised system translated into failures at lower levels, and site specific problems were not addressed by the centralised system.

The inadequate and uneconomical supply of biomass fuel was the most important cause for the failure of the dendrothermal programme in the Philippines. The underlying reason for this failure was the non-existence of a well functioning biomass energy market. The institutional structure, co-ordination system and operational regime which should have been developed side by side with the programme did not develop. Inexperience and poor training of tree farmers, and the absence of a system for dissemination of innovations led to inefficient plantation management. These institutional weaknesses led to failures to provide dynamic response to locale specific issues. In short, the programme was pushed without the support of the political environment and the declining oil prices only aggravated the situation. The failure of the dendrothermal electric power programme in Philippines does not necessarily imply non-competitiveness of biomass based electricity generation vis-à-vis conventional energy forms. At the same time, it does indicate the complexities of managing the dendropower system as an integrated operation.

The delinking of biomass supply and the electricity generation through a well developed biomass market can be one important step in improving the performance of dendrothermal plants. Alternatively, a reliable feedstock supply can be ascertained from a strongly planned, efficiently managed and dedicated biomass plantation system. In developing countries, either condition is difficult to achieve. Unless the market and other institutional infrastructure is put in the right place, the dendrothermal programme in developing countries will face the risk of failure.

Other Asian Countries

Biomass contributes a quarter of the energy consumed in Thailand. Two thirds of the biomass energy is consumed in the residential sector and the rest in the manufacturing sector. Bagasse is used in sugar mills as a boiler feedstock (Panyatanya, 1997). A cogeneration potential of 3100 MW power is identified in chemical, agroprocessing and textile industries (Verapong, 1997). Following the National Energy Policy Council and the Energy Conservation Act of 1992, the Electricity Generating Authority of Thailand (EGAT) announced in 1992 its policy of purchasing power from Small Power Producers - SSP (Verapong, 1997). The response to the SSP policy has so far been slow.

In Indonesia, biomass energy provides over a third of the energy consumed. A forest area of 109 million hectares covers sixty percent of Indonesia's landmass. Besides, 9 million hectares of land is under plantations. The wood waste from over a hundred plywood plants can provide fuel for 200 MW power and saw mill waste is adequate to support another 800 MW. The policy of facilitating the small-scale private producers (30 MW) is expected to be beneficial for biomass electricity applications. Although a large potential exists, under the present energy pricing, the biomass energy has not been competitive (Martosudirjo, 1997) and penetration has been marginal.

Malaysia has a significant biomass resource base. Nearly sixty percent of the land is under forests and fifteen percent under cultivation. The forest and agriculture industry generate substantial quantities of wastes and residues which are available cheaply. The wood briquetting industry utilises sawdust. A major source of residues in Malaysia is the palm oil industry. Another vast biomass source is rice husk. In 1995, there were 328 rice mills producing 430 thousand tons of rice husk (Ang, 1997). Several fishmeal manufacturers use rice husk for drying. Cogeneration systems (350 kW) using rice husk have been established in three rice mills. Seven demonstration plants for cogeneration and efficient biomass combustion are being promoted under the EC-ASEAN COGEN Programme (Ang, 1997).

Biomass supplies three quarters of the energy consumed in Bangladesh. Most biomass is used in the residential and traditional manufacturing and service sectors. Although substantial potential exists, the modern biomass technologies for electricity generation have yet to penetrate (Rauf and Khan, 1997) the Bangladesh electricity market.

Biomass provides over half the energy consumed in Vietnam. Recent estimates (Hahn and Hung, 1997) indicate an even higher share of biomass in the national energy balance (60% - 65%) and in the rural energy balance (70% - 80%). Biogas plants were introduced in the mid-1980's, but penetration has been slow. Nearly 3000 small biogas plants exist at present, which are used for cooking, lighting and fuel for small engines. Nationally, two major focal areas identified for biomass energy are the improvement in energy efficiency of traditional wood stoves used for domestic cooking and improvement or substitution of wood burning boilers used in processing industries (Hahn and Hung, 1997).

Traditionally, biomass is the primary energy source in Myanmar. Modern biomass technologies have only recently been promoted in Myanmar. The privatisation and anti-pollution initiatives of the government have created favourable conditions for modern biomass energy applications. The programme for efficient use of biomass resources is jointly implemented by private and government organisations. Briquetting of wood chips and agriculture residues is carried out in private and government owned factories (Swe, 1997). Attention is also paid to biomass conversion technologies for gasification and for producing liquid fuels. A 50 kW gasifier using rice husk has been developed under the Science and Technology Ministry (Aung, 1997). However, as yet modern biomass technologies have not entered the Myanmar market.

8.14 Supply of Woodfuel and other Biomass Resources

The supply of wood fuel and other biomass resources depends critically on sunlight, plant species, land availability and quality, climatic conditions, nutrients and pest and disease control. The competition for land exists from different sources like housing, industry, recreation and agriculture. Readily available sources of land for wood or other biomass plantations are wastelands and excess agricultural lands. Globally, the estimates of degraded and abandoned land lie between 700 to 1,000 million hectares, which is equivalent to half the world's present arable land (Woods and Hall, 1994). The potential of excess agricultural lands in Europe is estimated at 33 million hectares by 2020 (Hall, 1994) and 40 million hectares for the European Union countries (Wright, 1991). In the USA, the idle crop land was estimated to be 33 million hectares in 1990 and it is projected to grow to 52 million hectares in three decades (SCS, 1989). For tropical regions, Grainger (1988, 1990) estimates 630 million hectares of degraded land suitable for reforestation. The wood supply can be obtained through integrated land use planning which can achieve sustained yields and at the same time enhance the well being of local communities and conserve the quality of the environment.

Increasing population and enhanced standards of living generate higher demands for both food and energy. A concern often raised against biomass energy is that it can add to the pressures on land and growing population and thereby threaten food security (Ehrlich et al., 1993). On the other hand it is also argued that the biomass production can ease the problem of surplus agriculture production faced in many industrialised countries (Patterson, 1994). The historical trends of grain yields suggest that considerable land will be available for biomass energy production in many developing regions (Larson et al., 1995). With efficient management of agriculture land and plantations, it is possible to grow adequate biomass for food, fibre, fodder and fuel without causing land conflicts. It is however important to recognise that the food security in some developing countries may be threatened if the biomass plantations are grown without improving agriculture yields or generating an adequate trade surplus which would allow the import of food grains.

8.15 SOURCES OF BIOMASS ENERGY

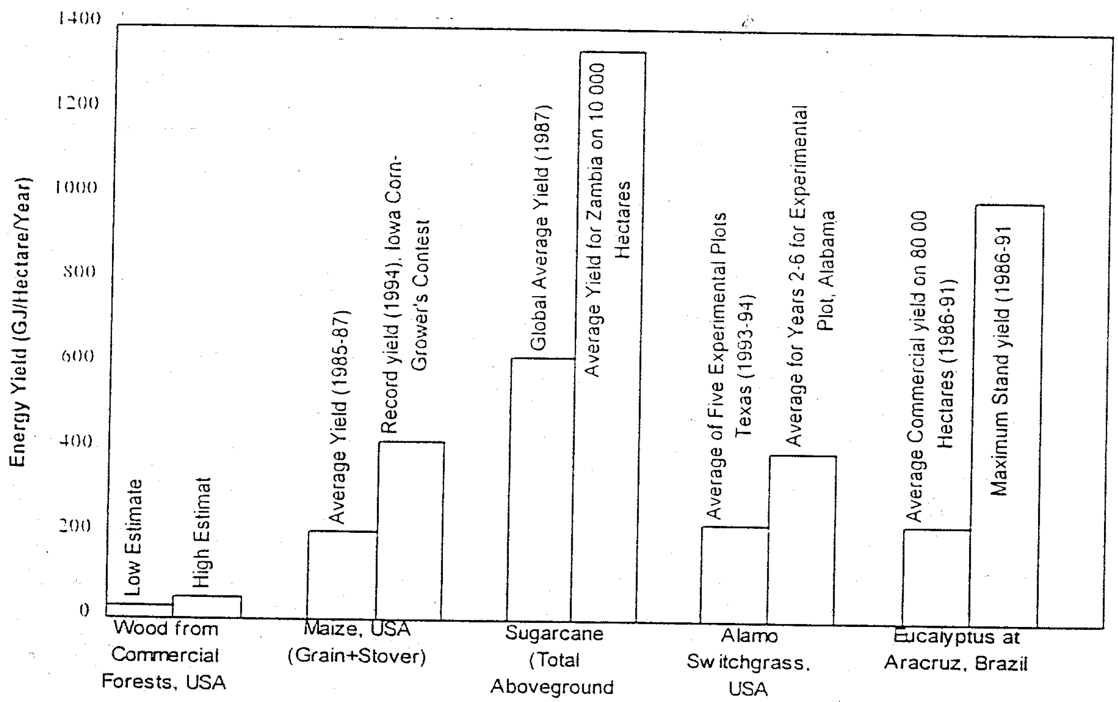
Biomass supply is available from diverse sources like forests, wood plantations, residues from industries and agriculture and municipal solid waste (MSW). The energy content of the annual decline in the world's forests is a third of global energy consumption. More intensive forest management will be needed to offset the decline in forest cover. At present, 100 million hectares of industrial tree plantations exist globally. Recoverable crop, forest, and dung residues contain 10% of present global commercial energy use (Hall et al, 1993). In industrialised countries, per capita MSW produced is 0.9 to 1.9 kg/day which has 4 to 13 MJ/kg of energy content (IPCC, 1996a). Energy can be recovered from MSW by biodigestion, incineration, gasification etc.

The least expensive and yet good quality biomass energy sources are the waste products from wood or agro-processing units. The supply of waste resources is restricted by size, location and the business cycle of these industries. The next cheapest sources are wood fuels available from home-grown trees or plantations grown on lands not used for other purposes (like trees on farm peripheries, canal banks or on common village lands), agriculture waste at farms and cattle dung. These sources are cheap, especially in developing countries where they are collected by unpaid family labour from degraded and low cost lands. Sources of these fuels are restricted by land availability for plantations and by crop pattern and seasonality in the case of agriculture lands.

8.16 PRODUCTIVITY OF BIOMASS ENERGY PLANTATIONS

Plants have been cultivated for food, timber and fibre for thousand of years. However, the intensive cultivation of plantations for energy is of recent origin. The productivity estimates for biomass are based on the biomass grown for food and fibre (IPCC, 1996a). The highest biomass yields that are achieved over large areas are for sugarcane (Figure 8.1). In 1987, the global average yield of the above ground biomass was 36 dry tons per hectare per year (dt/ha/yr), the yield for Zambia was 77 dt/ha/r (IPCC, 1996a). The average yield of maize is low compared to sugarcane, but comparable to wood biomass (Figure 8.1). The yields of woody biomass are much lower in comparison. The average yield of Eucalyptus plantations grown for pulp at Aracruz in Brazil (from 1986 to 1991) averaged 23 dt/ha/yr, with a maximum yield of 52 dt/ha/yr (IPCC, 1996a).

Figure 8.1: Actual biomass yield from various activities



Source: IPCC (1996a)

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

8.17 COST OF PLANTATION GROWN FUELS

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

A summary of costs and productivity of plantation grown biomass fuel is provided in Table 8.5. The costs vary widely across the nations, and even for sites within a nation located in different agroclimatic zones. The costs across nations or locations are also incomparable due to site specific factors such as land rent, government assistance, infrastructure and the quality and type of biomass fuel. In certain locations, the intensive biomass plantation grown fuel can be competitive vis-à-vis coal at the price of around $2/GJ. The estimates based on the commercial experience with intensive eucalyptus plantation in Brazil suggests that biomass production on 50 million hectares of land can produce 13 exajoules of energy per year at an average cost of $1.7/GJ (Carpentieri et al., 1993). The average cost of plantation grown biomass in five bio-geoclimatic zones in Brazil was $1.4 per GJ (Hall et. al, 1993). A study in the USA suggests that with a strong and sustained R&D effort the biomass cost can fall to $1.5/GJ or less by 2020 (Graham et al., 1995). Another study (Turnure et al., 1995) in the USA points out the increasing price of land due to additional demand from biomass and estimated the cost of biomass to be $1.8/GJ by the year 2020. The price of coal in the same year in the USA is projected to be $1.3/GJ (EIA, 1995). Estimated costs of different biomass feedstock vary from $1 to $3 per GJ (Woods and Hall, 1994). At $2 per GJ, the biomass cost is equivalent to the present oil price at $ 20 per barrel. The organised production of wood fuels and other energy crops through intensive farming, and their conversion to useful energy with modern technologies have the potential to make biomass a competitive commercial fuel vis-à-vis fossil fuels (Ahmed, 1993; Ravindranath, 1993).

Table 8.5: Summary of the costs and productivity of plantation-grown fuel

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

Source: Perlack et. al., 1995

8.18 ECONOMIC ANALYSIS OF DENDROTHERMAL POWER

Dendrothermal power competes in niche applications as well as in direct competition with conventional electricity sources in centralised electricity supply. In some niche applications, dendropower generation has a natural competitive advantage. Some important niche areas for dendropower are: i) wood or agro processing industries where waste materials are cheaply available for energy and a demand for electricity and steam (i.e. co-generation) exists, ii) remote or underdeveloped areas where a centralised electricity grid is not accessible or economical and where biomass supply exists (e.g. mountainous regions), iii) locations where biomass is available but other conventional energy resources and foreign exchange are scarce. In these niches biomass energy is competitive either because the location offers a specific cost advantage to biomass energy or excludes conventional fuels from competition. Such niche applications open the “window of opportunity” for the penetration of biomass technology. The learning opportunity provided through the niche applications is vital for improving technology characteristics and thus enhancing competitiveness.

The ability of dendropower to compete with conventional power generation technologies is of recent origin. The competition here is based primarily on cost and reliability of delivered electricity to the consumer. Through the direct combustion as well as gasification routes, the biomass technologies are set to achieve technological performance equivalent to that of the fossil fuel based technologies. The economic performance of biomass based systems depends vitally on the comparative fuel prices and capital costs. The scale of biomass technologies is still much smaller. For instance, the standard large sized biomass electricity generation units operating through combustion or gasification routes are available in 50 MW capacity. The scale of operation of large size coal thermal power plants is usually 500 MW. The unit capacity costs of biomass plants are therefore higher, although the gap has narrowed considerably in recent times. Due to the existence of a global coal market, coal prices are globally determined and are relatively stable. Sizeable differences in coal prices still remain at the mine head and delivery points several hundred kilometres away. The biomass prices exhibit greater variation due to factors such as soil character, climatic conditions, selection of tree species or energy crops, water availability and differences in inputs and technologies.

8.19 ASSUMPTIONS ABOUT TECHNOLOGY, FUEL AND ECONOMY

The economic analysis here considers a generic representation of technologies. Three sizes of biomass technologies are considered - 100 kW, 1 MW and 50 MW. The generic coal power technology is considered to be a 500 MW plant. The assumptions relating to the technology and fuel characteristics are as in Tables 8.6 and 8.7. Cost of capital (i.e. annual rate of interest on investment) is presumed to be 10 percent. Although this rate is higher than the interest rates in developed economies, it is similar to the interest rates prevailing in developing countries which are higher due to the scarcity of capital.

