DRAFT REPORT

Environmental Resources Management UK

Renewable Energy In India: *A Special Study*

February 1997

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ERM

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Reference I5066/3888

For and on behalf of
Environmental Resources Management
India

Approved by: ______________________

Signed: TK Hamilton

Position: ______________________

Date: ______________________

LIST OF ABBREVIATIONS

ERM UK	-	Environmental Resources Management, UK
ERM	-	Environmental Resources Management
MoP	-	Ministry of Power
RETs	-	Renewable Energy Technologies
MW	-	Mega Watts
DNES	-	Dept of Non-Conventional Energy Sources
MNES	-	Ministry of Non-Conventional Energy Sources
IREDA	-	Indian Renewable Energy Development Agency
PV	-	Photovoltaics
TERI	-	Tata Energy Research Institute
SHP	-	Small Hydel Projects
CEA	-	Central Electricity Authority
KWe	-	Kilo Watt (electrical)
REC	-	Rural Electrification Corporation
MSW	-	Municipal Solid Waste
KW	-	Kilo Watts
SPV	-	Solar Photovoltaics
NRSE	-	New Renewable Sources of Energy
NPBD	-	National Project for Biogas Development
CASE	-	Commission of Additional Sources of Energy
RE	-	Renewable Energy
PPC	-	Policy Planning Cell
REPL	-	Renewable Energy Policy & Legislation
SEB	-	State Electricity Boards
R&D	-	Research and Development
HRD	-	Human Resource Development
RFQ	-	Request for Quotation
ICB	-	International Competitive Bidding
ECP	-	Established Commercial Practice
LIB	-	Limited International Bids
E&M	-	Electrical Institutions
UTS	-	Union Territories
SC	-	Schedule Caste
ST	-	Schedule Tribes
ARCs	-	Action Research Centres
B-C	-	Benefit-Cost
KWh	-	Kilo Watt hour
PLF	-	Plant Load Factor
IRR	-	Internal Rate of Return
SWH	-	Solar Water Heating
mECU	-	million European Currency Unit
GDP	-	Gross Domestic Products
NEPC	-	National Energy Productivity Council
LAC	-	Lavelised Annual Cost
DOC	-	Department of Energy
O&M	-	Operation and Maintenance
NPU	-	Net Present Value
BoS	-	Balance of System
WEG	-	Wind Electric Generators

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HT	-	High Tension
LPG	-	Liquid Petroleum Gas
ICCI	-	Industrial Credit Corporation of India
IFCI	-	Industrial Finance Corporation of India
IDBI	-	Industrial Development Bank of India
NGO	-	Non Government Organisation
KVIC	-	Khadi & Village Industries Commission

EXECUTIVE SUMMARY

Introduction

This report has been prepared by Environmental Resources Management (ERM) India, on behalf of the ERM UK. It serves as an input in the World Bank Project titled "*Environmental Issues in the Power Sector*" undertaken by ERM UK on behalf of the Ministry of Power, through the Energy Management Centre.

The main objective of the study was to critically analyse the potential of renewable energy technologies in the country, and the role they can play in augmenting energy supply, particularly in the power sector.

The report is presented in two main sections. The first section or the Main Text, includes 7 sub-sections of the analysis, while the second section contains Annexes and Tables.

Current Status of Renewable Energy in India

In this sub-section of the report an attempt has been made to study the present renewable energy scenario in India, alongwith development potential for the selected RETs. At present, the generated power from renewable energy sources is only 1.5% of the country's total power generation. The total renewable energy potential in the country stands at 126,000 MW. This can be met through governmental policy initiatives and continued fiscal incentives to manufacturers and developers of RETs.

Economics of Renewable Energy Technologies

Detailed cost estimates, consisting of investment and O&M costs are considered in this sub-section of the report, which deals with the economics of the selected technologies. After the analysis, based on certain assumptions, it has been found that Small Hydel Projects (SHPs), biomass and wind energy power projects are the most viable option. The generation costs of these technologies are at par with the conventional technology options of coal and gas, even in the absence of fiscal incentives. With the present technical know-how, solar energy systems are not at all cost effective. Serious R&D efforts have to made in the field to bring the technology at par with the others. Solar technology has developed to the present level due to the available fiscal incentives provided by the government.

