Renewable Energy and the development of dendropower in India and SE Asia

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Abstract

Concerns such as energy security, widening gap between supply and demand for electricity and high prices of imported oil have been driving several developing countries to search for renewable energy solutions. In India, a Commission for Additional Sources of Energy (CASE) had been formed in 1981. The Department of Non-conventional Energy (DNES) was subsequently formed in the ministry of power, in 1982, with biogas as the main program. An independent Ministry of Non-conventional Energy Sources (MNES) was created in 1992. The MNES has made very serious attempts to promote power from renewable energy. The main thrust so far has been wind power, bagasse co-generation, biomass power and power from wastes. Recently programs such as Village Energy Security Program (VESP) and Remote Village Electrification (RVE) have been launched to address the issue of energy access to some 18,000 remote unelectrified villages. Photovoltaic systems, micro-hydro plants and biomass gasifier systems are considered as promising technology options. Both capital subsidies and soft loans are being offered as promotional incentives. Bagasse co-generation, biomass power and biomass gasifier based systems can together be classified as dendropower. Several other SE Asian countries have also tried to formulate policies and programs for promoting renewable energy and biomass energy in recent years.

This paper attempts to review the various policies and measures undertaken by SE Asian countries for promotion of renewable energy in general and dendropower in particular, with India as the focus for detailed presentation. Land use statistics, biomass production potential, different policies and programs of the governments, achievements, and barriers for mainstreaming are discussed, again with India as the focus.

1. Introduction

Even since the oil crisis of 1973, several countries in SE Asia started exploring options for using renewable energy. Recent concerns such as rising oil prices, supply-demand gap for electricity as a consequence of growing economics and urbanization, and global attention on green house gas emissions with implication of opportunities such as carbon trading are spurring the demand for accelerated growth of renewable energy utilization. Technological improvements, better quality control, standardization and increased number of suppliers/ manufacturers/vendors in technologies such as wind turbines, biomass cogeneration, dendropower, biomass gasification, small and micro-hydro, bio-diesel and solar photovoltaics are also aiding the growth of renewables. Solar photovoltaic systems, are however, still expensive and small hydro and wind resources are site specific. Hence there seems to be a universal focus on biomass energy which does not have as many constraints as the other renewable energy sources.

This paper attempts to study recent trends of renewable energy utilization in some South-east Asian countries, with special reference to India and with a focus on biomass.

2. Technologies

There has been a steady improvement in technologies and products over the past 20 years, as detailed below for various technologies.

Wind turbines: The unit size of wind turbines has increased significantly. The size of a single wind turbine for the first wind farm in India was 55 kW. The latest wind turbine has a capacity of 2MW for one machine with rotor diameter of upto 90 m and hub height of 100 m. The capacity utilization factor has also been increasing steadily from about 15% for the earlier wind farm to 25-30% for the latest wind farm due to design improvements. However, there have not been similar improvements in smaller and stand-alone wind energy converters. There is, however, considerable R&D and some pilot testing of wind-diesel or wind-PV hybrid generators for stand-alone systems.

Bagasse co-generation: Sugar industry has always been using co-generation, but the electricity was utilized within the premises for self-sufficiency. Technologies are now available to use high pressure steam, enabling one to increase the thermodynamic efficiency. The excess power generated can then be sold to the grid. High pressure boilers using wet bagasse as fuel are now available to achieve steam pressure upto 85 bar. The equipments required for cogeneration projects, viz high pressure bagasse fired boilers, steam turbines and grid interfacing systems, are manufactured indigenously in India. The additional capacity per sugar mill ranges from 2-18 MW, depending on the crushing capacity, steam pressure selected etc.

<u>Dendro-power</u>

Dendropower projects in SE Asia were initiated in early 80's in Philippines. Apart from other factors, technology for power generation was one of the reasons for failure to take-off. The scale was also small. Today, however, the technology for use of biomass for power in the capacity range of a few MW (typically 6MW) is fairly well established. Both stoker type furnaces and fluidized bed combustion systems are used. Furnaces and grates have been developed to handle a variety of biomass materials, and with a mix of coal fines upto to a certain percent. High-pressure turbines and grid interfacing systems have been standardized.

The technology for using empty fruit bunches (EFB) of the crude palm oil (CPO) industry in Malaysia for power generation (6MW) also seems to be quite mature. The combustion-based technology has also been used for power generation from municipal solid waste (MSW). After separation of inorganic material, MSW is made into pellets, which can then be burnt in a furnace, generating steam and electricity.

<u>Biomass gasification</u>

Starting from early efforts in India, Philippines, Sri Lanka and other countries in the 80's, biomass gasification technology has come a long way. Several gasifier systems are operational in the field, both for thermal applications and for power generation. Electrical power plants based on gasification have been mainly relying on dual fuel engines (producer gas + diesel), but recent development allow 100% producer gas operation. Capacities of the power plants vary from 4 kW_e to 250 kW_e. There are issues still to be sorted out regarding producer gas purity, implementation of testing & performance standards, engine maintenance, material life and cost norms, but there is an increasing demand for small power packs, especially for rural electrification projects. It is hoped that the experience with field prototypes will sort out the remaining technological barriers.

<u>Biomethanation:</u> Biogas production from animal wastes for rural cooking application is well established since the early 80's in several countries in South Asian and Southeast Asian countries. Both floating dome (KVIC type) and fixed down (Chinese type) digesters have standardized design and operational procedures.

For using organic wastes like distillery waste, pulp and paper mill waste, starch industry waste, slaughter house waste etc. and for large scale plants, designs such as UASB (Upflow anaerobic sludge blanket), BIMA (Biogas induced mixing arrangement) are now quite standardized. There are several technology/R& D institutes which were involved in development/implementation activities. There are several commercial technology providers, turnkey operators, equipment manufactures and consultants in this field.

Large amounts of methane generated from the biomethanation process can either used for direct heating in boilers, or for power generation through the steam route. Biogas has also been used in 100% biogas engines to produce power.

Other technologies: The small/micro/pico hydro technologies are also quite mature, as are the PV (photovoltaic) systems for various applications. Solar (thermal) water heating, based on selective surfaces, has become quite popular in India. Concentrating type solar cookers (Schefler cookers) are also becoming popular for institutional cooking. Solar (thermal) power generation, based on parabolic trough type collection (Luz technology) has been on the agenda of MNES for some time, but the planned demo project in Rajasthan has not yet been commenced.
Geothermal energy is already popular in countries such as Philippines and Indonesia.