Table 8.6: Technology characteristics

	Biomass Power	Biomass Power	Biomass Power	Coal Power
	100 KW	**1 MW**	**50 MW**	**500 MW**
Life (Years)	20	25	30	30
Hours of Operation per year	4000	5000	6000	6000
Capital Cost ($ million / MW)	1.8	1.6	1.4	1.2
Fixed O&M Cost ($ 000/ MW)	12	10	8	9
Variable O&M Cost (cents/kwh)*	0.45	0.3	0.2	0.15
T & D Cost ($ million / MW)	0.1	0.3	0.6	0.6
T & D Loss (%)	5	10	15	15

**** Excludes Fuel Cost***

Table 8.7: Price of Fuels

	Base Price	Range
Biomass ($ / GJ)	2	0.5 to 4
Coal ($ / GJ)	1.5	-

The capital costs of technology are assumed to be scale dependent. The larger sized plants having higher scale economy have lower unit capital cost. The range of capital costs is assumed based on reported costs (Ahmed, 1994). The annual operating hours (utilisation) of a small sized plant is presumed to be less than that of a large-scale plant. This does not necessarily imply the technological inferiority of smaller plants. The lower utilisation can be attributed more to the operational reasons, most importantly to the type of application that may not need continuous operation of the plant in a niche application. The large sized biomass plants (50 MW) have an identical utilisation level (6000 hours per year) as that of the coal thermal power plant since both compete in the centralised electricity market and operate with advanced technologies and management practices. The electricity transmission and distribution (T&D) cost and power loss are lower for the smaller sized plants due to their decentralised character.

Biomass is available in many forms. Biomass energy is considered in this analysis in a generic sense. The price of biomass energy is presumed to vary from 0.5 to 4 $/GJ. In the wood or agro processing industry, biomass waste with good energy value is often available very cheaply. Such situations account for the low end of the biomass price. The supply of biomass available at these prices is limited. These industries often need steam as well as power. Highly energy efficient co-generation technologies are best suited for these requirements. Such situations provide an appropriate niche for penetration of biomass electricity technology. Woody biomass, such as wood from unmanaged forests or logging waste is available at moderate prices, including transport costs. Their supply is limited and if not properly managed, it may in the long run lead to deforestation.

The plantation based biomass systems which use high value crop land have higher costs, however they can provide reliable and sustainable biomass supply. Here, the main limitation can arise from the availability of land, besides the competition from conventional fuels. Varied estimates of costs of plantation based biomass exist. In the USA, the delivered cost of wood chip of $56.36/ ton (1990$) from a poplar plantation (Hall, 1991) converts to a price equivalent of $2.9/GJ. The cost of short rotation woody crops was earlier estimated (Hall, 1991) to range between $3 to $4.1/GJ (1985$). For village plantations in developing countries, where lower energy costs are possible due to the low cost of land and labour. For instance, the biomass energy cost of $0.85/GJ is reported for village plantations in India (IPCC, 1996b).

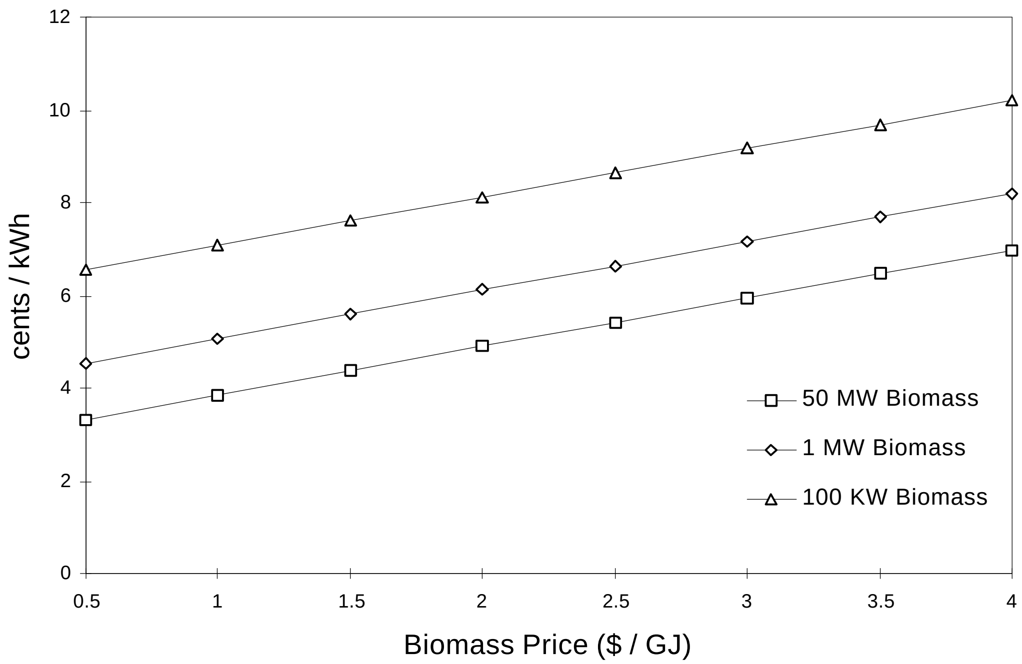
The analysis in this paper presumes $2/GJ price for the biomass. This is the expected cost of biomass in the OECD countries as indicated by some recent studies (IPCC, 1996b). Hall (1991) also indicates this to be the achievable cost for the USA. The base price of coal is assumed to be $ 1.5/GJ. The biomass energy cost is highly variable and at the same time a very significant constituent of electricity generation cost. Therefore, in the economic analysis of the electricity cost, the entire range of the biomass energy cost is considered.

8.20 COST OF ELECTRICITY FROM BIOMASS PLANTS

The costs of electricity generation with biomass technologies, for varying prices of biomass energy, are shown in Figure 8.2.

The electricity cost is quite sensitive to the size of the technology as well as the price of the biomass. For any price of biomass, the electricity generation cost of a 100 kW plant is 2 cents/kWh higher than that for a 1 MW plant. The generation cost of a 1 MW plant is 1.2 cents/kWh higher than that for a 50 MW plant. The sensitivity of electricity cost to the fuel cost is also very high. The generation cost for a 50 MW plant using cheap biomass waste (at a price of $1/GJ) is 3.85 cents/kWh. The generation cost at an energy price of $2/GJ is 4.9 cents/kWh. The generation cost rises to 7 cents/kWh for an energy price of $4/GJ. For a small sized biomass plant (100 kW), the electricity generation price is very high and exceeds 10 cents/kWh if only high priced biomass is available. Except in niche applications such as in remote areas where centralised electricity cannot reach, the combination of small sized technology with high priced biomass is unlikely to compete. The small sized plant can generate electricity at a cost below 7 cents/kWh, if cheap biomass below $1/GJ price is available. The 1 MW plant can generate electricity at a cost of around 6 cents/kWh with a moderate biomass price of $2/GJ.

Figure 8.2: Cost of Electricity Generation with Biomass Technology



A comparison of electricity generation costs (Figure 8.3) for different sizes of biomass plants and a 500 MW coal plant shows that the generation cost for a large sized biomass plant (50 MW) is higher only by 0.7 cents/kWh. The fuel cost for the biomass plant is higher by 0.3 cents/kWh since the coal is presumed to be available at price of $1.5/GJ whereas the base price of biomass is presumed to be $2/GJ. The capital cost of the biomass plant is higher by 0.35 cents/kWh due to the larger scale economy in the coal plant. The smaller scale of a 100 kW plant together with a lower utilisation rate results in a very high proportion of capital cost in the unit generation cost.

Figure 8.4 shows the composition of the cost of a delivered unit of electricity to the consumer. This includes the electricity losses in delivery and the costs of the T&D network. The delivered costs of electricity make the costs from the smaller units more comparable since they have much lower T&D costs and lower delivery losses. For instance, the T&D cost per unit of electricity delivered for 100 kW plant is a fourth of the cost for the coal plant. Besides, due to only 5% T&D loss in the small plant compared to 15% in the large plant, 11% more electricity delivered per generated unit is delivered from the small plant. Still, the coal plant has a 1 cent/kWh advantage in the delivery cost over the 50 MW biomass based plant and a 2.7 cents/kWh advantage over the 100 kW plant.

Figure 2: Composition of electricity generation cost

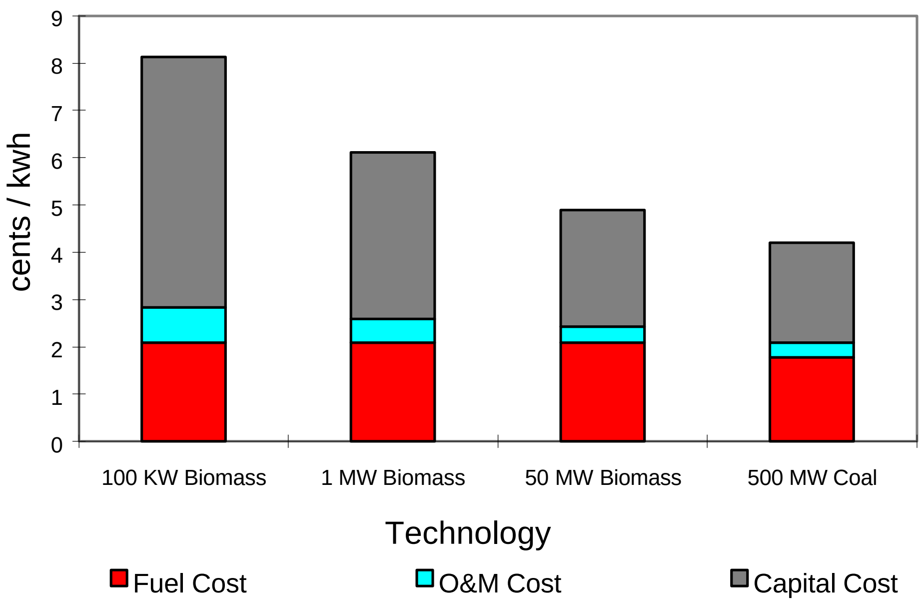
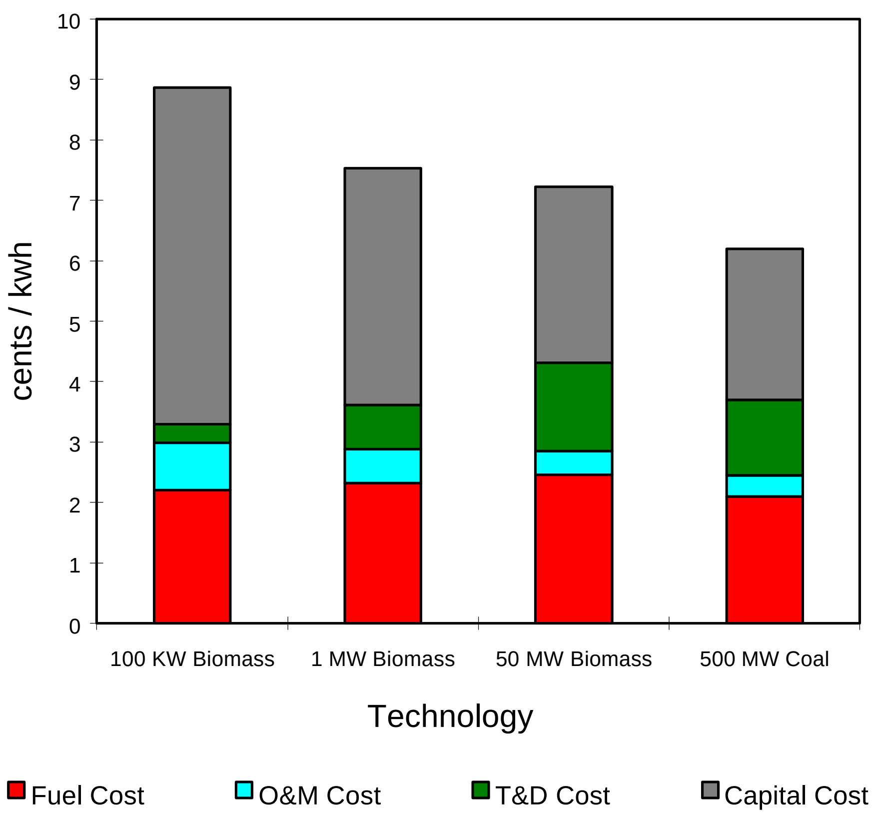


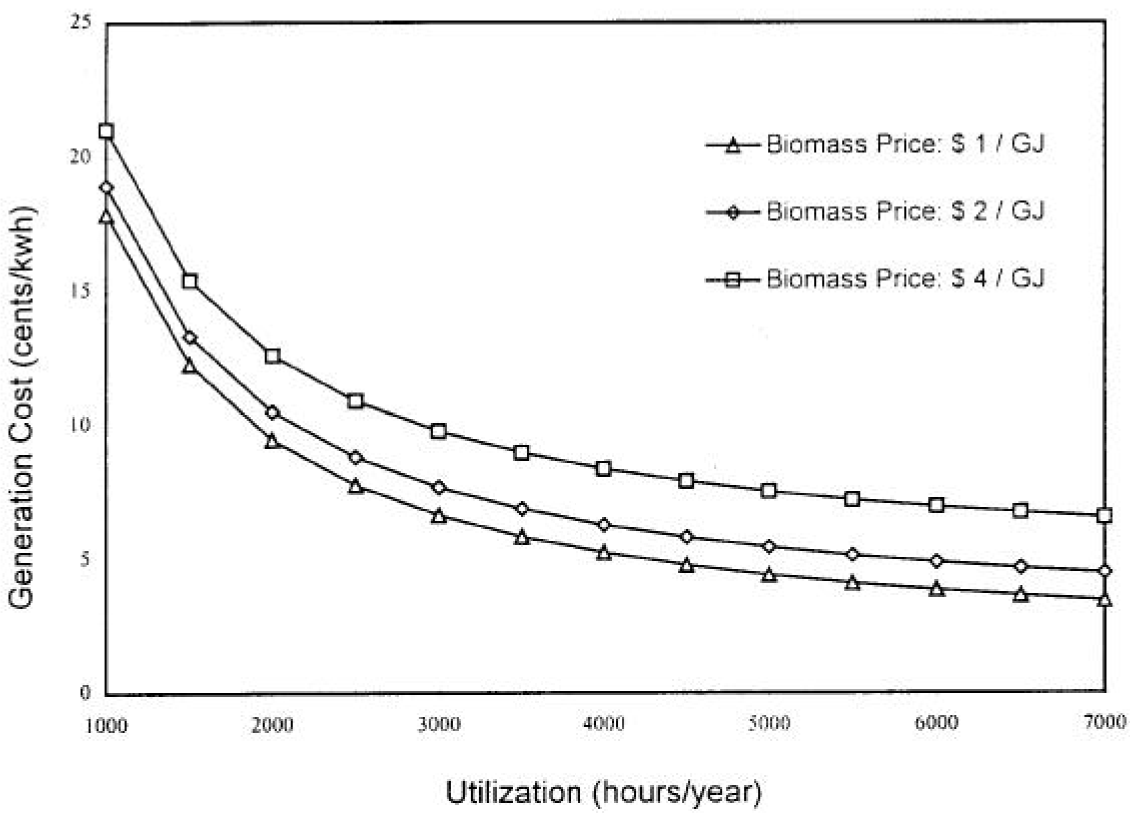
Figure 3: Composition of delivered cost of electricity



8.21 SENSITIVITY TO UTILISATION RATE

A vital factor to which the electricity generation cost is most sensitive is the utilisation rate. There are factors which may typically affect the utilisation of biomass based power plants such as - shortage of biomass (e.g. due to seasonality or crop failure), quality of biomass (e.g. uniformity, dryness) and evolving technology (e.g. size). Besides, in many niche applications, the demand profile may lead to a low utilisation rate, such as in agro-processing industries which operate seasonally or in remote village applications where daily and seasonal load profiles are highly uneven. Figure 4 shows the sensitivity of the electricity generation cost to utilisation for a 50 MW biomass based power plant. For an annual operation below 4,000 hours, the costs rise very rapidly. Operating under competitive dynamics would require an annual utilisation beyond 6000 hours. As is evident from Figure 8.5, an annual utilisation higher than 3,000 hours is more critical to controlling the electricity generation cost than the cost of biomass.