Environmental Impacts

This sub-section of the report studies the external environmental impacts of RETs. In the absence of studies in India, we have taken examples from other countries. As compared to environmental damage incurred by electricity generation using conventional technology, there are no severe environmental impacts from power generation from renewable energy technology, which cannot be mitigated.

Wind technology has problems with noise, visual impacts, impacts on wild life (bird mortality), huge land requirement, interference with electromagnetic signals - affecting television transmission and occupational accidents. These impacts are not of great significance in India. SHPs have minimal effect on the environment pertaining to landuse and terrestrial and aquatic ecosystems. Biomass energy has potential negative impacts due to deforestation, but these can be mitigated with proper management of biomass resources. Solar technologies have little environmental impact which are related to land requirement, and that is applicable only in cases where it is grid connected.

Renewable Energy Supply Curve

This sub-section of the report deals with market penetration potentials of various renewable technologies, over the period 1996-2012. It has been concluded that RET capacity of 8560 MW (3% of the country's total power generation) can be achieved in the year 2011/12 even in the absence of any subsidy. The present government policy however gives a boost to RET penetration to 11,440 MW in 2011/12.

Constraints to Expanded Use of Renewable Energy

In this sub-section dealing with constraints, major problem areas are associated with the institutions, technology and finance availability. Lack of funds or poor funding for renewable energy projects are a major barrier for its development. Also, RET development is further blocked by lack of viable technology options and site-specificity of projects. Awareness in the field of renewable energy is limited as the promotion and marketing strategy is not well defined.

Policy Measures to Remove Constraints

This last sub-section of the main text outlines the possible policy measures which can be adopted to remove constraints and summarises the major conclusions of the study. Policy measures specifically mention the functions of government agencies, utilities, private sector, financing institutions and donor agencies, research institutions and training institutions.

Some other measures have been identified by ERM India, in their Working Paper document prepared for the MNES on National Renewable Energy Policy. These include Resource Mobilisation and creation of a National Renewable Energy Revolving Fund.

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1 INTRODUCTION

1.1 BACKGROUND

This report has been prepared by Environmental Resources Management (ERM) India on behalf of Environmental Resources Management UK (ERM UK). The study is expected to serve as an input in the World Bank Project titled "*Environmental Issues in the Power Sector in India*" undertaken by ERM UK on behalf of the Ministry of Power (MoP) through Energy Management Center (EMC). It critically analyses the potential of Renewable Energy Technologies (RETs) in India and the role they can play in augmenting the supply of energy in the Indian Power Sector.

1.2 RATIONALE FOR THE STUDY

1.2.1 Environmental Issues in the Power Sector

The project "*Environmental Issues in the Power Sector*" will identify the main environmental effects (including environmental externalities and costs) related to electricity generation from coal and the associated increase in the production of coal. Based on the identified environmental effects, the project is expected to generate a *menu of options* to mitigate those effects and to assist decision makers in India to assess the trade-offs between options. The project is expected to create a decision making tool, which will help in the following:

- energy development strategy;
- defining pollution mitigation programmes; and
- assessing investments and financial requirements to implement them.

The major portion of the project will be carried out on the basis of Case Studies in the states of Andhra Pradesh and Bihar. In these case studies, the environmental costs and impacts associated with each technological option will be identified and quantified, to the extent possible, through simulation of coal power generation system. This will be followed by a National Synthesis to draw conclusions at the National level about the environmental costs and externalities.

The Indian Power system is dominated by coal based generation technologies in spite of large hydro and renewable energy potential existing in the country. In India, power sector is the single largest contributor of CO_2. The Indian power sector is expected to grow at an average rate of 6-7% per annum which could pose serious threats to the environment in the coming years if current coal dominated expansion path continues. It is in this context that the renewable energy sources are considered to be mitigative measure for environmental effects of the power generation system.