3. Renewable energy potential

There is a combined potential of about 82,000 MW for power generation through wind, biomass, bagasse cogeneration, waste-to-energy and small hydro in India. Details are given in Table 1. The potential for using solar energy is even higher. Similar estimates for other countries have been made (Table 2.)

Table 1. Renewable energy in India at a glance

Source/system	Estimated potential	Cumulative installed capacity/ number*
Wind power	45 000 MW	2980 MW
Biomass power	16 000 MW	290.50 MW
Bagasse cogeneration	3500 MW	437.03 MW
Small hydro (up to 25 MW)	15,000 MW	1705 MW
Waste to energy		
▪ Municipal solid waste	1700 MW	17 MW
▪ Industrial waste	1000 MW	29.50 MW
Family-size biogas plants	12 million	3.71 million
Improved chulhas	120 million	35.20 million
Solar street lighting systems	-	52 102
Home lighting systems	-	307 763
Solar lanterns	-	538 718
Solar photovoltaic power plants	-	4.33 MW
Solar water heating systems	140 million m^2 of collector area	1 million m^2 of collector area
Box-type solar cookers	-	559 030
Solar Photovoltaic pumps	-	6452
Wind pumps	-	1087
Biomass gasifiers	-	62 MW

*** as on 31 December 2004**

Source: MNES Publication (2005)

Table 2. Land use classification – All India

Classification	1990-91		1997/98	
	Million hectares	(%)	Million hectares	(%)
Geographical area	328.73		328.73	
Reporting area for land utilization statistics (1 to 5)	304.86		304.92	
1. Forests	67.80	22.2	68.85	22.6
2. Not available for cultivation (A+B)				
(A) Area under non agricultural uses	21.09	6.9	22.53	7.4
(B) Barren and uncultivable land	19.39	6.4	19.03	6.2
3. Other uncultivated land excluding fallow land (A+B+C)				
(A) Permanent pastures and other grazing lands	11.40	3.7	10.91	3.6
(B) Land under miscellaneous tree crops and groves not included in net area sown	3.82	1.3	3.57	1.2
(C) Culturable wasteland	15.00	4.9	13.88	4.5
4. Fallow lands (A+B)				
(A) Fallow land other than current fallow	9.66	3.2	9.76	3.2
(B) Current fallows	13.70	4.5	14.36	4.7
5. Net area sown (6-7)	143.00	46.9	142.02	46.6
6. Total cropped area (gross cropped area)	185.74		190.76	
7. Area sown more than once	42.74		48.74	

Source. Ministry of Agriculture (2000)

For dendro-power, three factors assume importance: i) land available for growing trees, ii) economics of growing suitable species and, iii) uniform and coherent government policies.

The land use classification and changes between 1990-91 and 1997-98 for India are shown in Table 2. The numbers for forest area etc. appear to be inconsistent at times, but it can be due to a change in the classification, accounting method etc. Despite such confusion, some numbers, for example, the area under dense forest (40% crown cover), the net area sown etc. have not changed significantly. The trends in net area sown, the total cropped area and the cropping intensity (% of total cropped area the net area sown) are shown in Figure1. It can be seen that the cropping intensity is steadily increasing, but the net area sown seems to be more or less stabilized since last two decades.

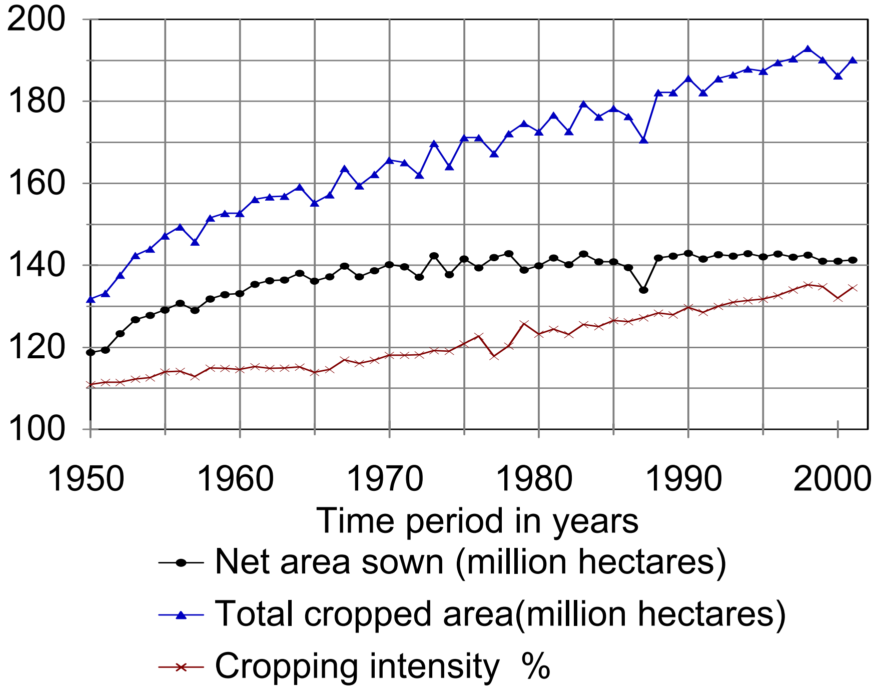

Figure 1: Trends in cropping intensity

The greatest promise as well as uncertainty seems to be in the projections available for wastelands in India. Though figures are always available at the national land, there are uncertainties at regional and state levels. Questions such as the availability of wastelands, plantations, who has control on what land, how much is under illegal settlements, how much is being handled by property dealers, etc. do not get straight-forward answers. State-wise estimates of wastelands, however, are available for Indian as shown in Table 3. The situation varies from country to country

The land use categories and patterns for some selected countries are shown in Table 4.