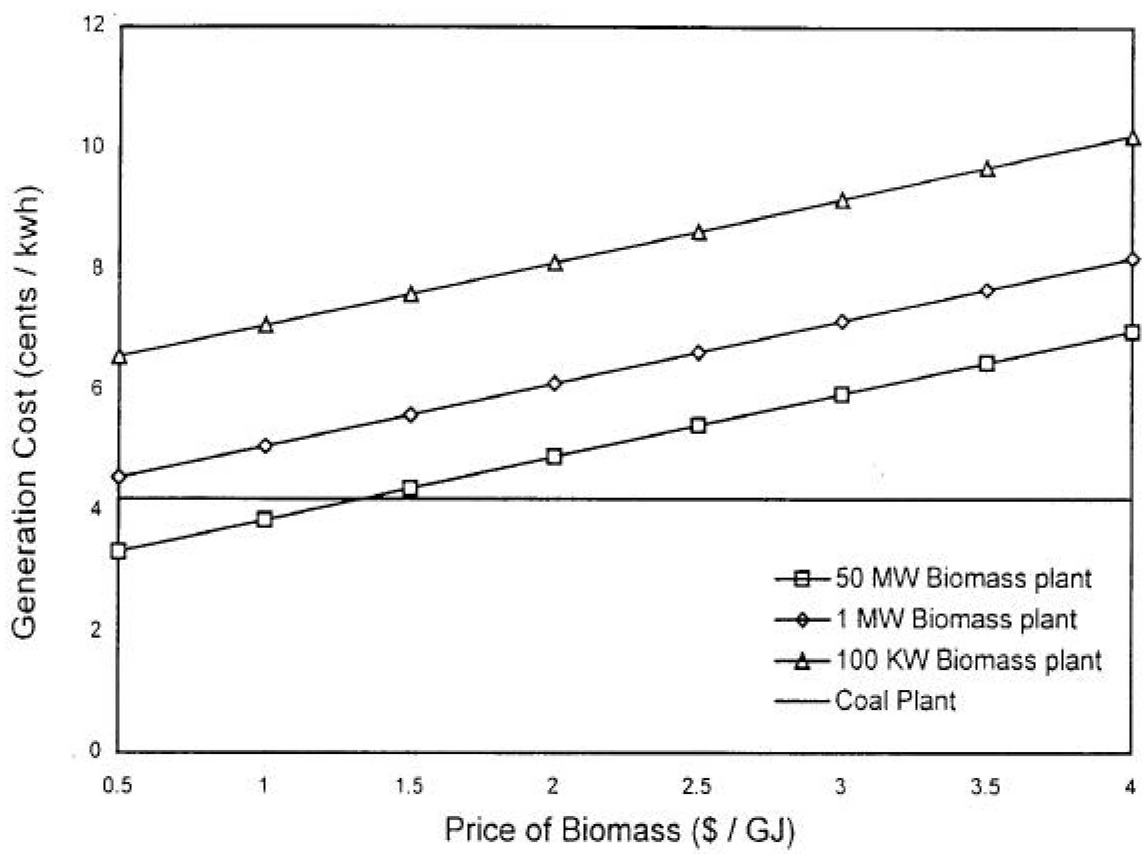
Figure 8.5: Cost of Electricity versus Utilisation (50 MW Biomass Power Plant)



8.22 COMPETITIVENESS VIS-À-VIS COAL THERMAL POWER PLANT

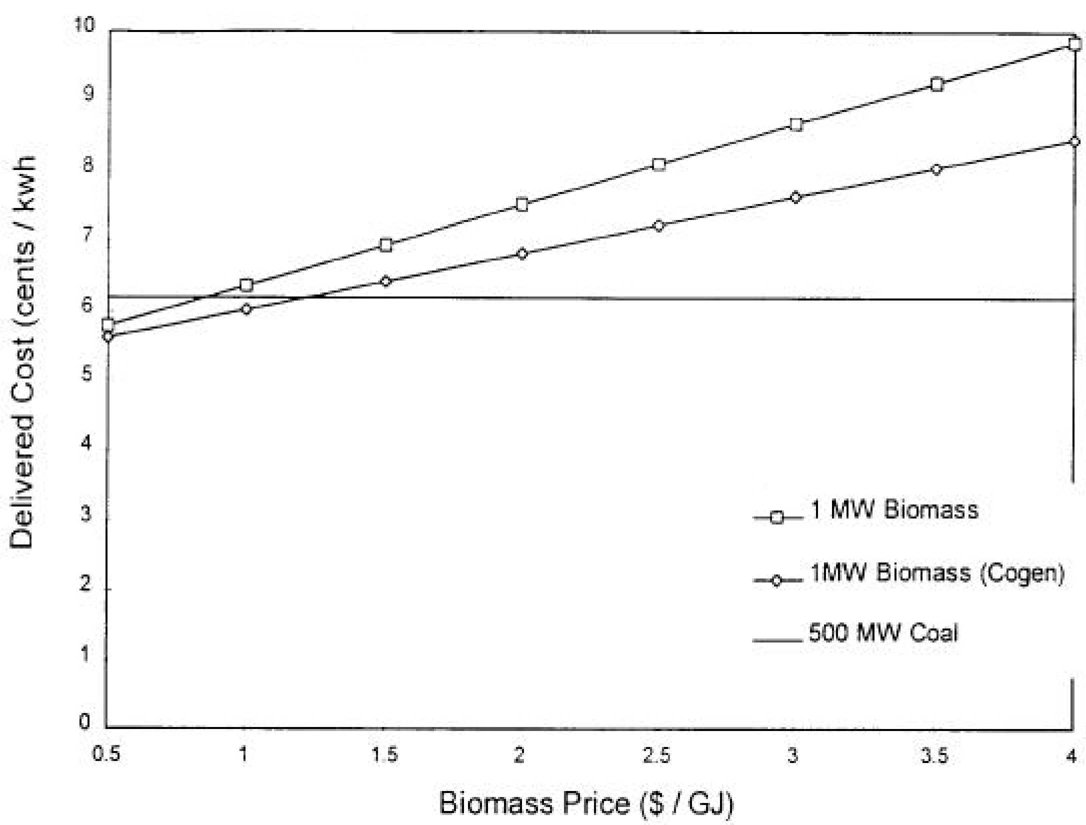
A comparison of costs of electricity generation from biomass based power plants with coal thermal power plant (500 MW) is shown in Figure 8.6. Evidently, the small sized power plants can not compete with the coal thermal plants even if biomass is very cheap. This can be expected and is immaterial since small biomass plants are not expected to compete with large scale conventional power plants. As discussed, small plants are suited to niche applications. A large scale biomass plant (50 MW) has lower electricity costs than a coal plant if biomass is available at a cost below $1.3/GJ.

Figure 8.6: Costs of biomass and coal power



It is important to recognise that the conclusions of the above economic analysis are assumption dependent. The base price for coal is assumed to be $1.5/GJ. The coal price varies considerably depending on the distance from the mine and the quality of the mine. Situations may exist at some locations where the coal price may be higher than the assumed base price and the biomass energy may be available cheaply. In such situations, biomass electricity will be competitive vis-à-vis conventional power plants. Also, the present scale of biomass plants is much smaller than conventional fossil fuel based plants. As this gap narrows, the biomass electricity cost can be expected to decline. The cogeneration applications in wood and agriculture processing industries typically achieve fuel efficiency of 40 to 45% compared to the 30% efficiency of the conventional electricity generation technologies. In applications where cogeneration is feasible and low cost biomass energy is available, such as in the pulp and paper and sugar industries, the 1 MW biomass plant operating for 5,000 hours can be competitive with a large-scale coal power plant operating for 6,000 hours (Figure 8.7).

Figure 8.7: Delivered cost of electricity: biomass cogeneration and coal



8.23 SOCIAL AND ENVIRONMENTAL EXTERNALITIES

Associated with conventional electric power plants are some serious social and environmental problems. Throughout the coal and nuclear fuel cycles, there are significant environmental and social impacts. Besides not causing the negative environmental impacts associated with conventional fuel use, biomass energy offers positive environmental and social benefits. Biomass plantations are often the best way to reclaim degraded lands and to generate sizeable employment (Miller et al., 1986). Fossil fuel based power plant operations pose local, regional as well as global hazards. Local pollution causes direct health impacts such as respiratory diseases. Regional impacts result from long distance transport of emissions and acid rain. The global impacts manifest through the climate change via the greenhouse effect that causes global warming. Governments in countries like Sweden (Box 3) and Denmark have implemented measures to internalise the externalities caused by conventional fuel use. Environmental impacts determined by a study under the Joule II programme (ETSU/IER, 1995) of the European Commissions (EC) for a proposed state-of-the-art coal-fired power plant with 99.7% particle removal are reported in Table 8.8. Biomass based power also causes pollution throughout the fuel cycle (Mahim, 1991). However, compared to fossil fuels the damage is much lower.

Box 3. Internalising the externalities in Energy Costs: Sweden

The negative externalities from the use of conventional fuels and positive externalities from biomass energy are not internalised in the energy and electricity costs in most nations. As a result, the benign fuels like biomass and other renewable energy sources are at a comparative disadvantage vis-à-vis fossil fuels and nuclear energy. The carbon dioxide and sulphur dioxide produced during coal combustion have significant associated externalities.

The Swedish government has imposed taxes on sulphur dioxide and carbon dioxide emissions from fossil fuels to internalise the costs of damages resulting from the emissions of these gases (Hillring, 1997). The present tax rates for the coal with 0.5 percent sulphur content, when used by the industry, result in an equivalent coal tax of $1.67/GJ. The tax on coal used by the other sectors of the economy is much higher and results in an equivalent tax of $4.75 per GJ. The electricity producers in Sweden are however not yet taxed. The tax is imposed on electricity consumption, regardless of the source. This policy is unfavourable to biomass and other renewable electricity generation technologies. Fair competition in the electricity power sector calls for internalisation of externalities from the fuel cycle in electricity production. This fact is being increasingly recognised by the policy makers.

Table 8.8: Impacts from coal fuel chain (state-of-the-art technology)

Impacts	Type of impact:
Environmental impacts	
Plant construction/decommissioning	NA
Plant operation	
CO_2 emissions	880 g/kWh
SO_2 emissions (may from aerosols)	1.1 g/kWh
NO_x emissions (may from aerosols)	2.2 g/kWh
Particulates emissions	0.16 g/kWh
CH_4 emissions	3 g/kWh
N_2O emissions	0.5 g/kWh
Greenhouse warming	From CO_2 , CH_4 ,etc.
Degradation of building materials	From acid rain
Reduced crop yields	From acid rain
Forest and ecosystem impacts	-
Ozone impacts	-
Mortality	
From particles(PM_{10})	1 case per TWh
From aerosols	0.2 cases per TWh
From chronic effects	7 cases per TWh
Morbidity from dust and aerosols	
Major (acute)	0.4 cases per TWh
Minor (acute)	40 000 work days lost /TWh
Chronic cases	150 cases per TWh
Noise (from power plants)	-
Occupational health and injury	
Mining	
	0.1 cases per TWh
Major injury	3.1 cases per TWh
Minor injury	27 cases per TWh
Transport	
Deaths	0.02 cases per TWh
Major injury	0.15 cases per TWh
Minor injury	0.69 cases per TWh
Construction / decommissioning/ operation	0 cases per TWh

Source: Sorensen ,1997

8.24 BIOMASS, FORESTS AND GLOBAL CLIMATE CHANGE

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

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

Better management and growing use of biomass offer the most promising future carbon mitigation options. Estimates (Richards et al, 1993) suggest that carbon sequestration up to about 50 PgC can be achieved over 160 years through forest plantation with a total cost of 250 billion US dollars. At present values, the average operational cost of mitigation of 77 to 99 billion tons through sequestration would fall within the range of $1.2 to $1.4 tC (IPCC, 1996c). The future development of wood energy and forest policies are therefore vital to the cost effective global climate change regime. Some important biomass related policies in the context of global climate change are - i) commercial biomass fuel production, ii) sustainable wood plantation and biomass cropping practices, iii) conversion of biomass into readily usable energy forms (such as liquid or gas), iv) modernised technologies for combustion of biomass or its energy products, and v) carbon sequestration through wood and forest management practices. These policies meet the need to manage climate change and are consistent with globally sustainable economic development.

8.25 COMPETITIVENESS OF BIOMASS ELECTRICITY WITH INTERNALISED COSTS

The social and environmental advantages of biomass fuels over conventional fossil fuels become apparent when the externalities of the fuel cycle are internalised. This analysis considers the competition with coal electricity when two externalities of coal use - namely CO_2 and SO_2 emissions- are internalised. The characteristics of typical coal used in power plants are assumed to be as in Table 8.9. Two sets of environmental tax assumptions for internalisation of environmental costs are made (Table 8.10). Estimates of carbon tax needed to stabilise emissions in 2010 at the 1990 level are highly variable. Comparative assessment of different models in the USA by the Energy Modelling Forum indicates a range of $20 to 150 (EMF, 1993). In developing countries, a much lower marginal cost for carbon mitigation is reported (UNEP, 1993; Shukla, 1995; IPCC, 1996b). In this analysis, a $50 per ton of carbon tax rate is assumed as high tax and $25 as low tax. The low and high tax ranges translate respectively into $1/GJ and $2/GJ tax on coal energy (Table 8.11). In the case of sulphur emissions, an alternative to a tax is mandatory desulfurisation. The costs for typical wet scrubber flue gas desulfurisation technology are shown in Table 8.12. This technology removes 70 to 90 percent of SO_2 from low sulfur coals. The range of costs of desulfurisation for electricity generated for retrofit as well as new plants works out to be 1 to 2 cents.