1.3 *Objectives of the Study*

The overall objectives of the study are to:

- identify generic candidate renewable energy technologies;
- assess the costs (and benefits) of the various renewable energy options;
- identify the likely constraints to renewable energies; and
- identify the overall energy potential of the various forms of renewable energy at the national level.

1.4 *RETs Considered*

The current study will cover following renewable energy technologies:

- Wind Energy;
- Small Hydro;
- Solar Thermal;
- Solar Photovoltaic;
- Biomass Energy (consisting of cogeneration, wood based biomass energy, etc.);
- Biogas for electricity.

1.5 *Structure of the Report*

The remaining part of the report is presented in 7 sections, structured as follows:

- *Section 2* contains the current scenario in renewable energy sector in India describing the demonstration and promotional programmes sponsored by Government of India. Information regarding manufacturing base in India and finance for renewable energy promotion is presented in this section.
- *Section 3* presents the results of economic and financial analysis carried out to analyse the viability of RETs. Further, results of the sensitivity analysis are also presented in this section.
- *Section 4* contains the identified external environmental impacts of RETs.
- *Section 5* contains the renewable energy supply curve along with the assumptions and methodology used for deriving the supply curve.
- *Section 6* contains technical, financial, institutional and infrastructural constraints to the expanded use of RETs.
- *Section 7* presents the revised potential of RETs in India based on previous sections of the report.
- *Section 8* presents the summarised major conclusions.

2.1 THE PRESENT SCENARIO

With the increased rate of development in the country, the demand for electricity is increasing at the rate of 7% annually. There is a huge gap between demand and supply in the Indian power sector, with current energy and peaking shortages at 8% and 19% respectively. This gap between demand and supply can be decreased by tapping renewable sources of energy. It has been estimated that India has the potential for generating 126,000 MW of energy from renewable sources. A source wise breakup of this potential power is presented in *Table 2a* below.

Table 2a *Estimates of Potential For Renewable Energy*

Sources/Technologies	Units	Approximate Potential/Availability
Biogas Plants	Nos.	12 million
Biomass	MW	17,000
Improved Chulha (Woodstoves)	Nos.	120 million
Solar Energy	KWh/y	5×10^{12}
Small Hydro	MW	10,000
Wind Energy	MW	20,000
Ocean Thermal	MW	50,000
Sea Wave Power	MW	20,000
Tidal Power	MW	9,000

Source: MNES Annual Report, 1995-96

The prevalent Renewable Energy Technologies (RETs) in the country are energy through biomass, solar energy, small hydro-electricity and wind energy. These have replaced conventional sources of electricity to a small extent, mainly in remote inaccessible areas and show a great promise for future energy planning.

2.1.1 *Current Status*

The total installed capacity of renewable energy in the country has reached 1000 MW or 1.5% of the total power generation capacity of the country. This figure is expected to rise to 1400 MW by 1997. The Government of India's 9th

Five Year Plan has set a target of additional generation of 3000 MW from renewable energy sources.

In India Renewable Energy Programme was started in 1982 with the establishment of the Department of Non-Conventional Energy Sources (DNES), now the MNES. Renewable Energy Technology promotion and dissemination was supported by subsidies and financial incentives. However, in recent years it was realized that faster penetration would be achievable by providing fiscal rather than financial incentives to the private entrepreneurs and developers. The Indian Renewable Energy Development Agency Limited (IREDA), was set up in 1987 to serve as a financing body for the MNES. This step was taken in order to give greater market orientation to RETs by involving the private sector.

Through IREDA's initiative private sector participation in renewable energy power generation has increased, specially electricity availability through wind resource. The other promising sector in India is the small hydel projects in remote hilly areas where the cost of supplying conventional energy is prohibitive. Solar PV and solar thermal water heaters for industrial use are also gaining popularity.