Table 3. State-wise Estimates of Wastelands in India (2002-2003)					
(Lakh Hactare)					
State/UTs	**Forest Degraded Area**	**Non-Forest Degraded Area**			
		Saline and Alkaline Lands	**Wind Eroded Area**	**Water Eroded Area**	**Total**
Andhra Pradesh	37.34	2.40	-	74.42	76.82
Arunachal Pradesh	-	-	-	-	-
Assam	7.95	-	-	9.35	9.35
Bihar	15.62	0.04	-	38.92	38.96
Goa	-	-	-	-	-
Gujarat	6.83	12.14	7.04	52.35	71.53
Haryana	0.74	5.26	15.99	2.76	24.04
Himachal Pradesh	5.34	-	-	14.24	14.24
Jammu & Kashmir	10.34	-	-	5.31	5.31
Karnataka	20.43	4.04	-	67.18	71.22
Kerala	2.26	0.16	-	10.37	10.53
Madhya Pradesh	71.95	2.42	-	127.05	129.47
Maharashtra	28.41	5.34	-	110.26	115.60
Manipur	14.24	-	-	0.14	0.14
Meghalaya	11.03	-	-	8.15	8.15
Mizoram	-	-	-	-	-
Nagaland	8.78	-	-	5.08	5.08
Orissa	32.27	4.04	-	27.53	31.57
Punjab	0.79	6.88	-	4.63	11.51
Rajasthan	19.33	7.28	106.23	66.59	180.10
Sikkim	1.50	-	-	1.31	1.31
Tamil Nadu	10.09	0.04	-	33.88	33.92
Tripura	8.65	-	-	1.08	1.08
Uttar Pradesh	14.26	12.95	-	53.40	66.35
West Bengal	3.59	8.50	-	13.27	21.77
Total	**358.89**	**71.65**	**129.26**	**736.00**	**936.91**
Union Territories	**27.15**	**0.16**	-	**8.73**	8.89

Source : Statistical Abstract India, 2003, Central Statistical Organisation,
Ministry of Statistics and Programme Implementation, Govt. of India.

Table 4. Land use categories and pattern (Mha)

Categories	China (1997)	India (1995)	Malaysia (1997)	Philippines (1997)	Thailand (1997)	Sri Lanka (1997)
Crop land	94.97	142.81	2.10	4.40	19.85	3.99
Forest	133.70	50.38	20.57	14.73	12.77	1.91
Plantations	0	14.62	0.10	1.15	0	0.10
Wasteland/ barren land/ open land/ area available for afforestation/ pasture etc.	628.97	14.20	0.98	5.12	18.69	0.50
Other categories	75.00	106.72	9.22	4.60	0	0.28
Total (Mha)	932.64	328.73	32.97	30.00	51.31	6.56

Source: S.C. Bhattacharya et al. / Biomass and Bioenergy 25 (2003) 471-482

Similar figures for many SE countries are compiled by FAO [1]

In recent years, plantation as an alternative to conventional agriculture is gaining importance. A recent survey of agriculture in India showed that 40% of the farmers are no longer interested in growing food crops as it is not economically viable due to a variety of reasons such as increasing cost of inputs, lesser remuneration and lack of facilities such as credit, insurance etc. On the other hand, plantation crops such as eucalyptus, rubber etc are becoming attractive because of their linkages with industries (paper & pulp, tyres etc.). Thus, in spite of initial criticism that eucalyptus lowers ground water table and that it consumes a lot of water, eucalyptus plantations have been growing steadily. The plantation area is now more than 10 million ha in 100 countries, with Brazil leading with 40% and India standing as second (8%) in the global coverage. It thus seems that plantations for energy generation also have the potential for significant growth, provided there are adequate market linkages with dendro power companies in future.

The plantation options and biomass productivity for selected countries are shown in Table 5.

Table 5. Plantation options and biomass productivity (t ha^{-1} yr^{-1})

Country	Species	Plantation options	Biomass productivity (t ha^{-1} yr^{-1})
China	C. lanceolata	Sandy waste, short rotation	0.8
		Open forest, long rotation	1.0
		Area for planting, long rotation	4.0
		Area for planting, short rotation	6.0
India	Eucalyptus (8 yr rotation with 3 rotations)	No genetic improvement and no fertilizer	6.6
		With genetic improvement only	8.0
		With genetic improvement and fertilizer	12.0
Malaysia	Meranti sarang punai	Long rotation (40 yr)	1.0-3.0
	Acacia	Short rotation (6-10 yr)	5.0-10.0
	Rhizophora and Acacia	Short rotation (5-8 yr)	8.0-11.5
Philippines	Gmelina	Short rotation (15 yr)	10.5
	Swietenia macrophylla	Long rotation (25 yr)	5.6
	Gmelina and Mango	Agro-forestry	10.5
Sri Lanka	Gliricidia sepium	With fertilizing (1.5m x 1.5m)	12.0
	Eucalyptus cameldulensis	Without fertilizing (2.5m x 2.5m)	8.0
	Eucalyptus grandis	With fertilizing (2.5m x 2.5m)	10.0
Thailand	Eucalyptus cameldulensis	Short rotation (5 yr) 4m x 4m	4.0
		Short rotation (5 yr) 4m x 4m	6.9
		Short rotation (5 yr) 2m x 2m	12.8

Source: S.C. Bhattacharya et al. / Biomass and Bioenergy 25 (2003) 471-482

Table 6. Electricity generation potential from sustainable biomass production

Country	Scenario		Surplus biomass for energy (Mt yr^{-1})	Electricity generation potential (TWh yr^{-1})		Total electricity generation in 2000[a] (TWh)
				Rakine cycle power plant	BIGCCC power plant	
China	SI	IBD	210.5	210.5	368.4	1356
	SII	IBD	182.5	182.5	319.4	
India	SI	IBD	186-310	186-310	325.5-542.5	477.2
		FBD	62-112	62-112	108.5-196	
	SII	IBD	116-182	116-182	203-318.5	
Malaysia	SI	IBD	1.7	1.7	3.0	66.7
	SII	IBD	0.4	0.4	0.7	
Philippines	SI	IBD	10.8-20.4	10.8-20.4	18.9-35.7	45.3
		SBD	8-15.1	8-15.1	14-26.4	
	SII	IBD	6.5-12.2	6.5-12.2	11.4-21.4	
		SBD	307-6.9	307-6.9	6.5-12	
Sri Lanka	SI	IBD	6.6-9.9	6.6-9.9	11.6-17.3	6.8
		SBD	5.5-8.2	5.5-8.2	9.6-14.4	
		FBD	4.1-6.2	4.1-6.2	7.2-10.8	
	SII	IBD	4.4-6.7	4.4-6.7	7.7-11.7	
		SBD	3.3-5.0	3.3-5.0	5.8-8.8	
		FBD	2-3	2-3	3.5-5.3	
Thailand		IBD	33.3-106.6	33.3-106.6	58.3-186.6	95.5
		FBD	11.6-37.3	11.6-37.3	20.3-65.3	

Source: ADB Growth and change in Asia and the Pacific-Key indicators of developing Asian and Pacific countries, vol.XXXII. Oxford University Press (for the ADB, 2001)

The electricity generation potential for sustainable biomass production for these countries is shown in Table 6. SI represents Scenario I, where there will be no increase in the area under food production by 2010 and SII represents Scenario II, where the area under food production will increase by 10-20% by 2010. The terms IBD, FBD and SBD stand for incremental biomass demand, full biomass demand, and sustainable biomass demand [2]. It can be seen that in countries such as India, Philippines, Sri Lanka and Thailand, a substantial fraction of electricity demand can be met from biomass.