Table 8.9: Coal characteristics

Heat value (GJ/Ton)	25.2
Carbon (%)	75
Sulfur (%)	1.6

Table 8.10: Environmental tax assumptions

	Carbon ($/tC)	SO_2 ($/t SO_2)
Low	25	200
High	50	400

Table 8.11: Environmental tax on coal ($ / GJ)

	Carbon	SO_2	Total
Low	0.745	0.255	1
High	1.490	0.510	2

Table 8.12: Cost projections for flue-gas desulfurisation units

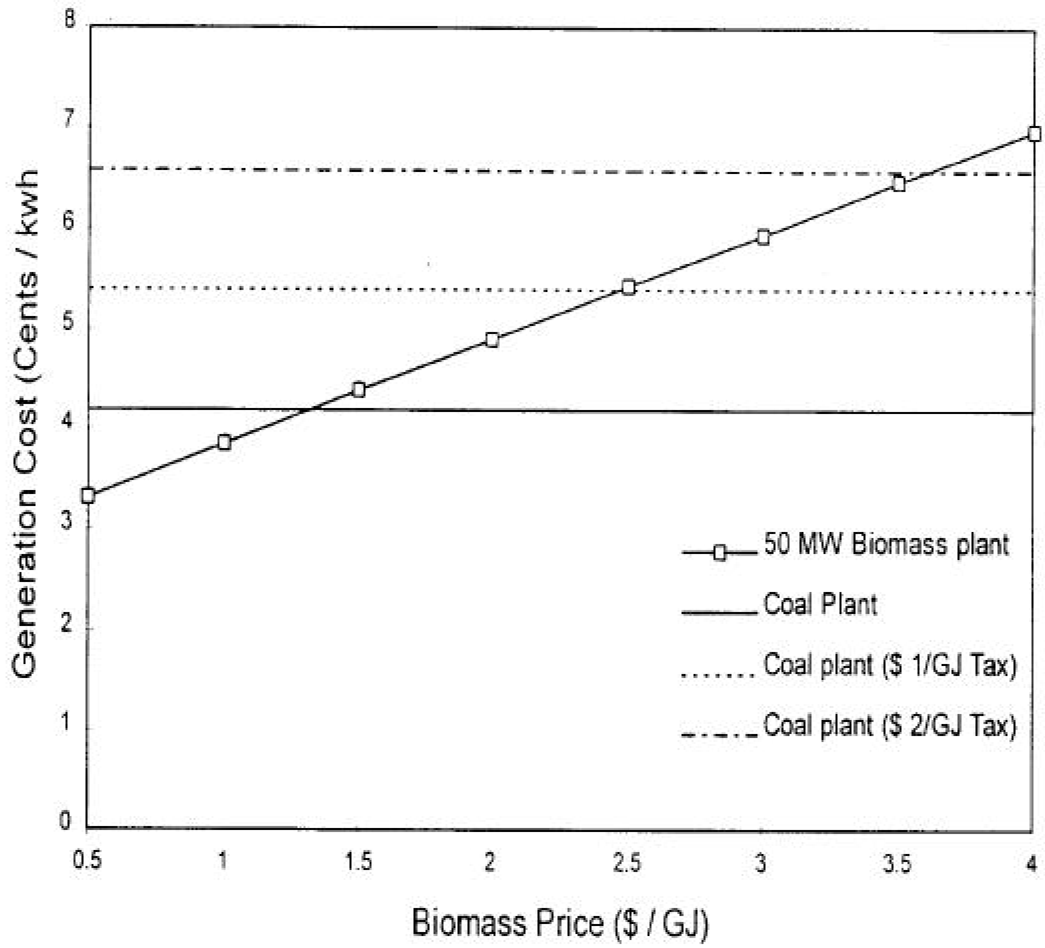
Cost Factor	Retrofit	New Plant
Capital Costs ($/kW)	150 – 270	120 – 210
Variable O&M (cents/kWh)	0.15 - 0.33	0.13 - 0.32
Total O & M (cents/kWh)	0.66 - 1.2	0.74 - 1.3

Note: Costs in 1990 US$

Source: Tavoulareas and Charpentier, 1995

The implications of these taxes on the electricity generation cost of a coal thermal power station (500 MW) using coal with a base price of $2/GJ are shown in Figure 8.8. With no environmental taxes, electricity from a coal power plant is cheaper than electricity from a biomass power plant for a biomass price above 1.3$/GJ. With low environmental taxes, the cost of electricity from biomass power plant is lower than electricity from a coal plant for a biomass price below $2.5/GJ. With high environmental taxes, biomass electricity is cheaper below the biomass price of 3.7$/GJ. The electricity generation cost for the coal plant increases by 1.2 cents/kWh under a low tax case and by 2.4 cents/kWh under a high tax case. The cost of delivered electricity under the low tax and high tax cases for coal power increases by 1.4 and 2.8 cents/kWh respectively. The desulfurisation cost range of 1 to 2 cents, suggests that desulfurisation technology is more expensive than a high sulphur tax. From this analysis, it is evident that under fair competition whereby externalities from fossil fuels are internalised, biomass power can be quite competitive with conventional fossil fuel based power plants.

Figure 8.8: Cost of biomass and coal power (with environmental taxes)



8.26 INSTITUTIONAL FRAMEWORK AND IMPLEMENTATION ISSUES

Two most critical factors contributing to the successful penetration of dendropower plants are institutional support and effective implementation. This is amply demonstrated by the experience of the dendropower programme in the Philippines. For conventional electricity generation technologies, the institutions, infrastructure and policies have evolved over a long period. The biomass based energy systems are of more recent origin and have different system features which require the creation of new and different institutional and infrastructure support, compared to that which exists for conventional energy. Since dendrothermal is a decentralised system, the institutional support has to come from diverse sources including the government, private sector, non-government organisations, international development agencies, extension services, co-operatives and financial institutions (Durst, 1990). The institutional framework for biomass based power systems needs to be developed pro-actively to support individual producers as well as to assist and co-ordinate national and regional programmes.

8.27 ROBUST INSTITUTIONAL FRAMEWORK FOR DENDROTHERMAL POWER

Compared to the conventional power technologies the need for an institutional framework to support dendrothermal power is greater for many reasons. The main reasons and the features of the institutional framework to deal with them are discussed below.

Market Failure**:** The fundamental reason for a stronger institutional framework to support dendrothermal power is that under existing energy and environment policies in most nations, the market is unable to recognise the environmental and social benefits offered by dendropower. Private investors, acting on market signals, have no incentive to invest in institutions and infrastructure to overcome this barrier. This market failure can be corrected only if robust institutions and appropriate policies are in place. Their absence would give unfair competitive disadvantage to conventional power technologies over dendropower.

Weak Market Linkages: The market for biomass energy is weak or non-existent. The support of the usual market institutions is therefore not naturally forthcoming in the case of biomass energy. The institutional linkages need to be created and supported, especially until the biomass energy is commercialised (Shukla, 1997a). Logistics support, trading infrastructure and an information network are crucial aspects for market development. Private organisations engaged in biomass plantations seldom include market development as part of their projects (EDI, 1986). This is often a cause contributing to the failure of dendropower programmes such as in the Philippines during the mid-1980's.

Biomass Energy Feedstock System**:** Dendrothermal power requires dedicated plantations for ensuring reliable biomass feedstock supply. Energy plantations are a relatively new concept. Besides, it is more akin to agriculture whereas the extraction operations for producing fossil energy are akin to industrial activities. The infrastructure and institutions to support agriculture are usually weaker than for industry, especially in developing countries. The supporting institutions therefore need to be developed afresh for biomass energy.

Financing the Biomass Growers: The farmers who switch to energy plantation are used to agriculture crop production which has a rotation period of a few months. They need the financial support during the long gestation period till the first harvesting. An institutional framework is needed for financing, for risk coverage as well as for technical inputs. Such support is essential in developing countries where the plantations are often owned by co-operatives of small farmers.

Risk Coverage: Users of biomass energy are exposed to greater risks of supply failure due to the dependence of biomass production on the agroclimatic factors which have natural variability. This calls for establishing supply and logistic linkages with other plantation sites or alternative energy sources. Besides, the risk coverage would require forming new insurance arrangements and co-operative agreements among the producers to share the risk. Trading institutions, which may offer price guarantees or make quantity purchase agreements (Durst, 1990) are also vital for risk coverage.

Decentralised Power Generation: Unlike conventional power generation technologies, dendrothermal power is a decentralised system. The role of co-ordinating institutions is therefore vital for technology research and development (R&D) as well as for the dissemination of innovations, information and learning (Ravindranath and Hall, 1995). The dissemination of knowledge and capacity building requires a stronger and decentralised institutional set-up, compared to that for the conventional electricity generating technologies.

***Role of the Government*: ** Strong institutional linkages with the government are essential for land tenure (Durst, 1990; Ravindranath and Hall, 1995), R&D support, demonstration projects (Ravindranath and Hall, 1995), liaison with international agencies (Davidson, 1990), and infrastructure. Since dendropower technology is at an early stage of the life cycle, it requires the "push" through government policies and institutional support. Regulatory support is also vital for exhorting the centralised power utilities which own the T&D network to wheel and bank the electricity generated by the decentralised dendrothermal units. The regulations and policies for internalising the externalities in the electricity costs are equally crucial for providing a level playing field for dendropower (Woods and Hall, 1994).

8.28 IMPLEMENTATION ISSUES AND STRATEGY FOR DENDROTHERMAL POWER

Dendrothermal power is an integrated system of energy feedstock production and power generation. It is also a decentralised system. These distinct features of biomass based electricity generation raise implementation issues which are very different from those of conventional centralised power generation systems. Some typical implementation issues in the context of dendrothermal systems are dealt with below.

Ownership: Ownership issues for biomass based power generation are typically due to the critical importance of land for biomass production and the decentralised nature of electricity generation. Often, the wastelands are owned by the government or local communities (Ravindranath and Hall, 1995). For private or even co-operative plantations, the long term land tenure arrangements are vital to provide an incentive to the growers, as well as to establish a stable plantation regime. In developing countries, agricultural land is parcelled among a large number of small landowners. The scale of each owner is not adequate for an economical tree plantation. The co-operative ownership of plantations is important in these situations for enhancing the scale of operations.

As a decentralised and moderately scaled system, the ownership pattern of dendrothermal plants can be different from that of the large utilities operating conventional power plants, that are either owned by large corporate firms or by the government - especially in many developing countries. The common ownership of plantations and the electricity generation plants would reduce the feedstock supply uncertainties. The ownership of the T&D network is usually with the centralised utilities. Very efficient management and co-ordination abilities are needed when all three systems - i.e. plantation, electricity generation plant and T&D network are owned separately. The government role is also vital in this situation to enforce a co-operative regime among the owners of different systems. The failures of the Filipino dendrothermal programme can be attributed to the absence of co-ordination among the owners of different systems, especially tree growers and power plant owners, as well as reduced government interest in the mid-1980's during the period of political crisis.

Decentralisation: Implementation problems for dendrothermal power plants are compounded by the decentralised nature of the system. Decentralised plantations, located in diverse agroclimatic zones, require different types of scientific and technological inputs. Strong logistical arrangements are needed for transporting the biomass and the electricity transmission. The unavailability of skilled personnel to manage decentralised systems operating in rural locations is often a major barrier in developing nations. An effective approach to assist decentralised implementation is that followed by the Indian government, which has set-up Biomass Research Centres in nine separate agroclimatic zones and four Gasifier Action Research Centres (Shukla, 1997a).

Site Development: The implementation issues vary critically across sites where plantations or power plants are located. Most vital aspects of site development are infrastructure development, capacity building and market development (Johansson et al., 1993a). Since the infrastructure is shared with other economic activities, arrangements have to be made to share the costs. The capacity building is needed for training the local persons in the operation and maintenance of dendrothermal systems, for providing the impetus to local innovations and encouraging rural enterpreneurship. Weak market development in the rural areas of developing countries is a primary barrier to the penetration of new and efficient technologies (Shukla, 1997b). Demonstration projects - supported by the government, local community, industry associations and development agencies - are very useful instruments for dissemination of technological knowledge as well as for gaining the initial implementation experience. The infrastructure, capacity building and market development has a close relationship with economic development which is akin to the classical "chicken and egg" paradox. The principal issue in site development is to break this vicious cycle through co-ordination, government support, long-term strategies and creating synergy with other development activities (Johansson et al., 1993a). Site development is crucial for realising maximum gains from dendrothermal projects and also for making the projects competitive and viable.

Technology Choices: An important decision influencing the implementation strategy is the technology choice. The type of biomass feedstock and scale of operations are vital elements in technology decision making. Unless advanced technologies are chosen, the personnel with experience in coal power plants can be available to operate and maintain the biomass technology. Technology supply however shall require new channels since the standard technology size for centralized coal plants is much higher (500 MW) than the largest biomass based power plants (50 MW). The lack of a manufacturing base or access to the biomass technologies is a major barrier to the selection of biomass power technologies in developing countries. International co-operation in technology and finance is very critical to overcome this barrier.

Management of Finances: The finance management function for biomass electricity is very different. The small farmers who switch over from agriculture to a plantation require financial support for subsistence during the long gestation period to first harvesting. The regular institutions providing finance for industries do not have such a facility. Arranging security is not easy for the farmers as their assets are not easily marketable. The financing for risk coverage against crop failure, which is very important for attracting the small growers has many implementation problems - such as the assessment of failure probabilities as well as the assessment of actual losses. In the developing nations, the insurance and financing infrastructure is very weak even for the regular commercial crops and acts as a major barrier for biomass plantations.

Identification of Niche Market: New technologies often penetrate through the window of opportunity created initially by niche applications. An important issue for the successful implementation of a dendrothermal programme is to carefully identify the niche applications, such as the co-generation in agroprocessing and wood processing industries where biomass is inherently competitive. The niche applications help to accumulate experience and thereby reduce costs.

Participatory Approach: The decentralised nature of dendropower makes the participatory approach inherently suitable for its implementation, especially in the developing countries. Here, multifarious barriers exist to the entry of large corporations which can operate dendropower as a unified commercial system. The land laws, traditions and other socio-economic considerations require participation of numerous small farmers, as well as the support of the government, non-government organisations and the local community. Co-operation is vital, as is revealed by the dendrothermal programme experience in the Philippines, where the allocation of poor land sites for plantation by the government was a major cause of programme failure (Durst, 1990). A key to successful dendropower programmes is centralised co-ordination, decentralised implementation and participatory management. The economic rationale for the participatory approach is that it reduces the risks as well as the transaction costs of dissemination and co-ordination. The participatory approach also helps in establishing synergy with other development programmes.

Monitoring and Control: The decentralised character of dendropower and the uncertainties associated with new technology and the feedstock supply from plantations make the monitoring and control very important elements of a dendrothermal programme. The success of dendrothermal plants requires industrial type management practices within a decentralised, rural and agriculture type system. Crucial items for monitoring and control are cash flows, operating performance of the plant, plantation yields, feedstock supply and all other major cost contributing activities. In the absence of support from established institutions, the monitoring and control must be exercised by the project stakeholders.