Wind Power Generation

Wind technology in India is fairly advanced and well established. Estimates made by MNES put wind energy potential at 20,000 MW, while the Tata Energy Research Institute (TERI) estimate this to be 50,000 MW, after conducting a survey of the coastal regions. However, the discontinuous nature of wind and grid characteristics are two factors preventing the actual available potential to be met.

The first wind farms in India were installed in the coastal areas of Tamil Nadu, Gujarat, Maharashtra and Orissa in 1986. The performance of these windfarms established the technical viability of wind turbine technology in the country. Figures of 98% power availability and a capacity utilisation factor as much as 30% at some locations, encouraged interest in the sector of wind power.

In 8 States, as many as 92 potential locations have been identified which have annual mean wind speed of 18 km/h and above. 12 of these locations were identified in 1995-96. Under the demonstration programme of wind power, an aggregate capacity of 48.108 MW has been established in 8 States and additional programmes of 8.44 MW capacity are under implementation. These demonstration programmes have fed a total of 307 million units of electricity to the State grids, upto March 1996. During 95-96 alone these projects generated over 40 million units of electricity.

The private sector contributed an aggregate capacity of 684 MW in Tamil Nadu, Gujarat and Andhra Pradesh. During the same period, 6.3 MW capacity was established in Madhya Pradesh, by a private sector enterprise. Private investors have fed more than 675 million units to their respective grids. Projects aggregating to more than 600 MW are under different stages of discussions in the different States. *Table 2b* gives the statewise breakup of wind energy projects

Table 2b ***Installed Wind Power Capacity (MW) as of 31 March 1996***

State	Demonstration Projects	Private Sector Projects	Total
Tamil Nadu	19.355	537.035	556.390
Gujarat	16.345	99.328	115.673
Andhra Pradesh	3.050	41.850	44.900
Karnataka	2.575	-	2.575
Kerala	2.025	-	2.025
Maharashtra	2.600	-	2.600
Madhya Pradesh	0.590	6.300	6.890
Orissa	1.100	-	1.100
Others	0.465	-	0.0465
Total	48.105	684.513	732.612

MNES Annual Report, 1995-96

Small Hydro Power (SHP)

Small Hydro Power systems in India include the small-, mini- and micro-hydro-electricity projects. These SHP systems are available in a wide range of sizes and capacities and are categorised as under:

- Micro-HP - less than 100 kW
- Mini-HP - between 101-2000 kW (unit size upto 2 MW)
- Small-HP - ranging from 2001-15000 kW (unit size upto 15 MW)

These subdivisions have been made by the Power Ministry, which has given the MNES the responsibility of all SHPs uptill 3 MW capacity. The Central Electricity Authority (CEA) looks after SHPs with capacity over 3 MW till 15 MW.

Till March end, 1996, upto 3 MW capacity SHP under operation was 119.56 MW and 235.86 MW capacity was under construction. There are 2481 potential sites for these SHPs in 25 States and Union Territories of Andaman and Nicobar Islands with an aggregate capacity of 1805 MW.

Power generation from small hydro projects is still at the initial stage. IREDA began to support these projects in earnest only since 1993, though it had supported a few earlier. There is a minimum three year gestation period for a SHP, therefore it will take some more time before we know the results.

Rural lighting holds vast potential for application of gasification technology. 85% of the approximately 550,000 villages are electrified, but only 30% of the households have electricity connection. Over 80,000 villages with population less than 500 do not have electricity. Therefore biomass gasifier (of 20 kWe to 100 kWe capacity) installation in these remote areas will help to meet the domestic energy demands of such villages.