The potential of using agro-residue such as bagasse, rice husk, cotton stalks etc for energy generation is also quite large. Bagasse and rice husk, as mentioned earlier, are already used in India for power generation, though the actual installed capacity is far less compared to the potential. The total non-plantation bio-energy potential for selected countries is shown in Table 7.

Table 7: Total non-plantation bio-energy potential (PJ)

Type of Biomass	Srilanka		India		China		Philippines		Malaysia		Thailand	
	1997	2010	1997	2010	1997	2010	1997	2010	1997	2010	1997	2010
Agricultural residues	49.6	55.6	4714	6564	5068	5246	164	178	343	454	425	562
Animal wastes	6.3	6.5	336	374	1102	2095	209	4.9	-	-	13	13
Biomass from conservation	51.3	50.2	-	525	-	744	249	296	-	-	-	156
MSW	3.7	4.8	86	219	50	91	36.4	46.8	10	17.8	19	21.3
Waste water	0.2	0.4	6.5	15.1	102	102	-	-	-	-	7.8	8
Black liquor	-	0.2	-	-	157	287	0.4	0.02	-	-	8.8	9
Palm oil	-	-	-	-	-	-	-	-	67	90.5	1.3	1
Biomass from substitution	-	15.5	-	900	-	914	109	254	-	-	-	109
Total	111	133	5142	8597	6479	9479	561	779	420	562	475	880

Source: S C Bhattacharya, et. al , *Biomass Energy in Asia: A Study of Selected Technologies and Policy options,* ARRPEEC, Asian Institute of Technology Thailand

4. Achievements so far

There has been a rapid progress of installation of wind power system in India. State-wise achievements along with gross and technical potential (20% grid penetration) are shown in Table 8.

Table 8. Wind power potential (gross and technical)

State	Gross potential (MW)	Technical potential (MW)	Achievement
Andhra Pradesh	8275	1920	101
Gujarat	9675	1780	219
Karnataka	6620	1180	276
Kerala	875	605	2
Madhya Pradesh	5500	845	29
Maharashtra	3650	3040	411
Orissa	1700	780	-
Rajasthan	5400	910	263
Tamil Nadu	3050	1880	1677
West Bengal	450	450	--
Total	**45195**	**13390**	**2978**

Source: Booklet No.6, Wind Energy, MNES., 2005

The installed wind power capacity for the top 10 countries is shown in Figure.2. India ranks 5^{th}, while Germany tops the list.

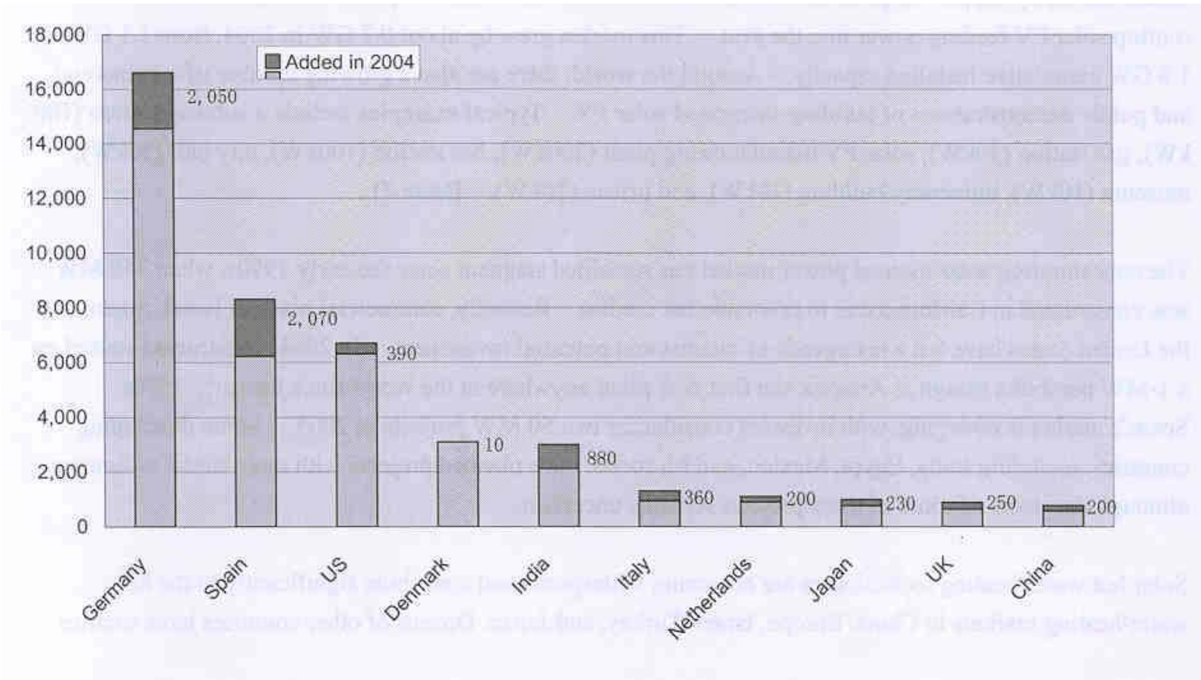

Figure 2: Installed wind power capacity for the top 10 countries

The biomass power and cogeneration plants installed state-wise are shown in Table 9.