Dissemination Approach: The dendrothermal programme, such as in the Philippines, is run under a target based and “technology push” type approach in which planning and co-ordination are carried out centrally. The dissemination can be more effective if the market centred instruments such as tariff policies or environmental taxes and subsidies, which follow the “technology pull” paradigm, are integrated with the centralised target oriented approach. In general, the dissemination approach has to reconcile the basic top-down and centralised nature of dendrothermal planning (which is essential until the technology is commercially established) with the bottom-up and decentralised nature of its implementation and operation, which requires grassroots participation.

8.29 MODERN BIOMASS ENERGY: CASE STUDIES FROM INDIA

There is limited and yet growing experience of biomass energy projects in India. A few selected case studies are briefly described below.

8.30 BIOMASS GASIFIER FOR GLUTEN DRYING

The Universal Starch Chem-Allied Ltd., a private firm, installed a 500 kWh wood gasifier system for gluten drying in Maharashtra State in August, 1996. The gasifier unit was manufactured by an Indian company under the demonstration programme of MNES. A gasifier replaced the drying system with a capacity of consuming 135 litres of light diesel oil per hour. The gasifier system, costing Rs. 1.9 million (including Rs. 0.3 million subsidy), requires 0.4 tons of wood at capacity operation. The pay-back period for the system was estimated to be less than four years. The gasifier system is attributed with the added benefit of achieving a better coloured product.

8.31 TEA DRYING SYSTEM

Coonoor, a tea growing area in Nilgiris in Tamil Nadu state, has two thousand small, medium and large tea estates. Tea drying is normally done by two methods: i) indirect air heating through ducts using combustion furnaces of firewood or coal, or ii) using natural gas by direct combustion and subsequent dilution of the air to the desired temperature level for drying (120 to 130^{o}C). The latter process is common in the Darjeeling and Assam tea regions where natural gas is available. In Coonoor, natural gas is not available. Firewood or coal is used for energy for tea drying. In late 1996, M/s. Gur Tea Factory at Coonoor installed a 100 kWh gasifier and blower system (retrofitted with dryer) for tea drying with producer gas at a cost of Rs. 3.1 million. The gasifier system requires only 0.3 kg of wood per kilogram of dried tea (3% moisture) compared to 2 to 3 kg of wood for the combustion process of drying tea to 15% moisture. The quality of gasifier dried tea is better as cuppage and other marketable features of tea are not only preserved but are even enhanced in some batches.

8.32 VILLAGE ELECTRIFICATION

An important niche application area for the dendrothermal systems is village electrification. Two case studies of village electrification using biomass energy and operating under different conditions are presented below.

Biomass Electricity in Hosahalli Village

Hosahalli, a small non-electrified village of 42 households (population over 200), is located 110 km from Bangalore in Karnataka State. In 1988, a small scale energy plantation (2 hectares) and gasifier cum diesel generation (5 kW) demonstration project supported by the MNES was initiated to supply electricity to specified services in the village such as water pumping, lighting and flour mill operation (Woods and Hall, 1994). The engine was modified to operate both on diesel and wood gas to ensure a reliable electricity service. The gasifier system replaced 67% of the diesel. The system is managed by trained local personnel. Economic tariffs for electricity and water are locally decided. The project investment was Rs. 350,000 and the delivered electricity cost was Rs. 3.5 per kWh (14 cents) for a 4 hours per day operation period.

Biomass Electricity in Gosaba Village

Gosaba, an unelectrified remote island village with a population of 16,000, is located in the Sunderbans area of West Bengal State. The village is approachable only by boat/barges from Sonakhali, located 100 kilometres from Calcutta. There is an abundant biomass potential in the region. The electricity availability can change the development pattern in the region through myriad means such as improving: i) the quality of domestic life, ii) productivity of agriculture (irrigation and de-watering of low lying areas), iii) development of agro-based and small scale industries, and iv) preservation of fish for transportation to the mainland. There is an existing state owned forest on 10,000 hectares of land. On 1000 hectares of land available near the village, a successful captive plantation has been promoted with standardised techniques. A quarter of the plantation yield is presently committed for local consumption and the remainder is sold elsewhere at a price of Rs. 300-400 per ton. The site is ideal for biomass-based electricity project. A 500 kW (5x100 kW) gasifier project costing Rs. 9 million is under installation with full financial support from MNES and the state government. The state forest department has initially guaranteed the wood supply. A dedicated energy plantation operated by the local community is also planned. The project, anticipated to be operational in February 1997, is estimated to generate electricity at Rs. 2 per kWh (5.6 cents per kWh).

8.33 SMALL SCALE CAPTIVE POWER AND GRID INTERACTIVE SYSTEM

Ankur Scientific Energy Technologies, a private firm located at Vadodara city, in Gujarat state is a leading gasifier manufacturer in India. The company installed a 40 kW gasifier in 1988 for meeting its own power requirement during the periods of load shedding by the utility. A tree plantation with 4000 fast growing trees was set up on private land to ensure wood supply for the gasifier. The primary aim of the system was to demonstrate the feasibility of integrated energy plantation and power generation for captive use and grid feeding. The system has been supplying the surplus power to the Gujarat Electricity Board since 1989 at a competitive price (Rs.1.25/KWhr).

8.34 MEGAWATT SCALE GRID INTERACTIVE SYSTEMS

Kutch, a desert district in the State of Gujarat, is less developed and thinly populated. The average annual rainfall in the locality is only 250 mm. The rainfall pattern is very erratic and dry spells of long duration are common. There is little industrialisation in the locality. Electricity supply has the potential to change the development in the region. In 1987, MNES supported an energy plantation on 1000 hectares of wasteland in Moti Sindhodi village in Abdasa locality in Kutch. The plantation, completed in 1990, is estimated to yield 8-10 tons/ha/year wood in very difficult soil conditions and inadequate irrigation. In 1995, a project for the installation of a 500 KW grid-interactive gasifier- cum-diesel electricity generator was taken up near the energy plantation site. The electricity generation is to be expanded by adding new gasifier units since the plantation is able to support a 3-4 MW power system. The project, to be commissioned in early 1997, is expected to generate electricity at Rs. 2.25 per kWh (6.3 cents per kWh).

8.35 BIOMASS IN FUTURE ENERGY SCENARIOS

The growing concerns about global climate change and the awareness about the need to develop sustainable energy resources for the future have renewed interest in all renewable energy resources. In the Renewables-Intensive Global Energy Scenario (RIGES) designed to understand the outlook for renewable energy in the global context (Johansson et al., 1993b), biomass power emerged as a competitive option vis-à-vis coal “under a wide range of circumstances” (Johansson et al., 1993). Even under stringent assumptions, which restricted the biomass plantations to excess agriculture lands in industrialised nations and to deforested and degraded lands in developing countries, it was found that primary biomass energy supply can amount to 145 exajoules of energy in 2025 and 206 exajoules in 2050 (Johansson et al., 1993). For comparison, the global energy use in 1985 was 323 exajoules.

8.36 MODERN BIOMASS IN GLOBAL ENERGY SCENARIOS

In RIGES, most biomass is used for electricity generation and for fluid fuels. The biomass electricity provides over 17 percent of global power in the period 2025 to 2050. Nearly half of the biomass electricity generation in developing countries comes from sugar cane bagasse based co-generation. The plantations based power systems also have a large share. In RIGES, biomass replaces fossil fuels. Another important exercise for future energy systems has been carried out by the Response Strategy Working Group (RSWG) of the

Intergovernmental Panel on Climate Change (IPCC, 1991). The Accelerated Policy (AP) scenario, considered by the RSWG, makes similar projections for high biomass use in the future.

The low CO_2 energy supply system (LESS), constructed as "thought experiments" to explore the plausible energy futures with low CO_2 emissions also suggest high penetration of biomass energy (Johansson et al., 1996; IPCC, 1996a) in versatile forms like electricity, hydrogen derived by thermochemical process from biomass and liquid fuels (synfuels). Under the biomass intensive (BI) variant of the LESS scenario, biomass can provide one sixth of total global electricity from 2025 to 2050 and a quarter of global electricity from 2075 to 2100 (IPCC, 1996a).

The least costly liquid fuels from renewable sources are ethanol and methanol derived from biomass. These fuels have the potential to be competitive vis-à-vis refined oil products in the transportation sector. In RIGES, biomass derived methanol provides 45 exajoules energy in 2025 and 61 exajoules in 2050 representing 37 and 50 percent of global liquid fuel demand, respectively (Johansson et al., 1993b). In RIGES, biomass derived hydrogen is produced at a level of 16 exajoules in 2025 and 25 exajoules in 2050 representing 12 percent and 20 percent of gaseous fuel demand, respectively (Johansson et al., 1993). The future energy scenarios thus show considerable potential for the penetration of modern biomass fuels.

8.37 PROSPECTS OF BIOMASS POWER IN INDIA: AN ANALYSIS

The economic reforms in India have opened the doors for a competitive electricity sector in the future. The long-term penetration potential of biomass power is analysed by presuming the electricity sector to be subject to competitive dynamics. The analysis is performed using the Indian-MARKAL model (Shukla, 1996; Loulou et al., 1997) set up for the next forty years (1995-2035). In a competitive economic environment, different electricity generating technologies compete and penetrate in suitable niches. At present, the conventional energy technologies have unfair advantage to the extent that they fail to internalise the environmental costs. Under fair competition, these externalities need to be internalised. Apart from the business-as-usual (BAU) scenario where externalities are not neutralised, two other policy scenarios are considered. Each scenario uses different economic instruments to neutralise the unfair competitive advantage of fossil energy forms. One scenario considers the subsidy to biomass technologies to neutralise the negative externalities from fossil fuels. The second scenario imposes emissions targets for cumulative carbon emissions from energy use in India. This would annul the unfair advantage of fossil energy over biomass technologies.

At present, government policies in India provide subsidies to renewable technologies (Sinha, 1994). The entire subsidy package for biomass power, when converted in terms of equivalent subsidy on the investment cost, turns out to be equivalent to forty percent of the capital costs. In this analysis, two subsidy scenarios with forty and twenty percent subsidies on capital investment are considered. Two carbon emission limitation scenarios assume respectively a 20% and 10% reduction of cumulative emissions from India over the BAU scenario.

8.38 PENETRATION OF BIOMASS POWER TECHNOLOGIES

Penetration of biomass power under different subsidy and carbon emission reduction scenarios is shown in Figures 8.9 and 8.10. The biomass electricity generation technologies have substantial penetration potential. However, under the BAU scenario, the penetration in the year 2035 will be only 4,380 MW. Evidently, the level of subsidy or emission reduction target (or alternatively a carbon tax) has significant impact on the penetration of biomass power. The push provided by the subsidy prompts rapid early penetration (Figure 8.9), whereas the market pull resulting from carbon emission reduction accelerates the penetration levels only after two decades (Figure 8.10). Under high subsidy or high emission reduction policies, the penetration in the year 2035 reaches 35,000 MW. The share of biomass power will be 9% in the total power capacity in India. Biomass-based electricity would then replace 70 million tons of coal and save 40 million tons of carbon emissions annually.

Figure 8.9: Biomass electricity under subsidy scenarios

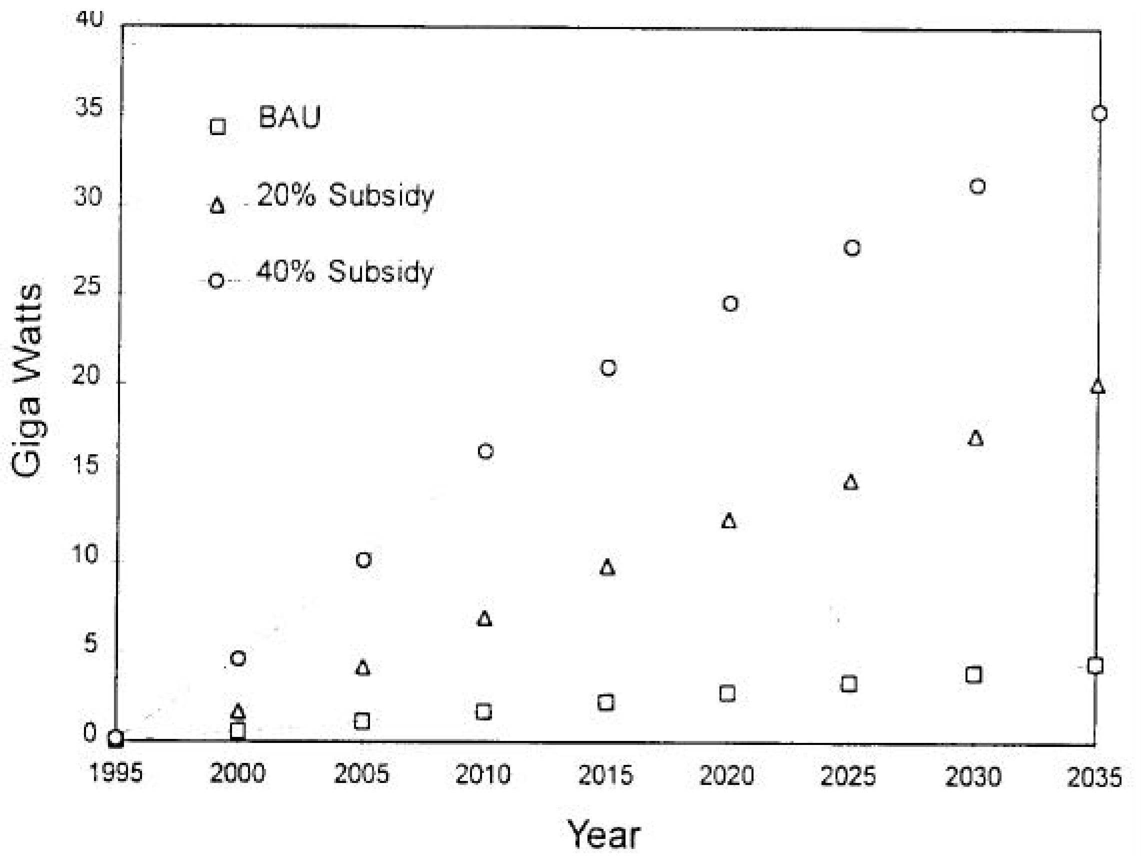
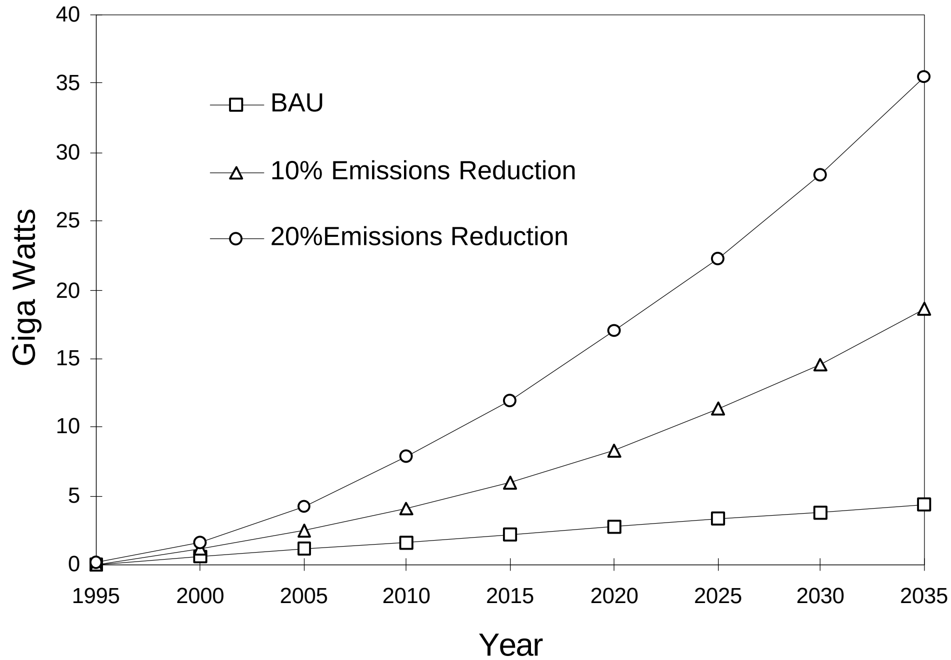


Figure 8.10: Biomass electricity under carbon emissions limitations



8.39 DISCUSSION AND CONCLUSIONS

Biomass remains an important energy source in the world, and especially in the developing countries. The biomass use in the developing countries is confined to traditional and rural sectors. A primary reason for the inefficient use of biomass in developing countries is that the biomass fuels acquire little or no monetary value since these are collected by family members who have little or no alternate employment opportunities (Mahadevia and Shukla, 1996). The efficiency of biomass use is thus inherently linked to the development policies such as the policies for employment generation, skill development and decentralised industrialisation.