Gasifier programmes in the country launched in 1986 by the MNES, was based on 3.7 kW wood-based gasifiers. At present electric generators of capacity range from 3 kWe to 500 kWe are commercially available. Till 1995-96, about 1600 gasifier systems of 16 MW equivalent capacity were installed in the country, with an estimated power generation capacity of 42 million KWh. Statewise details of gasifier systems sanctioned during 1995-96 is presented below in *Table 2c*

Table 2c ***Statewise details of gasifier systems sanctioned during 95-96***

State	No. of systems sanctioned	Capacity (KWe)
Andhra Pradesh	78	3870
Goa	2	118
Gujarat	7	280
Haryana	14	1280
Karnataka	2	15
Himachal Pradesh	7	2020
Maharashtra	1	500
Tamil Nadu	1	40
West Bengal	5	500
Total	117	8623

MNES, **Annual Report 1995-96**

Making use of locally available biomass, these gasifiers can be used for generating electricity in small and remote rural areas. The Rural Electrification Corporation (REC) is expected to provide funding for laying distribution lines. In India, two such projects have been sanctioned, one in village Goshaba in Sunderbans (West Bengal) of 500 KW capacity and the other in village Similiguda in Raigarh (Orissa), having a capacity of 10 KW.

A study conducted in 1993, covering about 20% of the installed gasifiers by 14 nodal agencies in India found that less than 45% of the systems were in use and only 14% were in the dual-fuel mode. More than 25% of the gasifiers were used either intermittently or not at all. Roughly 57% were never used at all after commissioning and a little less than 5% were never commissioned, even after delivery of equipment to the site. Field level performance for working biomass gasifiers is not well documented.

Cogeneration

Industries requiring substantial combined heat and power are prime candidates for cogeneration in India. This includes sugar, textile, paper, fertilizer, food processing, chemicals and petrochemical industries. Industries where cogeneration is already practised in the country are paper and pulp, rayon, sugar, chemicals and fertilizer.

Approximately 30% of the electricity requirement of paper mills is met through cogeneration with steam production. In 1994, the MNES launched a bagasse based cogeneration programme for optimising the generation of surplus power for the grid from the existing 421 sugar mills and approximately 90 newly licensed sugar mills with 20 MW surplus power generation capacity. A total of 54 MW capacity projects are under construction. A plan of 200 MW capacity is underway for all sugar producing States.

Power Generation from Urban and Industrial Wastes

India has a vast potential for energy recovery from waste, both domestic and industrial. *Table 2d* give details of the amount of waste generated annually by different sources. Realising this potential, the MNES launched a National Programme in June 1995, to promote adoption of these technologies as well as provide a means to improving waste management practices.

Table 2d ***Estimated Quantity of Waste Generated in India***

Waste	Quantity
Municipal solid waste	27.4 million tonnes/year
Municipal liquid waste (121 Class I & II cities)	12145 million litres/day
Distillery (243 nos.)	8057 kilo litres/day
Pressmud	9 million tonnes/year
Food & fruit processing waste	4.5 million tonnes/year
Willow dust	30,000 tonnes/year
Dairy industry waste (COD level 2 kg/m^3)	50-60 million litres/day
Paper &pulp industry waste (300 mills)	1600 m^3 waste water/day
Tannery (2000 nos.)	52500 m^3 waste water/day

Bio Energy News: Vol 1, No 1, Sept 1996

According to estimates both solid and liquid urban wastes can generate upto 1000 MW of power, while 700 MW can be recovered from industrial wastes. The industries qualifying for this are dairy, distillery, pressmud, tannery, pulp and paper and food processing industries. Thus there is tremendous potential for generating electricity from these sources.

There are many technologies already available for conversion of waste to energy, mainly thermal. Power can be generated using landfill, biomethanation and palletisation technologies. Indicative parameters for the later two are presented below in *Table 2e & 2f:*

Table 2e ***Indicative Parameters for Biomethanation Based Power Projects***

Parameters	Range				
City Population (lakhs)	3.5-4	7-8	10-12	14-16	17-20
MSW treatment tonnes/day	150	300	450	600	750
Plant capacity (MW)	1	2	3	4	5
Est. project cost (Rs. crores)	6-8	10-12	15-20	22-24	25-30
Land required (hectares)	2	4	6	8	10

Bio Energy News, Vol 1, No 1, Sept 1996

A 3 MW capacity biomethanation based power plant using Municipal Solid Waste (MSW) of Cochin city is in the finalisation stage. While the Calcutta, Pune and Ludhiana municipal corporations have tied up a private entrepreneur to install 3 MW capacity biomethanation based power plants in each city.