Table 9.Selected State-wise Commissioned Biomass Power/Co-generation Projects in India (2002-2003 to 2004-2005)								
(MW)								
States	**2002-2003**			**2003-2004**			**2004-05**	
	Biomass Power	**Co-generation**	**Total**	**Biomass Power**	**Co-generation**	**Total**	**Biomass Power**	**Co-generation**
Andhra Pradesh	108.7	35.35	144.05	143.7	53.62	197.32	182.2	63.00
Chhatisgarh	11	-	11	11	-	11	11.00	-
Gujarat	0.5	-	0.5	0.5	-	0.5	0.50	-
Haryana	4	-	4	4	-	4	4.00	2.00
Karnataka	10	99.38	109.38	36	99.38	135.38	36.00	116.00
Madhya Pradesh	-	-	-	1	-	1	1.00	-
Maharashtra	3.5	21	24.5	3.5	21	24.5	3.50	32.50
Punjab	10	12	22	10	12	22	10.00	12.00
Rajasthan	-	-	-	7.8	-	7.8	7.80	-
Tamil Nadu	16.5	89.5	106	16.5	134	150.5	34.00	138.50
Uttar Pradesh	-	46.5	46.5	-	59	59	-	73.00
Total	**164.2**	**303.73**	**467.93**	**234**	**379**	**613**	**290.00**	437.00

Source : Ministry of Non-Conventional Energy Sources, Govt. of India.

The list of some biomass power projects in India is provided in Table 10. A similar list exists for biomass gasifier installations. However, it is not certain how many of these are functional/operational. A survey conducted by TERI in 1997 for the state of Haryana [3] showed that a large number of the gasifiers are not operational. There is a definite growth and considerable interest in biomass gasifiers in India and other countries, but valuable information on field performance and analysis of field data is lacking. Progress of other renewable energy installations in India is available in the annual reports of MNES.

Table 10: List of Biomass Power Projects

S.No	Project Name	State	Year of sanction	Installed Capacity MW	Project cost (Rs. in lacs)	Commissioned
1	HCL Agro Power Ltd.	AP	94-95	6.75	2607	6.75
2.	Indo-Lahari Bio Power Ltd	MP	94-95	6	2165	6
3.	Mohan Breweries & Distilleries Ltd.,	TN	96-97	12	3450	12
4.	Ind-Barath Bio Energies Ltd.,	AP	98-99	6	2440	6
5.	Gayatri Agro Industrial Power Ltd.,	AP	98-99	6	2440	6
6.	Vamshi Industries Ltd.,	AP	98-99	4	1655	4
7.	Malavalli Power Plant Pvt. Ltd.,	Kar	99-00	4.5	1235	4.5
8.	Sree Rayalseema Green Power Ltd.,	AP	99-00	5.5	2030	5.5
9.	Circar Power Corporation Ltd.,	AP	99-00	6	2440	0
10.	Varam Power Projects Ltd.,	AP	99-00	6	2440	6
11.	Rohsini Powertech Ltd.,	AP	99-00	6	2440	6
12.	Gowthami Bio Energies Ltd.,	AP	99-00	6	2440	6
13.	Vandana Vidhyut Ltd.,	MP	99-00	6	2440	6
14.	Matrix Power Ltd.,	AP	99-00	4.5	1655	4.5
15.	Rithwik Energy Systems Ltd.,	AP	00-01	6	2440	6
16.	KMS Power (P) Ltd.,	AP	00-01	6	2450	6
17.	Suchand Powergen (P) Ltd.,	AP	00-01	6	2426	6
18.	Rithwik Energy Systems Ltd.	AP	00-01	6	2428	6
19.	Shalivahana Constructions Ltd.,	AP	00-01	6	2428	6
20.	Sri Satyanarayana Power Projects Ltd.,	AP	00-01	4	1648	0
21.	Saro Power Projects (P) Ltd.,	AP	00-01	6	2428	6
22.	Malavalli Power Plant Pvt. Ltd.,	Kar	01-02	0	103	0
23.	Bhagyanagar Solvent Extractions Ltd.,	Kar	01-02	6	2428.5	6
24.	Koganti Power Ltd.,	Kar	01-02	6	2428.5	0
25.	Poweronics Ltd.,	Kar	01-02	6	2428.5	6
26.	Koppal Green Power Ltd.,	Kar	01-02	6	2428.5	6
27.	Prasad Biofuel	AP	01-02	0	30.5	0
28.	Sri Indra Power Ltd.,	Kar	01-02	6	2386	6
29.	Konark Power Project Ltd.,	Kar	02-03	6	2376	6
30.	Malwa Power Pvt Ltd	Pun	03-04	6	2102	6
31.	Pathyusha Power Pvt. Ltd	TN	03-04	10	3850	0
32.	Ind-Barath Energies (Thhothukkudi) Ltd.	TN	03-04	20	6510	0
33.	Neeraj Power Pvt. Ltd	Chha	04-05	7.5	2844	0
	Total			**204.75**	**78040.5**	**151.25**

5. Economics of dendro-power

In spite of the fact that several renewable energy applications, such as biomass gasifier for thermal applications, are economically competitive with fossil fuels, it is widely recognized that a range of incentives and suitable policy measures would have to be in place to create a conducive atmosphere for promotion of renewables. While it is established that electricity from wind, small/micro hydro and biomass is only marginally expensive than a fossil-fuel based electricity, it is also true that the real cost of electricity from fossil fuels is not always reflected in the tariffs. Generation costs of electricity from public sector or government controlled companies always appear to be lower compared to those of private companies or independent power producers (IPPs), due to a variety of reasons such as fixation of lower prices of raw materials, lack of transparency in fuel procurement/power purchase agreements, taxation policies, failure to apply uniform methods of calculating costs etc. It is beyond the scope of this paper to dwell on all issues related to economics of renewable energy-based electricity, and only a small attempt is made to compare dendro power with coal thermal power form an economic point of view.

The economics of biomass plantations has been worked out in ref [2], and is shown in Table11. The internal rates of return (IRR) for plantations in many countries seem to be favourable. The cost of production of wood is mostly in the range of 5-10 $/ton. The cost of biomass procured for the biomass power plants in AP and the other states in India is about 1000 Rs/ton (~ 23$/ton), which includes transportation. Notwithstanding the lower calorific value of biomass compared to coal, the fuel cost (or variable cost) of power for dendro-power would be lesser at the current prices of 45-75 $/ton for coal. The costs of electricity for biomass power, as calculated by the AP electricity regulatory commission (APERC) [4] are shown in Table 12. The tariffs are lesser compared to what the project developers would have got if the MNES guidelines were applicable.

The cost of electricity (generation cost) for a typical coal power plant is worked out in Table 13. It can be seen that, for a landed cost of 44 $/ton for coal, the levelized generation cost is about 2.95 Rs/kWh which is similar to that of dendro-power. The added advantages of dendro power, i.e., income generation in rural areas, energy security, control of soil erosion and pollution abatement, are well known.