In commercial energy markets, the vital barrier to the competitiveness of bioenergy is the implicit environmental as well as other subsidies enjoyed by fossil fuels. Governments can play a vital policy role by helping to correct the market failure which is hindering the penetration of biomass based power generation. In the past, governments have helped new energy technologies such as nuclear power in France (Johansson et al., 1996), wind power in Denmark (Johansson et al., 1996) and India (Naidu, 1997), and ethanol from sugarcane in Brazil (Goldemberg et al., 1993). The significant social and environmental benefits of biomass energy renders it a deserving alternative for support from the governments committed to sustainable development.

What is first needed to promote biomass energy, especially in developing countries, is a shift away from the traditional view of biomass to a new perspective whereby - i) biomass is treated as a competitive modern energy resource rather than a traditional “poor man's” fuel, ii) biomass energy applications are developed not only for decentralised niche markets, but also for competitive energy service markets, iii) technology policy is reoriented from a supply push to a demand (market) pull approach, iv) implicit and explicit subsidies on conventional fuels are abolished and v) biomass energy policies are integrated with other developmental and environmental policies. Myriad economic, social, technological and institutional barriers to the penetration of dendrothermal power exist. The prospects of biomass technologies depend on removing these barriers. The key issue before the policy makers is to develop the market for biomass energy services by ensuring a reliable and enhanced biomass supply, removing the tariff distortions favouring fossil fuels and producing energy services reliably with modern dendropower technologies at a competitive cost.

The analysis in this paper shows that if the social and environmental externalities from the conventional fuels are internalised in the electricity cost, the dendrothermal plants will be competitive at locations where biomass supply is reliably and economically available. The most critical factor affecting the competitiveness of biomass based power is the absence of an efficient market for biomass energy. Two vital responses to make biomass power competitive are - i) a reliable biomass supply, and ii) reliable delivery of energy services at a competitive cost. Biomass supply is enhanced by technologies which accept a wider range of biomass fuels like agriculture residues and wood processing waste. Advanced biomass gasification technologies are available which are highly efficient and can use a variety of biomass forms.

In the long run, a sustained supply of biomass can be ensured only through the enhanced production of energy crops. Three critical factors for ensuring a reliable biomass supply are: i) land supply, ii) technologies to improve land productivity, and iii) capabilities to manage biomass production. In many countries, especially in the developing world, some soft and yet effective responses to improve the productivity are: i) shift of ownership from government to private, co-operative and community organisations, ii) professional management of biomass plantations and end-products systems, iii) improved institutional support by co-ordination with multiple agencies, iv) policy support for awareness, capacity building, technology R&D, and enacting regulations for tariff guarantees, wheeling and banking of electricity by the utilities.

The experience of operating modern biomass plantations and energy conversion technologies is growing. The learning effects and the shared knowledge from the development of conventional technologies are rapidly enhancing the efficiency and the reliability of biomass production systems and conversion technologies. Although the present penetration of modern biomass energy services is limited, considering the technological developments and policy reforms in many countries which aim to eliminate energy subsidies and to internalise the externalities caused during the fuel cycle, the prospects will dendrothermal power are brighter. The realisation of these prospects will help many developing countries to make a smooth transition from the present inefficient biomass energy use in traditional sectors to a competitive, commercial and efficient biomass energy use in the future. This will lessen the burden of importing energy and thereby conserve scarce finances for national development.

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9. KUTCH POWER PLANT[1]

by

N.P. Singh, Director
Ministry of Non-Conventional Energy Sources
New Delhi, India

Kutch, a desert district in the state of Gujarat, is less developed and thinly populated. The average annual rainfall in the locality is only 250 mm. The rainfall pattern is very erratic and dry spells of long duration are common. There is little industrialisation in the locality. Electricity supply has the potential to change the development in the region. In 1987, MNES supported the establishment of an energy plantation on 1,000 hectares of wasteland in Moti Sindhodi village in Abdasa, Kutch. The plantation, completed in 1990, is estimated to yield 8-10 tons/ha/year wood in very difficult soil conditions and with inadequate irrigation. In 1995, a project for installation of 500 kW grid-interactive gasifier-cum-diesel electricity generation system was carried out near the energy plantation site.

Two basic options have been considered for harvesting the plantation - first, a heavily labour intense option and the second option involving use of portable, motorised hand tools. In the first case, felling and declimbing can be done by traditional methods using axes, hand saws, bush knives, etc. and with high quality steel and correct design, these simple tools can give acceptable results. In the second case, simple portable motorised chain saws or circular saws can be employed both to increase the productivity and to reduce the drudgery. There is a two-weeks waiting period for partial drying of piles of green wood at the landing sites. Partial drying will reduce the transportation costs.

It is proposed to store raw, partially dried feed i.e. logs brought from the plantation site for one month to take care of the rainy season. Chipping of logs/stems into pieces of 200-300 mm size is recommended. The proposed chips belt conveyor will move towards the feed-stock buffer storage. The other end of this conveyor will be at the buffer storage and then to another inclined conveyor moving upwards to the daily feed bunker above the gasifiers.
The gasifier installed at site is a single unit of 500 kW downdraft gasifier, developed and manufactured by an Indian company, M/s Ankur-Energy & Development Alternative, Vadodara. The technical specifications of the gasifier - DG Gen Set and sub systems, installed are as follows:

Weigh Bridge	:	3 tonne capacity
Wood Cutters (5 Nos)	:	600 kg/h of each cutter (motorised)
Belt Conveyor	:	Endless belt of rubber reinforced nylon, with side guards and speed control mechanism with ton/hour capacity.
Mechanical dryer	:	5 tonnes of dried material per batch (3 hour) capable of reducing moisture to 15% from 35% in 3 hours.

[1] ***Study prepared for RWEDP, 1997***

Gasifier		
Type	:	Down draft (stainless steel)
Capacity	:	500 kW net
Fuel (Biomass)	:	*Prosopis juliflora, P. tortillis, Acacia nilotica*
Turn down ratio	:	3
Gasifier efficiency	:	70%
Biomass Consumption	:	0.9 kg/kWh
Biomass feeding interval	:	15 mins
Ash removal	:	50 hrs. operation
Gas pre-ceaning system	:	Cyclone separator with ash disposal water seal
Ash removal system	:	Manual
Gas / cooling / scrubbing /	:	Ventury scrubber utilising water for cooling
cleaning system	:	Duplex filter with reusable filter medium.
Generator		
Rating	:	400 kVA 3 phase, 50 Hz
Ambient temperature	:	50 ^{o}C
Transformer	**:**	1000 KVA step up, 3 phase 50 Hz

The installation work of the various systems/subsystems has been completed and tested and the commissioning of the plant is expected by the end of September 1998. The expected cost of generation of electricity is Rs. 2.25 per kWh (6.3 cents per kWh).

M/s HCL Agro Power Plant

M/s HCL Agro Ltd., a private company based in Hyderabad, capital of Andhra Pradesh State decided to establish a 6 MW dendro power plant in 1995 with financial support of Rs.4.2 crores from MNES. *Prosopis juliflora* and other fuelwood species, grown nearby are the proposed feedstock for the power plant. The location of the plant is about 250 km from Hyderabad city. The company has already acquired 10 hectares land for the plant. The total plant cost is estimated to be about Rs.18 crores. The major equipment like boiler and turbine generator set has been procured from China. The power generated will be fed to a nearby 33 kV line of the Andhra Pradesh Electricity Board (APSEB) who will buy the power. Major indigenous equipment includes water treatment plant, cooling water circulating pumps, belt conveyor and overhead crane etc.

The total fuelwood requirement for the plant is expected to be about 7 tons/hr. The collection, transportation and handling of fuelwood is a critical component for successful operation of the plant. The company proposes to have 3 collection Centres with chippers at Nalagonda (150 km), Prakashan (250 km) and Krishna for the collection of fuelwood utilizing cement company trucks which come to the cement factory to load cement. The power plant is expected to be commissioned by June 1998. The salient features of the plant are given below:

Capacity	**:**	**6 MW**
Type of Boiler	:	Spreader Stoker Travelling Grate, 35 TPH, 39 kg/sqcm, 380 Deg C
Main Fuel	:	*Prosopis juliflora*
Storage Provision	:	2 Months
Fuel Preparation	:	Chopping to less than 3 inch size
Annual fuel requirement	:	45000 tonnes
Back-up fuel	:	Coal
Alternate Biomass	:	Bagasse, pulp mill rejects

The total anticipated cost of energy plantation and power generation is US $ 10 million. The project is founded jointly by the Ministry of Non-conventional Energy Sources (80 %) and Gujarat State (20 %). Gujarat Energy Development Agency will execute the project. The electricity generated is to be fed in the 11 KVA grid of Gujarat Electricity Board.

M/s MBDL Power Plant

M/s Mohan Breweries & Distilleries Ltd. Chennai, a major private sector company engaged in breweries and distilleries, commissioned a 12 MW biomass based power plant at Palayaseeram village in Chennai-MGR District of Tamil Nadu state. The plant has been in operation since May 1997 and utilizes bagasse, sugarcane waste (after bailing) and fuelwood. The plant is located next to a sugar mill of 2500 TCD capacity belonging to the same group. In the district of Cengai-MGR, nearly 10000 hectares of fellow land is covered with *prosopis juliflora* and other fuelwood species such as *casuarina.* The total cost of the land and building plant and machinery was Rs 40 crores (10 million US dollars). Rs. 12.50 crores is the promoter's contribution and the rest is a term loan from the Indian Renewable Energy Development Agency (IREDA) and Industrial Credit & Investment Corporation India (ICICI).

The yearly consumption of various types of biomass, for 325 days operation in a year, is 105,703 tonnes of bagasse, 8500 tonnes of cane waste and 38148 tonnes of wood chips. The company has contracts with farmers, forest department and sugar mills located within a radius of 40 kms from the plant.

The electricity generated is fed to the 33 kV grid of Tamil Nadu Electricity Board (TNEB) TNEB and MBDL has entered a power purchase agreement @Rs 2.25 per kWh (6 cents per kWh) with a wheeling charge of 20%.

The technicial specifications of plant machineries are as follows:

Steam Generator

Type	:	Natural circulation
Pressure (Kg/sg cas)	:	64
Temperature (oC)	:	480
Capacity (tonnes/hr)	:	70

Steam Turbine / alternative

Type	:	Condensing
Design rating (Mw)	:	12 (2 x 6 MW)
Specific steam consumption	:	4 Kgs. KWh
Suppliers/manufacturers	:	i) M/s Binny Engineering Works, Chennai for boiler & accessories
		ii) M/s Triveni Engineering Works, Bombay for Turbine and auxiliaries.

Cooling water

Consumption/day	:	60 cu m.
Open loop/closed loop	::	Closed loop / (cooling water)

<u>Financial Viability</u>

Loan repayment	:	7 years
construction / commissions period	:	8 months
Average debt service coverage:		**1.92**
Ratio (DSCR) over 10 years operation		

Present Status

At present the power plant feeds only 150,000 units of electricity to the grid as there is some back pressure problem in the turbine. This is being investigated by the supplier.

Fiscal And Financial Aspects

The power generation sector was opened to private companies in 1991 to augment the installed power generation capacity in India. A number of fiscal and financial incentives are available to manufactures and users of renewable energy technologies. Barriers to the participation of private industry or international manufacturers, in the setting up of manufacturing facilities or in the supply of equipment, materials and products, have been removed. Financial and technical collaborations are encouraged. There are a host of benefits available to both manufacturers and users of renewable energy systems. Some of these are as follows:

i) 100% depreciation for tax purposes in the first year of the installation of the systems.
ii) No excise duty on finished products.
iii) Low import tariffs for capital equipment and most materials and components.
iv) Soft loans to manufacturers and users by Indian Renewable Energy Development Agency (IREDA).
v) Wheeling and banking facility by State Electricity Boards.
vi) Remunerative price for the power generated through renewable energy systems, fed to the grid, by State Electricity Boards.