Table 2f ***Indicative Parameters for Pelletisation Based Power Projects***

MSW generated (tpd)	Plant rating (tpd)	Power plant rating (MW)	Est. project cost (Rs. crores)	Land required (acres)	Water required (GPD)
100	30	0.66	2	2	40
200	60	1.33	4	3	80
300	90	2.00	10	5	110
450	135	3.00	15	8	140
600	180	5.00	20	10	220
1200	360	10.00	35	15	440

Bio Energy News Vol 1, No. 1; Sept 1996

A pelletisation based power plant is in the final approval stage in Chennai. This 5 MW capacity plant will utilise the available MSW generated in the metropolis.

Municipal corporations of numerous cities have been conducting feasibility studies for landfill gas based power generation projects. Apart from Calcutta, Delhi and Lucknow, there are three cities in Andhra Pradesh which are going in for pre-feasibility studies.

Solar Photovoltaic (SPV)

PV technology serves as a power source for small applications such as lighting, water pumping and telecommunications. It also finds application as medium sized power source at the village level. At present, the most economically viable PV application is the telecommunication sector. Since the mid-'80s, the total installed manufacturing capacity in India has gone up to 5.75 MW/yr, of which 30% are on a commercial, unsubsidised basis for telecommunications, signalling, defence and other similar operations. The rest were primarily for rural purposes such as domestic lighting, street lighting, water supply and community services. *Table 2g* presents the targets and achievements for the same during the year 95-96. Village level power plants have array sizes ranging from 1 to 10 kW.

Table 2g ***SPV System - Targets and Achievements (1995-96)***

System	Approved Target	Revised Target	Achievement
Solar lantern	35,000	70,000	44,938
Domestic Lighting System	1,000	20,000	7,470
Village Level Power Plants	50 kW	100 kW	89 kWp + 26 kWp
Street Lighting		1,500	680

MNES Annual Report, 1995-96

Solar Thermal

Currently the solar water heaters installed in India have capacity ranging from 50 litres (hot water) per day (lpd) for domestic purposes to 240,000 lpd for industrial use. As of March end, 1996, the total collector area installed in the country is about 50,000 m^2 as reported by various State nodal agencies and manufacturers. It is estimated that up till now, the total installed collector area in the country is 3,40,000 m^2.

According to a study carried out by TERI, at the end of 1995, the installed collector area for industrial solar water heating systems was 250,000 m^2, while the corresponding figure for domestic use was only about 40,000 m^2. The estimated industrial market size is 10-20 million m^2 and the domestic market is about 1-2 million m^2.

Till date there are no solar thermal power generating systems in the country. A private sector company in Rajasthan has proposed a 35 MW gross Luz type solar electricity generation system. This plant in conjunction with a 140 MW naptha-fired combined cycle is expected to cost US$ 100 million. The expected cost of electricity generation will be Rs 4.93p per kWh at an assumed 45% load factor.

2.2 *POLICY FRAMEWORK*

Till date, none of the laws and regulations governing power generation and distribution [Indian Electricity Act, 1910; Electricity (Supply) Act, 1948], nor the periodic modifications effected in these laws, mention explicitly or encourage renewable energy sources. Nor do these laws cover isolated power options.

Table 2h presents a brief history of policy initiatives taken for Renewable Energy. The vital importance and role of renewable energy sources was first recognised in 1970, when the Fuel Policy Committee (FPC) of India was set up. FPC was also responsible for officially incorporating renewable energy sources for the first time in a policy document. The oil-shock of the 1970s served as another push factor for the increased policy and planning efforts of renewable.