Table 11. Financial assessment of bioenergy production~

Country	Plantation options or density	Productivity ($t\ ha^{-1}yr^{-1}$)	Discount rate (%)	NPV ($\$\ ha^{-1}$)	Internal rate of return (%)	Benefit-cost ratio (%)
China	Productive wood Fuel wood	5.3 5.6	10 10	396-1498 139-1093	15.48-32.55 15.56-47.93	
India	With no genetic improvement and fertilizer	6.6	12	373	19.8	172
	With genetic improvement only	8.0	12	503	21.5	187
	With genetic improvement and fertilizer application	12.0	12	963	26.2	246
Malaysia	Favourable yield Less favourable yield	10.0 10.0	12 12	262 89.6	13.68 12.58	109.6 103.2
Philippines	Short rotation (SR) Long rotation (LR) Agro-forestry (AF)~~	10.5 5.6 10.5	12 12 12	117 90	15.40 12.67	114 112
Sri Lanka	1.5m x 1.5m with fertilizing	12.0	10	231	14.3	118
	2.5m x 2.5m without fertilizing	8.0	10	273	19.2	138
	2.5m x 2.5m with fertilizing	10.0	10	434	22.7	154
Thailand	2m x 2m 2m x 4m 4m x 4m	12.8 6.9 4.0	10 10 10	679 253 45	18.24 9.89 2.35	263 175 115

Source: S.C. Bhattacharya et al. / Biomass and Bioenergy 25 (2003) 471-482

~ China-1US$ = 8.29RMB Yuan (1997), India-1US$ = 42Rs. (1999), Malaysia-1US$=RM 3.8, Philippines-1US$ =50 Php, Sri Lanka-1US$=85 Rs.(2000), Thailand-1US$=40 Baht (1997)

~~ Financial analysis for AF is incomplete due to incomplete data.

Table 12 Tariff calculation of Biomass power plant acoording to the Tariff Order given by APERC **Figures in millions.**

Capacity =1 MW

Project Cost= 40.00 ROE= 16% Interest on loan: 12% Interest on working capital=12%

O & M expen.= 0.04 O & M escalation= 0.04 Depreciation = 7.84% till 70% cost is recovered.

Debt equity ratio 70/30 after it, depreciation will be= 20%/remaining PPA period: 1.84%

at the end of financial year

Fixed cost	1st year	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year	9th year	10th year
ROE=	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**	**1.92**
Depreciation=	**3.14**	**3.14**	**3.14**	**3.14**	**3.14**	**3.14**	**3.14**	**3.14**	**3.14**	**0.72**
Cumulative Depreciation=	3.14	6.27	9.41	12.54	15.68	18.82	21.95	25.09	28.22	
O &M expense=	**1.60**	**1.66**	**1.73**	**1.80**	**1.87**	**1.95**	**2.02**	**2.11**	**2.19**	**2.28**
annual Loan repayment=	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80	2.80
Remaining loan for interest payment	28.00	25.20	22.40	19.60	16.80	14.00	11.20	8.40	5.60	2.80
Interest payment	**3.36**	**3.02**	**2.69**	**2.35**	**2.02**	**1.68**	**1.34**	**1.01**	**0.67**	**0.34**
Interest on working capital	**0.08**	**0.09**	**0.09**	**0.09**	**0.10**	**0.10**	**0.11**	**0.11**	**0.12**	**0.13**
Total cost=	**10.10**	**9.83**	**9.56**	**9.30**	**9.04**	**8.79**	**8.53**	**8.28**	**8.04**	**5.38**
Annual MUs generated=	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Fixed cost (Rs/unit)=	***1.58***	***1.54***	***1.50***	***1.46***	***1.42***	***1.38***	***1.34***	***1.30***	***1.26***	***0.84***
Variable Cost										
Sp. Fuel Consumption (kg/unit)=	1.16									
Auxilliary consumption=	0.09									
Fuel price escalation=	0.05									
	1st year	2nd year	3rd year	4th year	5th year					
Fuel cost (Rs/Kg) =	1.00	1.05	1.10	1.16	1.22	1.28	1.34	1.41	1.48	1.55
Variable Cost (Rs/unit) =	**1.27**	**1.34**	**1.41**	**1.48**	**1.55**	**1.63**	**1.71**	**1.79**	**1.88**	**1.98**
Total cost (Rs/unit)	**2.86**	**2.88**	**2.91**	**2.93**	**2.97**	**3.00**	**3.05**	**3.09**	**3.14**	**2.82**
calculation of working capital										
Annual Mus generation=	6.38									
monthly Mus generation=	0.53									
monthly Fuel required (MTon)=	677.44									
fuel cost(Rs./MT)	1000	1050	1103	1158	1216	1276	1340	1407	1477	1551
Monthly fuel Cost(working cap.)	677440	711312	746878	784221	823433	864604	907834	953226	1000887	1050932

Table13-(a): Fixed cost calculations

Sample calculation of generation cost for an indigeneous coal based power project in India

Project Capacity 500 MW Exchange rate = 42 Rs. / US$

		Foreign Component	Equivalent Rs.	Indian Component	Total	
		Million US $	**Rs. Cr.**	**Rs. Cr**	**Rs. Cr.**	
		1	2	3	4	
a	Project Cost	1452.13	1452.13	1051.05	2503.2	
	Financing					
b	Equity	178.8	750.9552		750.9552	of the Project Cost
c	Debt	417.2	1752.2288		1752.2288	of the Project Cost

d Debt : Equity Ratio 70 : 30

Fixed cost Calculations parameters

e	Interest rate for Loan	10.25%	as per loan terms
f	Interest rate for working capital	17%	as per market rate
g	Return on equity	16%	of equity at 68.5% PLF as per GOI guideline
h	Incentive	6.61%	of equity for 68.5% to 80% PLF @ 0.575% per each PLF
i	Operation and maintenace expenses	2.50%	of the total Project Cost
j	Depreciation	7.75%	of the total Project Cost
k	Plant Load factor (PLF)	80.00%	
l	Auxiliary consumption	9.50%	
m	No. of units sold per annum (Kwh)	317.11	Crore units per annum [capacity x 8760 x k x (1 - l)/ 10000]

All figures in Rs. Cr.