PART III: ANNEXES

ANNEX 1: LIST OF EXPERTS

China

Mr. Wang Xiwu
Director - General
Department of Environment Protection & Energy (DEPE)
Ministry of Agriculture, People's Republic of China
No. 11 Nongzhanguan Nanli
Beijing 100026
Tel: 86-10-64192612
Fax: 86-10-65002448

India

Prof. P.R. Shukla
Professor, Indian Institute of Management (IIM)
Vastrapur, Ahmedabad 380 015
Tel: 91-79-6407241
Fax: 91-79-6427896
E-mail: shukla@iimahd.ernet.in

Shri. N.P. Singh
Director
Ministry of Non-Conventional Energy Sources
Block No. 14, CGO Complex
Lodhi Road, New Delhi 110003
Tel: 91-11-4361920
Fax: 91-11-4361298, 4362706, 4361151
E-mail: npsingh@mnes1.hub.nic.in

Indonesia

Dr. Suwarto Martosudirjo
R&D Centre for Applied Physics – LIPI
Indonesian Institute of Sciences
Jalan Sangkuriang Kompleks LIPI
Bandung 40135
Tel: 62-22-2503052, 2504826
Fax: 62-22-2503050

Sri Lanka

Mr. P. Joseph
General Manager
Energy Conservation Fund (ECF)
Ministry of Irrigation & Power
Suite 2-202, BMICH, Baudhaloka Mawatha
Colombo – 7
Tel: 94-1-682534
Fax: 94-1-682534
E-mail: ecfujd@slt.lk

Philippines

Asian Development Bank

Mr. Kenneth McDicken
Forestry Specialist
Forest and Natural Resources Division West
Agriculture and Social Sectors Dept. (West)
Asian Development Bank
Manila

Mr. S. Tahir Quadri
Senior Environmental Specialist
Environment Division West
Asian Development Bank
Manila

Department of Energy

Dr. J. Elauria — Tel: 63-2-8447214
Director — Fax: 63-2-8447214
Energy Utilization Management Bureau
Department of Energy
PNPC Complex, Merritt Road
Fort Bonifacio, Metro Manila 1201

Dr. Francisco L. Viray
Secretary
Department of Energy

FAO Investment Centre Division

Mr. Roland Schurmann — Tel: 63-2-8939593
Senior Economist — Fax: 63-2-8171654
Investment Centre Division
FAO, P.O. Box 7285 DAPO
Pasay City, Metro Manila

Finland Embassy of the Philippines

Mr. Pertti Majanen — Tel: (63-2) 8915011..5
Ambassador — Fax: (63-2) 8914107
Embassy of Finland
Far East Bank Center
Sen . Gil Puyat Ave., Makati City

Cristina M. Marquinez — Tel: (63-2) 8915011..15
Chief Trade Officer — Fax: (63-2) 8914106..7
Finland Trade Center — Email: ftcphil@csi.com.ph
Embassy of Finland
Far East Bank Center
Sen . Gil Puyat Ave., Makati City

Netherlands Embassy of the Philippines

Eric T. J. T. Kwint
Ambassador
Netherlands Embassy of the Philippines

Preferred Energy Incorporated

Grace Santibanez-Yeneza — Tel: (63-2) 6312826; 635-4713
Managing Director — Fax: (63-2) 6327097
Preferred Energy Incorporated — Email: PEI@info.com.ph
10/F Strata 100 Bldg., Emerald Ave.
Ortigas Center, Pasig City 1600, Metro Manila

United Nations Development Programme
Jorge L. Reyes — Tel: (63-2) 8927666, 8920611-25 ext 276
Sustainable Development Advisor — Fax: (63-2) 8164061
United Nations Development Programme — Email jorge.reyes@undp.org
NEDA Makati Building
106 Amorsolo St. Legaspi Village
Makati, Metro Manila, Philippines
Thailand

Yala Power Producer Co., Ltd.
Mr. Pireeyutma Vanapruk — Tel: 66-2-6183204-5, 279-3810
Managing Director — Fax: 66-2-6186049
Yala Power Producer Co., Ltd.
71/5 Setsiri 2 Rd.
Phyathai
Bangkok 10400

Electricity Generating Public Company Limited
Mr. Anucha Chancharas — Tel: 66-2-5132330
EGCO — Fax: 66-2-5137335-6
444 Olympia Thai Tower
18-19th Floor, Rachadapisek Road
Samsennok, Huaykwang
Bangkok 10320

Mr. Direk Wangudomsuk — Tel: 66-2-5132330
EGCO — Fax: 66-2-5137335-6
444 Olympia Thai Tower
18-19th Floor, Rachadapisek Road
Samsennok, Huaykwang
Bangkok 10320

Asian Institute of Technology
Prof. S.C. Bhattacharya — Tel: 66-2-5245440
School of Environment, Resources and Development (SERD) — Fax: 66-2-5245439
Asian Institute of Technology (AIT)
P.O. Box 4, Klong Luang
Pathumthani 12120

EC-ASEAN COGEN Programme
Dr. Ludovic Lacrosse — Tel: 66-2-5246399
Technical Advisor — Fax: 66-2-5245396
EC-ASEAN COGEN Programme — E-mail: cogen@ait.ac.th
Asian Institute of Technology
P.O. Box 4, Klong Luang
Pathumthani 12120

UN ESCAP

Mr. P.C. Saha
Energy Resources Section
Env. and Natural Resources Management Div (ESCAP)
The United Nations Building
Rajadamnern Nok Avenue
Bangkok 10200
Tel: (66-2) 288-1546
Fax: (66-2) 288-1059
E-mail: saha.unescap@un.org

Finland Embassy of Thailand

Mr. Jussi-Pekka Aittola
Trade Commissioner, Finland Trade Center
Embassy of Finland, Amarin Tower
16th Floor, 500 Ploenchit Rd. Bangkok 10330
Tel: (66-2) 2569611-3
Fax: (66-2) 2569920
E-mail: jussi@mozart.inet.co.th

USA
Alternative Energy Development

Mr. Matthew S. Mendis
President
Alternative Energy Development (AED)
8455 Colesville Road, Suite 1225
Silver Spring, MD 20910
Tel: 1-301-608-3666
Fax: 1-301-608-3667
E-mail: 74003.2214@CompuServe.COM

The Netherlands
Utrecht University

Dr. Andre Faaij
Department of Science, Technology and Society
Utrecht University
Padualaan 14, 3584 CH, Utrecht
Tel: 31-30-2537643/00
Fax: 31-30-2537601
E-mail: faaij@princeton.edu
FAO

FAO Philippines

Mr. Virander K. Sibal
FAO Representative of the Philippines

FAO RAPO

Mr. P. Durst
Regional Forestry Officer
FAO Regional Office
39 Phra Atit Road, Bangkok 10200
Tel: 66-2-2817844 Ext. 139
Fax: 66-2-2800445

FAO RWEDP
Regional Wood Energy Development Programme in Asia — *Tel: 66-2-2802760*
39 Maliwan Mansion, Phra Atit Road — *Fax: 66-2-2800760*
Bangkok 10200 — *E-mail: rwedp@fao.org*
W. Hulscher
Chief Technical Adviser

A. Koopmans
Wood Energy Conservation Specialist

J. Koppejan
APO/Wood Energy Conservation

Administrative Support Staff
Cristina Sriratana
Administrative Assistant, RWEDP

Jaruwan Thananimit
Secretary, RWEDP

NCED/Department Of Energy
Reuben T. Quejas — Tel: 63-2-8188614
Chief, Non-Conventional Energy Division — Fax: 63-2-8447214
Department of Energy

Lisa Go
Non-Conventional Energy Division
Department of Energy
Programme of the Consultation

ANNEX 2: CONSULTATION SCHEDULE

31 March Arrival of Delegates

19:00 *Cocktail reception*

1 April Energy, Climate & Biomass

08:30 *Registration*

09.00 Opening Ceremony

Welcome Address
Mr. Virander Sibal, FAO Representative, Philippines

09.10 Statement
Framework & objectives of the expert consultation
Dr. W. S. Hulscher, Chief Technical Advisor, FAO-RWEDP

FCCC, IPCC and Kyoto Protocol,
Dr. P. R. Shukla, Indian Institute of Management, India

10:15 *coffee and group photo*

10.45 Statement
Dr. Francesco L. Viray, Secretary, Department of Energy, Philippines

11.05 Dendropower and woodfuel production systems: Economic analysis and Implementation Strategies
Dr. P. R. Shukla, Indian Institute of Management, India

12.00 Discussion: Energy & Climate Policies

12.30 *lunch*

14.00 Shadow Pricing for Carbon Emissions
Mr. J. Koppejan, APO Wood Energy Conservation, FAO-RWEDP

14.10 Discussion: Energy & climate policies (continued)

15.00 *tea*

15.30 Opportunities for forestry investment in Asia and the Pacific through carbon offset initiatives
Mr. P. Durst, Regional Forestry Officer, FAO Regional Office, Bangkok

15.50 Biomass resource base in Asia
Mr. Auke Koopmans, Wood Energy Conservation Specialist, FAO-RWEDP

16.00 Discussion: Bio-energy resource base

..... *end of day 1*

<u>2 April Biomass Energy Projects</u>

09.00 Optimizing energy from biomass
Dr. Andre Faaij, Department of Science, Technology and Society, Utrecht University, Netherlands

09.50 Institutional Developments in Private Sector Participation in Power Generation in Asia
Mr. P.C. Saha, Env. and Natural Res. Management Div., UN-ESCAP, Thailand

10.30 coffee

11.00 Project preparation,
Mr. Roland Schurmann, Investment Centre Division, FAO, Philippines

11.30 Discussion: Options for dendro-power in Asia

12.30 lunch

14.00 Examples of co-generation projects
Dr. Ludovic Lacrosse, EC-ASEAN COGEN Programme, AIT, Thailand

14.20 Case study: Bagasse Power in Indonesia
Mr. Matthew Mendis, President, Alternative Energy Development, USA

14.40 Case study: Dendro power in India
Shri N.P. Singh, MNES, New Delhi, India

15.00 tea

15.30 Discussion: Projects, Technologies & Management

.... end of day 2

<u>3 April Economics, Investments & Financing</u>

09.00 Investments in Bio-Power and Financial Packaging of Projects
Mr. Matthew Mendis, President, Alternative Energy Development, USA

10.00 coffee

10.30 Discussion: Dendro Power Economics & Project Formulation

12.00 lunch

13.30 Discussion: Implementation, Investments & Financing Strategies

15.00 tea

15.30 Discussion: Conclusions & Recommendations

.... end of day 3

20.00 Farewell Dinner

ANNEX 3: OPENING CEREMONY

WELCOME ADDRESS BY MR. VIRANDER K. SIBAL, FAO REPRESENTATIVE IN THE PHILIPPINES

Secretary Viray, Colleagues from FAO, Participants, Ladies and gentlemen,

As you may be aware, one of the principle aims of the Food and Agriculture Organization of the United Nations is to support food security for all people. The World Food Summit in November 1996 at FAO's Headquarters in Rome, has renewed the global commitment to this end and to the common fight against hunger. The Rome Declaration on World Food Security led to the World Food Summit Plan of Action, which is now being implemented.

Achieving food security is a complex task, which needs support from various related policy areas. Amongst these are obviously agriculture, livestock and fisheries, but also forestry, environment, natural and human resources, rural development, infrastructure, and many more, because their contributions are necessary to secure food for all. As you may have observed, FAO is assisting the member countries of the Organization through its regular programme and several field projects in these policy areas.

Third parties who focus on the energy sector, may not associate that sector immediately with FAO. It is not yet sufficiently known that FAO has in fact a long-standing interest and programmes in the development of wood energy, which supplies about one third of the national energy consumption in this part of the world. Such information is often not included in energy statistics.

FAO's activities in wood energy arose from concerns for the daily needs of millions of subsistence users in the context of rural development. After all, food must be cooked using energy. For most people in the developing countries this energy consists of fuelwood and this situation is not likely to change in the foreseeable future. The dimensions of wood energy development are, of course, care for the local environment, the natural forests, the rural economy and the well being of people.

The attention to wood energy intensified when the need for renewable energy sources became prominent in the early 1980's, as a response to concerns for the global environment. FAO took up this challenge in various ways. In the 1980's the Regional Wood Energy Development Programme in Asia was conceptualised by FAO jointly with the then 8 member countries. This regional project, which is generously being funded by the Government of the Netherlands, is now in its third phase and is linking 16 member countries.

Over the years the activities have developed into a full-fledged programme addressing virtually all aspects of wood energy development. As the programme deals with the daily and main fuel needs of more than half of the world population, it may not be justified any more to ignore FAO as one of the world's major actors on the energy scene. Apart from FAO's pioneering role, the more important issue is to translate the tremendous importance of wood energy into relevant policies and to fully exploit the options, of course on a sustainable basis.

With increasing populations there is an increasing energy demand. More people have to be fed, more people are in demand for domestic energy, and more energy is required for industrial processes, including rural and agro-industries and services. The options for wood energy development go well beyond subsistence and small-scale use. We know already of numerous commercial and industrial uses of fuelwood in the rural and peri-urban settings in Asia, many of which use woodfuel still in a traditional way.

Increasing populations and economic advancements also demand increasingly modern forms of energy. At present modern and large scale applications of wood energy have proven to be feasible and successful. However, the latter applications happen to be more widespread and better accommodated in industrialised countries than in the developing countries of Asia. Why are the latter countries lagging in these modern developments? Is that necessary?

It is a laudable initiative of the Regional Wood Energy Development Programme, RWEDP, to convene the present Expert Consultation to overview the situation and to identify, analyse and discuss the options for modern applications of woodfuel in Asia, particularly for the purpose of electricity generation. Which are the potential resources? Which technologies are available and applicable? Which are the managerial and financial options? What are the policy and institutional implications?

I think the Consultation is very timely coming as it does in the aftermath of the Kyoto Summit, last December, when countries pledged their commitments to reduction of greenhouse gases for the sake of avoiding further risks of global climate change. Amongst the many options to reduce emission of greenhouse gases, the utilisation of renewable energy is an obvious one. This applies in particular to wood and other biomass fuels which are still under-utilised.

A recent study of RWEDP on Wood Energy Today and Tomorrow in Asia (published as RWEDP Field Document Number 50), has shown that by and large woodfuels are grown and utilized in a sustainable way. This is an important message with major policy implications. It allows us to make estimates of the current saving of greenhouse gases thanks to woodfuel use. With additional efforts, the benefits could be expanded further.

Interestingly, the Asia Pacific Forestry Commission in its meeting at Yogyakarta two months ago, underlined the present importance of woodfuels and their future potential, not only in the context of local conditions but also for the sake of the global environment. In your meetings in this Expert Consultation in the coming days, you will go a few steps further and analyse the options for modern uses of woodfuels in Asia, in the context of both local and global conditions. I think you will be guided very well by the draft study of Professor Shukla and Dr. N. P. Singh, which has been prepared for this meeting.

Amongst the strengths of a programme like RWEDP are the exchange of expertise and information amongst its member countries, and the provision of a platform for discussing common problems and new developments by regional and international experts. Throughout the three phases of RWEDP, the Philippines has always been an active member. Relevant experiences from this country have been communicated, contributions to workshops have been provided, and at the same time Philippine staff have benefited from training opportunities provided by RWEDP.

It may be no coincidence that the present regional meeting has been convened in the Philippines, because this country has already been involved in dendro-power generation since the early 1980's. It will be very interesting to review the subject against the background of recent developments, new technological options, and new policies with regard to global climate issues.

I am pleased to observe that FAO, in this case RWEDP, is working together with other specialized institutions. Individuals and experts from several important regional and international organizations and international financial institutions, as well as delegates from government and private sector organisations, including experts from USA and Europe, will participate in this Expert Consultation. I would like to congratulate RWEDP for the initiative of bringing the experts together on a subject which is very timely, in a meeting which seems to be well organised and facilitated by the Department of Energy of the Philippines.

I would like to extend a warm welcome to all of you. I am sure you will find the conditions set for fruitful discussions. I wish you a pleasant stay in Manila and all success with your work.
Thank you.

STATEMENT BY DR. W.S. HULSCHER, CTA, RWEDP

Mr. Eric T. J. T. Kwint, Ambassador of the Royal Government of the Netherlands in the Philippines,

Dr. Francisco L. Viray, Secretary of the Department of Energy of the Philippines
Ladies and gentlemen,

It is a privilege and a pleasure to make a few statements at the opening of the Expert Consultation on Options for Dendro-power in Asia. First, on behalf of RWEDP I like to welcome you all at this meeting. I am delighted to see so many experts and representatives from key organizations within and closely around the focus of our theme. I would like to welcome specifically Professor Shukla and Dr. N.P. Singh from India, who are the authors of the main report to be reviewed and discussed during our meetings. I also specially welcome those who have travelled a long way, Mr. Mathew Mendis from the USA and Dr. Andre Faaij from The Netherlands. In fact, I should like to specially mention all of you, friends, experts, delegates, but my statement would become too long.