		F1	F2	F3	F4	F5	F6	F7	F8
	Fixed cost calculations	Interest on Loan capital	Opertation and maintenance	Depreciation upto 90% of the project cost	Return on equity	Incentive	Interest on working capital	Total Rs. Cr.	Total Rs. / Kwh
		As per annexure 1	(a4 x i)	(a4 x j)	(b2 x g)	(b2 x h)	As per Annexure - 2	Sum(F1 to F6)	(F7 / no. of units (m))
	Year 1	179.60	62.58	194.00	120.15	49.66	37.79	643.78	2.03
	Year 2	161.64	62.58	194.00	120.15	49.66	37.79	625.82	1.97
	Year 3	143.68	62.58	194.00	120.15	49.66	37.79	607.86	1.92
	Year 4	125.72	62.58	194.00	120.15	49.66	37.79	589.90	1.86
	Year 5	107.76	62.58	194.00	120.15	49.66	37.79	571.94	1.80
	Year 6	89.80	62.58	194.00	120.15	49.66	37.79	553.98	1.75
	Year 7	71.84	62.58	194.00	120.15	49.66	37.79	536.02	1.69
	Year 8	53.88	62.58	194.00	120.15	49.66	37.79	518.06	1.63
	Year 9	35.92	62.58	194.00	120.15	49.66	37.79	500.10	1.58
	Year 10	17.96	62.58	194.00	120.15	49.66	37.79	482.14	1.52
	Year 11	0.00	62.58	194.00	120.15	49.66	37.79	464.18	1.46
	Year 12	0.00	62.58	194.00	120.15	49.66	37.79	464.18	1.46
	Year 13	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 14	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 15	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 16	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 17	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 18	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 19	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 20	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 21	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 22	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 23	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 24	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85
	Year 25	0.00	62.58	0.00	120.15	49.66	37.79	270.18	0.85

Table 13-(b)

Sample calculation of generation cost for an indigeneous coal based power project in India

Table 2: Variable cost calculations

				Unit
n1	Heat Rate		2500	Kcal / Kwh
n2	Heat rate for calculations		2465	Kcal / Kwh after providing discount due to secondary fuel (n1 - u)
o	Calorific value of fuel		3800	Kcal / Kg
p	Fuel price		44.19	$ / MT
		or	1855.89	Rs./ MT
q	Auxiliary consumption		9.50%	
r	Secondary fuel consumption		3.5	ml / Kwh
s	Calorific value of secondary fuel		10000	kcal / litre
t	Secondary fuel price		6000	Rs/ KL
u	Discount in heat rate due to secondary fuel		35	Kcal / Kwh
		base cost of 781 Rs /ton plus freight charges for 1500 kms of 1053.5 Rs/ton		
v	Limestone consumption rate		0.12	Kg per Kwh
w	Limestone cost		0	Rs. / MT
A	Fuel cost Rs. / Kwh		1.33	[n2 x p2 / (o x (1- q) x 1000)] [Heat rate x fuel cost / { cal.value x(1 - aux. consumption)x 1000}]
B	Secondary fuel cost Rs. / Kwh		0.02	[r x t / 1000] [secondary fuel consumption x cost / 1000]
C	Limestone cost Rs. / Kwh		0.00	[v x w /1000] [Lime stone rate x cost / 1000]
D	Total Variable charge Rs. / Kwh		1.35	[A + B+ C]

Calculation of Fuel Price

Pit head price	Rs/T	665
Sizing	Rs/T	20
Loading	Rs/T	10
Internal Transport	Rs/T	21
Royalty	Rs/T	50
Freight	Rs/T	1053.5
Handling charge @2%	Rs/T	36.39
Landed price of fuel	**Rs/T**	**1855.89**

Table 13-(c): Levellised tariff calculations

Sample calculation of generation cost for an indigeneous

			T1	T2	T3	T4	T5
			Fixed charge Rs. / Kwh	Variable charge Rs. / Kwh	Total tariff Rs. / Kwh	Discounting factor	Product of tariff and discount factor
			As per Table 1	As per Table 2		[1 / (1.12^year n)]	[T3 x T4]
1		Year 1	2.03	1.35	3.38	0.893	3.02
2		Year 2	1.97	1.35	3.32	0.797	2.65
3		Year 3	1.92	1.35	3.27	0.712	2.33
4		Year 4	1.86	1.35	3.21	0.636	2.04
5		Year 5	1.80	1.35	3.15	0.567	1.79
6		Year 6	1.75	1.35	3.10	0.507	1.57
7		Year 7	1.69	1.35	3.04	0.452	1.38
8		Year 8	1.63	1.35	2.98	0.404	1.21
9		Year 9	1.58	1.35	2.93	0.361	1.06
10		Year 10	1.52	1.35	2.87	0.322	0.92
11		Year 11	1.46	1.35	2.82	0.287	0.81
12		Year 12	1.46	1.35	2.82	0.257	0.72
13		Year 13	0.85	1.35	2.20	0.229	0.50
14		Year 14	0.85	1.35	2.20	0.205	0.45
15		Year 15	0.85	1.35	2.20	0.183	0.40
16		Year 16	0.85	1.35	2.20	0.163	0.36
17		Year 17	0.85	1.35	2.20	0.146	0.32
18		Year 18	0.85	1.35	2.20	0.130	0.29
19		Year 19	0.85	1.35	2.20	0.116	0.26
20		Year 20	0.85	1.35	2.20	0.104	0.23
21		Year 21	0.85	1.35	2.20	0.093	0.20
22		Year 22	0.85	1.35	2.20	0.083	0.18
23		Year 23	0.85	1.35	2.20	0.074	0.16
24		Year 24	0.85	1.35	2.20	0.066	0.15
25		Year 25	0.85	1.35	2.20	0.059	0.13
		TOTAL				7.84	23.12

Levelised Tari Rs. / Kwh	**2.95**	[Total sum of column T5 / Total sum of column T4]
Wheeling Charg	**0**	
Transmission lo	**0**	
Total	**2.95**	

There seems to be a misconception in some circles that electricity tariffs will come down with the introduction of coal thermal power in Sri Lanka but calculations do not support this theory. Assuming a generation cost of 2.95 INR/kWh (from Table 13, worked out for India), the cost to the customer would be at least 4.54 IR/kWh assuming a transmission loss of 35%. If one takes into account the costs for creation of infrastructure, handling & transportation costs upto the power plant, the final generation costs can work out to be very high. It thus seems appropriate that a debate be launched on the cost of coal based power for Sri Lanka, in view of sustainable alternatives such as dendro power.