I would like to thank Mr. Sibal, FAO Representative in The Philippines, for his Welcome Address. Mr. Sibal has already mentioned some important points to which I will link in my remarks. As you know, because of another commitment at this very moment, Mr. Viray will come later.

Ladies and gentlemen,

"Options for Dendro-power in Asia" in our subject here in The Philippines. What is the point? Are we to look back and unravel what has happened in this country some 15 years ago? Many people recall that in those days, the Philippines together with Brazil were the countries attracting most attention world-wide with their dendro-energy programmes. We also may know that these programmes failed to meet their promise for various reasons. Unfortunately, this has been rather traumatising for many years not only for dendro power, but also for renewable energies in general. Are we meeting here to find out what exactly has happened and why?

I would say no. Of course, we are keen to take lessons from the past, but we did not gather here as a group of expert-historians. We rather want to overview the present situation against the background of new technologies, new managerial concepts, new markets and demands, new legal structures and institutions, and new policies with respect to energy and environment. In the dendro-years of the mid 1980's the word 'Carbon shadow pricing' did not even exist, whereas these days it is part of the terminology of the World Bank. Around us the world has moved on, and we should take stock of that and look into the options for the future.

Having said this, I would like to briefly refer to a few relevant developments elsewhere. We can observe that worldwide a momentum is building up with regard to generating energy and power from woodfuels.

Almost two years ago the ninth European Bio-energy Conference was convened in Copenhagen under the title "Biomass for Energy and the Environment". In a nutshell, this very title carried the main message of that leading conference. It was noted that major technological and managerial advances had paved the way for making good use of biomass for the sake of supplying energy in an economically feasible way, at the same time supporting environmental policies. An increasing involvement of the large power producers was reported, as well as growing political commitments of several European countries. In the conference a lot of emphasis was put on bringing bio-energy to the marketplace. Interestingly, the representative of the European Commission also referred to the beneficial employment aspects of biomass energy supply and processing.

Policies and practices of biomass energy in industrialised countries are now advancing considerably. Recently, RWEDP published a brief overview of the present situation in Finland, Sweden, Austria, the European Union, and USA. This overview, compiled by Jaap Koppejan, clearly shows the significant momentum in the promotion of biomass energy for both environmental and economic reasons, and the resulting progress in the implementation of biomass power generation.

Interesting developments are also taking place on other fronts, for instance in the OECD, which is a major governmental policy making body. A year ago, the first workshop of the OECD-IEA focussed on biomass energy data, analysis and trends. Last week their second workshop on this subject again brought many specialists together in Paris. It is relevant to note that the studies of OECD include the position of non-OECD countries. This illustrates that OECD also takes biomass energy seriously for developing countries.

The World Energy Council which is the main international non-governmental policymaking body on the energy scene, has since long acknowledged the role of wood and biomass energy in its overviews of current and future consumption. The regional WEC Conferences in New Delhi and Beijing in 1996 and 1997 had special sessions devoted to biomass energy. The same will be the case at the giant world conference of the WEC at Houston, later this year.

Most significant in my view is that a multinational energy company like Shell is reported to be a partner in a large project for dedicated dendro-power in Brazil. The technology will be gasification and utilisation of gas turbines in units of 25 to 50 MW. The efficiency is reported to be twice the efficiency of conventional biomass steam technology. The initiatives came from local electricity companies and the whole programme received approval from the

Global Environment Facility. Shell foresees a world-wide expansion of these types of biomass power stations.

Coming to the UN family, it is noteworthy that the UNDP Report 'Energy after Rio' which was published last year, overviews the new opportunities in biomass power supply and systems. The report refers to various mature technical options in the range from 5 kW to 30 MW.

World-wide, our own FAO has been involved in wood energy for many years, initially in the context of subsistence and basic needs satisfaction. This involvement has become complemented by a broader interest in renewable energy options, within the Forestry and other Departments of FAO. Now FAO's assistance focuses on developing a blend of energy sources and applications to meet specific requirements for improved food security and fuel for people. That includes the production of wood-based commercial energy for industrial and community needs.

Focussing now on Asia, I observe that momentum for wood energy is gradually gathering. The options for biomass power are being accepted and even promoted by energy departments and policy bodies in several countries, for instance the National Energy Policy Office of Thailand. I will not elaborate on this, because it will be more interesting to listen to Dr. Viray on such subjects.

Rather, I would like to mention the forestry sector in which a parallel process seems to be taking off. The meeting of the Asia Pacific Forestry Commission 6 weeks ago at Yogyakarta, paid considerable attention to wood energy. The Commission observed that technological advancements in fuel preparation, co-generation, combustion and gasification, have allowed woodfuels to become a modern and accepted fuel for the industry and power sector in many industrialised countries. The Commission stated that wood energy faces the great challenge of coming closer to mainstream policy agendas in Asia.

According to the Forestry Commission, the applications are still limited in Asia, and extension services for such modern applications of woodfuels are not yet well-developed. Some countries have made substantial progress in this, others have not yet. In the latter countries wood energy is still largely considered a traditional and "poor peoples' fuel". Transforming woodfuels into a commercial industrial fuel is still in its initial stages in these countries.

The Commission further stated that the competitiveness of wood fuels, compared to conventional industrial fuels, may depend on market developments as well as financing arrangements in the context of international policies for the mitigation of global climate change. I think we gathered here in Manila exactly to discuss these matters.

I am keen to learn what further policies are being developed by the ASEAN Energy Ministers. Last year I was invited jointly with delegates from AEEMTRC and the COGEN project, to present the case of biomass power in the ASEAN energy meeting here at Manila. A document on this is available here in our meeting today.

Ladies and gentlemen,

If you allow me I will also briefly refer to our own work at RWEDP. As you may know, the Regional Wood Energy Development Programme links 16 countries in Asia. RWEDP's recent work addressed the current and future position of wood energy in the region. Our study has been reported in a document sent to all of you, and for our coming discussions I would like to summarise a few main points.

We have analysed and documented the sustainability of the present consumption patterns of woodfuels in Asia by modelling studies, making use of the best available data. Contrary to popular believe, it turns out that woodfuel use is generally sustainable, and that with present trends this will remain so at least until the year 2010. As Mr. Sibal mentioned, this has allowed us to make an estimate of the global environmental benefits achieved in Asia by utilising this CO_2 neutral fuel. The benefits are considerable.

RWEDP tries to correct the false image that woodfuel is just a traditional fuel, which even 'traps the people in poverty' as the World Bank mentioned in one of its policy documents. Our view is that nothing is wrong with the fuel. What does need to be improved is the technology by which people utilise woodfuels, whether large-scale or small-scale. Supported by proper institutions, woodfuel can be as modern as any other fuel. It is not widely known, though quite significant, that North America consumes the same amount of woodfuel per capita as South Asia. Who believes that the North-Americans are trapped in poverty?

Ladies and gentlemen,

Let's not be carried away by a renewable energy euphoria. What we are interested in is mature technologies, which are ecomically feasible and environmentally sustainable. And what we are particularly interested in, is dedicated dendro-power. We do not exclude other forms of biomass power though. In fact we aim to learn from experiences with these. I was told that for sugar plants in India these days, the sugar has more or less become a by-product of selling power from bagasse. That may be exaggerated, but still very interesting because it is only 4 years ago that institutional settings, market structures and attitudes of sugar producers were very much adverse to selling power.

I said 'dedicated dendro-power'. We mean to include of course co-generation, and also any options for a mix of feedstocks which could include wood residues or available biomass in general. I am sure we will learn from the experiences of the successful ASEAN-EC COGEN Project, to be presented by Ludovic Lacrosse. In Asia up to now, fuel is still largely a by-product from trees, though there are exceptions. Will that remain so? What are the niches, what are the mainstream options? How will they be realized? These are my questions, which I hope will be answered during this Expert Consultation.

Most important are of course, recent trends in global climate policies and associated financial options, developing after the Kyoto Summit. As far as I know, the Kyoto protocol does not specifically refer to wood or biomass energy, but I think the paper to be presented by Patrick Durst will show that wood energy fits very well in global environmental policies. At this very moment a major meeting of the Global Environmental Facility is going on in New Delhi and that is why, unfortunately, no GEF official can be with us here in Manila. However, next week I will meet with a senior official from the World Bank's International Finance Corporation who is in charge of GEF matters, to discuss the outcome of our Expert Consultation.

Issues which are very much related to our subject are those of project packaging, institutional requirements, power sector developments, etc, which are all in our programme. To what extent the present state of economies and exchange rates in Asia provide a constraint or in fact new options and new challenges will, no doubt, come into our considerations.

You may have noticed that we deliberately kept ample time in the programme for discussions. After all, you came here to interact, and not just to listen. That means that, unfortunately, we had to limit the time for presentations. The discussions will be plenary 'round table discussions' in which every expert is free to contribute. The conclusions of the Expert Consultation will be reported by RWEDP and presented to all member countries and other relevant parties.

Ladies and gentlemen,

Now I would like to give way to more competent speakers. However my last and very pleasant duty is to thank our partner, the Department of Energy of the Philippines, and in particular the Non-conventional Energy Division for taking care so competently of all local arrangements. It has always been a pleasure to work with our friends from the "Non-Con", a pleasure I have enjoyed for 15 years. Eventually, when we are really successful in our work, can we then drop the prefix "Non"? When will that be? Think about it.
Thank you very much.

STATEMENT BY SECRETARY F. L. VIRAY

Dr Virander Sibal, Dr. Wim Hulscher, participants in this consultation workshop, ladies and gentlemen,

A pleasant morning to all of you.

The Department of Energy continues to intensify its efforts to accelerate the promotion and utilization of New and Renewable Energy systems in the country through various projects and activities. I am very pleased that in today's consultation, the focus is on another NRE option -- dendro power or wood energy -- in the broad spectrum of biomass energy sources. I am very sure that the first attempt in the Philippines to sustain a dendro thermal power program will be taken up here. I think that the lessons learned from that experience would be valuable inputs in today's exercise.

NRES in the Planning Scenario.

In the energy mix of 1996, the contribution of NRE was around 66.6 million barrels of fuel equivalent (MMBFOE). Biomass took almost all of that, leaving only about 0.25 MMBFOE for other NRE systems. Wood / woodwastes contributed more than 50% at about 39.25 MMBFOE. The other large contributions came from bagasse, coconut residues and rice hull.

The Department has updated the Philippine Energy Plan (PEP) for the planning horizon 1998-2035. In the Plan Update, NRES are expected to contribute about 72 MMBFOE to the total energy mix in 1998, increasing substantially to around 252 MMBFOE by 2035. The biomass energy sources are expected to dominate the energy mix at about 99 percent, again with woodwastes, coconut residues, bagasse, rice residues and municipal wastes as principal contributors.

In terms of capacity additions from 1998 to 2025, NRE is expected to contribute a total of 4,172 MW, starting with 81 MW before the century is over, and almost 2000 MW in the period 2021-2025. Biomass and waste-to-energy systems are expected to give the significant shares here.

There is a window for other fuels, which are identified as imported coal, imported oil and nuclear energy at this stage. In response to the government program of "Pole-Vaulting the Philippines to the 21st Century", the Department forwarded a strong and visionary commitment to developing ocean, solar and wind energy resources to replace the 'other fuels' in the PEP.

Needless to say, the dendro thermal power option is not in the planning scenario. However, the Department, in a manner of speaking, has taken a second look. During the strategic planning workshop of the Department in January this year, the Energy Utilization and Management Bureau committed to a number of activities, which are of significance in this consultation exercise. These are:

- Formulation of a policy statement on wood energy development;
- Encouragement of wood energy farms in coordination with DENR and initiating ground working activities with the Department of Agriculture and DENR; and
- Development of biomass for power generation to be handled by the private sector while DOE will handle non-power applications.

The NRES program is part of the energy sector's firm plans and programs based on sound policies to keep pace with the country's determined efforts to become a newly industrialized economy by the turn of this century. The goal of the Department is three pronged: energy supply availability; competitive, affordable and reasonable energy prices; and socially and environmentally compatible energy infrastructures. These are to be pursued within a framework of national energy that include:

- energy self-sufficiency through continuous exploration, development of indigenous energy sources;
- large-scale use of NRES;
- judicious conservation and efficient utilisation of energy;
- adoption of environment-friendly energy systems;
- greater private sector investment and participation in all energy activities; and
- integrating social and environmental concerns in the planning and implementation of energy programs and projects.

The Kyoto protocol to the United Nations Framework Convention on Climate Change has undoubtedly cast its shadow in all energy program planning worldwide. There are "no developing country commitments, no evolution article for future commitments and no voluntary undertaking". But it is worth to note that each Party in the Protocol shall implement the "promotion, research, development and increased use of new and renewable forms of energy, of carbon dioxide sequestration technologies and of advanced and innovative environmentally sound technologies".

The Philippine Dendro-Thermal Power Experience

The dendro thermal energy option is not something new to the Philippines. In 1980, the fuelwood-based power or dendro-thermal power program was launched with the primary aim of providing low-cost electricity to the rural communities. Under the management of the National Electrification Administration (NEA), the program targeted the participation of the rural electric co-operatives and wood grower's co-operatives.

The project aimed to install 70 wood-fired power plants with a capacity of 200 MW by 1987. The project ended in utter failure: six (6) dendro-thermal power plants were completed but they were not operational. Today, NEA is trying to sell the installed equipment, which has deteriorated. Nevertheless, NEA has received proposals to buy and use them using other Ws.

This sad Philippine experience highlights key elements of a sustainable dendro-thermal power program:

- The need for integrated planning of the supporting fuelwood plantations. This will involve special attention to selection of wood species suitable to particular plantation sites, and compatible with the power plant equipment. Effective plantation management should be able ensure a steady source of fuelwood supply for sustaining efficient power plant operations.

- Tapping the resources of other government agencies. The plantation component of the project can be developed with the assistance of forestry experts, especially in such areas as nursery development, cultural treatment and plantation practices and harvesting techniques.

- Recognising the social impact of the program. The dendro-thermal program has social and rural development dimensions that have to be considered in the planning and implementation phases.

If dendro-thermal power option is to be considered seriously, it is essential to study this fully so as not to repeat the failures of the first experience.

Currently, developments worldwide indicate continuous increase in the appreciation of dendro-energy because of its importance for human welfare, sustainable land use and the environment. Mechanisms for information exchange and technical co-operation among countries are available for sharing knowledge and experiences in dendro-energy.

Conclusion

I have presented our policy framework and the experiential context of a possible second dendro-thermal power program. May I conclude with the hope that this consultation will bring about better perspectives, directions, and guideposts for mapping out a sustainable program not only for the Philippines but also for other developing countries in Asia, in their thrust for energy self-sufficiency.

Thank you and *Mabuhay!*