6. Government policies for renewable energy promotion

There are at least 45 countries worldwide which have policy targets for renewable energy. The renewable energy targets for some countries outside EU and developed nations like Canada, USA etc. are shown in Table14.

Table 14. Non-EU Countries with Renewable Energy Targets

Country	Target(s)
Brazil	3.3 GW added by 2006 from wind, biomass, small hydro
China	10% of electric power capacity by 2010 (expected 60 GW); 5% of primary energy by 2010 and 10% of primary energy by 2020
Dominican Rep.	500 MW wind power capacity by 2015
Egypt	3% of electricity by 2010
India	10% of added electric power capacity during 2003-2012 (expected/planned)
Israel	2% of electricity by 2007; 5% of electricity by 2016
Korea	7% of electricity by 2010, including large hydro, and 1.3 GW of grid-connected solar PV by 2011, including 100,000 homes (0.3 GW)
Malaysia	5% of electricity by 2005
Mali	15% of energy by 2020
New Zealand	30 PJ of added capacity (including heat and transport fuels) by 2012
Philippines	4.7 GW total existing capacity by 2013
Singapore	50,000 m2 (~35 MWth) of solar thermal systems by 2012
South Africa	10 TWh added final energy by 2013
Thailand	8% of total primary energy by 2011 (excluding traditional rural biomass)

The policies adopted in India include formation of a separate ministry, capital subsidies, interest subsidies, power purchase tariffs for renewable electricity, accelerated depreciation, tax concessions etc. There are programs supporting technology development, action research and demonstrations, formation of state nodal agencies for promotion of renewables and a central financing agency (IREDA) for providing soft loans. However, electricity being a state subject, each state formulates its own policies for renewable electricity. The policies for purchase of electricity from biomass power projects by various states are shown in Table 15.

Table 15. Policies Introduced by State Governments for Purchase of Electricity from Biomass Power Project in India (2002-03)						
States	**Partici-pation**	**Wheeling**	**Banking**	**Buy Back**	**Third Party Sale**	Other Incentives
Andhra Pradesh**	Pvt.	28.4%+ Rs. 0.5/kwh	Allowed at 2% for 8-12 months	@ Rs. 2.25 per unit, escalated at 5% (94-95)	Not Allowed	-
Chhatisgarh	Pvt.	-	-	@ Rs. 2.25 per unit	Allowed	As to Other Industry; Electricity Duty Exempted for 1st Five Year
Gujarat	Pvt.	4% of energy	Allowed 12 months	@ Rs. 2.25 per unit, escalated at 5% (94-95)	Allowed	-
Karnataka**	Pvt.	20% of energy	Allowed 12 months	@ Rs. 2.25 per unit, escalated at 5% (94-95)	Allowed linked to HT tariff	Subsidy @ Rs. 25 lakh/MW for co-gen. Only
Kerala	Pvt.	5% of Energy	Allowed 4 Months	@ Rs. 2.80 per Unit, escalated at 5% for five years (2000-01)	Not Allowed	50% cost of Power evacuation line to be borne by KSEB
Maharashtra**	Pvt./Coop.	7% of energy	Allowed	@ Rs. 3.05 per unit, escalated at 2% from years of Commission	Allowed	50% cost of Power evacuation line to be borne by MSEB
Punjab	Pvt.	2% of energy	Allowed 12 months	@ Rs. 3.01 per unit, escalated at 3% for 5 Years (01-02)	Not Allowed	As to other Industry
Rajasthan	Pvt.	2% of energy	Allowed 12 months	@ Rs. 2.25 per unit, escalated at 5% (94-95)	Allowed	-
Tamil Nadu	Pvt.	2% for sister concerns 15% others	Allowed 2% charge	@ Rs. 2.73 per unit, escalated at 5% for 9 Years (2000-01)	Not Allowed	-
Uttar Pradesh**	Pvt.	12.5%*	Allowed 24 months	@ Rs. 2.25 per unit, escalated at 5% (99-00)	Allowed*	-
Haryana	Pvt.	2% of energy	Allowed 12 months	@ Rs. 2.25 per unit, escalated at 5% (94-95)	Allowed	-
Madhya Pradesh	Pvt.	2% of energy	Not Allowed	@ Rs. 2.25 per unit	Allowed	-

Note : * : Not allowed for Co-generation.
** : SERC Policy announced.
Source : Annual Report 2002-03, Ministry of Non-Conventional Energy Sources & Past Issues, Govt. of India.

Formation of regulatory commissions at state level seems to have resulted in some kind of conflict of interest between the commitment to renewables on one side and the compelling need to minimize the loss of electric utilities on the other. Several SERCs tend to believe that renewable energy project developers are making more profits than they ought to make, and consider it their legal as well as moral duty to curb such `undesirable' profits without `unduly burdening' the consumers. There are no attempts, however, to quantify how much is the `undue burden' on the consumer or to quantify benefits of renewables.

7. Barriers for promotion of renewables and biomass power

Due to rapid advances in technology as well as due to experiences gained on the field, there do not seem to be many technological barriers for large wind power generation, small/micro hydro, photovoltaic systems, biomass cogeneration, dendro power etc. However, technology modules for small-scale power or small-scale cogeneration (e.g. rice mills) are yet to be either developed or standardized.

Financing is in place for large projects in India, but it is yet to be extended for decentralized applications and rural areas. Lack of easy financing for small entrepreneurs or micro credit for rural entrepreneurs can be barriers for future growth of renewable energy applications, especially in the SME and rural sectors.

Considerable human and institutional efforts and adequate funds are needed to launch, run, and learn from demonstration projects, as one can see from the Indian experience. Lack of support, either from the Government or from international donors, can thus be a barrier for further growth of renewables. There should also be simultaneous support for carrying out R&D and to establish an entrepreneurial base for manufacturing/assembling/service providing etc.

The biggest barrier, however, seems to come from not creating a conducive and consistent policy environment throughout the country. To give some examples from India: the same wasteland seems to be targeted to develop wind farms, biomass plantation, jatropha cultivation etc. and no clear guidelines exist for apportioning the available land for specific projects; there are too many clearances to be taken for setting up projects; guidelines for tariff, wheeling & banking of power etc. change `after' the project is set up; subsidies are re-introduced where market growth seems to be happening; subsidies are provided for unproven/ untested/under-tested products and in general there is little spirit of public-private partnership. It thus seems paramount that platforms be established at various levels for dialogue among various bodies such as users, entrepreneurs, govt. agencies etc. for promoting renewable energy development in a big way.

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