Table 2h ***Brief History of RE Policy Initiatives***

Year/Period	Department	Action
1970	FPC recommendation	RE sources first recognised and incorporated in an official policy document.
1970s	Following oil-shock	RE Policy and Planning received a further push for increased R&D and promotional efforts
5th Five Year Plan	DNES	National Project for Biogas Development (NPBD) launched Target set for establishing 1.5 million plants by 2001
6th Five Year Plan		Official emphasis on RE sources on a permanent footing Separate heading for New and Renewable Sources of Energy (NRSE)
1981		RE became an integral part of the Prime Minister's 20 Point Programme Commission of Additional Sources of Energy was created (CASE)
1982	Establishment of DNES	Department of Non-Conventional Energy Sources (DNES), an exclusive administration unit under the Ministry of Energy
7th Five Year Plan		A national level programme on social forestry and improved cooking was launched in addition to the planning of the 6th Plan. Mass demonstrations and experimentations on other renewable sources like wind, solar, biomass, tidal etc. Renewed process of modernisation and industrialisation Urjagram programme launched
1987	Establishment of IREDA	Indian Renewable Energy Development Agency (IREDA), set up by the DNES, to operate a revolving fund for development, promotion and commercialisation of NRSE through provision of soft term financial assistance
8th Five Year Plan		Shift of emphasis towards market orientation and commercialisation of technology in order to attract private investment

Year/Period	Department	Action
1992	DNES to MNES	DNES was given the permanent status and was converted into the Ministry of Non-Conventional Energy Sources (MNES)

Till July 1993, the MNES/DNES concentrated on promoting individual technologies through design and development support, as well as through large scale demonstration programmes. A RET manufacturing base was created through these programmes, whereby the government procured the RET devices for either demonstration or for onward sales to consumers.

In order to promote technology upgradation by manufacturers, a number of technical support centres were created in various Universities. These centres are responsible for quality certification of the devices procured by the government. State level 'Nodal Agencies' channel these devices and subsidies to the consumers, and they have to provide after-sales service and consumer support. However, because of low reliability of the devices, lack of remunerative tariffs for RET generated electricity and a lack of consumer-desired features in the design and sales package, the commercial demand for RET devices remained low.

To overcome these problems, the MNES was restructured in 1993, and it now has sectoral groups of rural energy, urban/industrial energy and power generation. This restructuring has shifted the emphasis towards policies, planning and institutional linkages for the promotion of RETs within each sector. Till 1992, over half of the funds allotted to Renewable Energy (RE) was directed towards the biogas plants, with all the other individual technologies receiving less than 10% of the funds. The restructuring has shifted the focus of the programmes. Currently, the rural energy division is the recipient of the largest financial allocation.

Another important change brought about by the restructuring has been the shift from direct financial incentives to fiscal benefits. This has stimulated private sector interest in wind and SPV power plants and encouraged RET manufacturers and financing intermediaries to develop consumer-friendly product designs.

The government package for fiscal incentives and tax holidays include:

- 100% depreciation allowance
- Soft loans
- Reduced customs duties on imported materials and equipments
- Exemption from excise duty and sales tax
- Remunerative price for power fed into the grid, and
- Facilities for wheeling and banking power.

In June '95, the MNES set up a Policy Planning Cell (PPC) with the primary objective being preparation of comprehensive Renewable Energy Policy and Legislation (REPL), so as to efficiently and effectively exploit the renewable sources of energy. Other activities of the PPC include R&D and new initiatives in the area.

The preparation of REPL involved a series of consultations with State Government Departments, industries, financial and S&T Institutions and renewable energy experts. Some of the recommendations of the consultative group include;

- Use of decentralized power generation through renewable energy sources for electrification of remote and difficult areas;
- Solar water heating systems should be made mandatory for functional buildings like hospitals, hotels, hostels, etc.;
- It should be made mandatory that the State Electricity Boards (SEBs) generate a certain proportion of power through the RE sources;
- A minimum price should be fixed for a predefined period and reviewed periodically for purchasing power through renewable energy sources;
- Energy audit and conservation programme should be linked with the RE programme;
- Encouragement of single window clearance concept for expediting clearance and environmental clearance should not be insisted upon for NRSE projects which are eco-friendly;
- Resource mobilisation should be adequately addressed, including cess and other budgetary and institutional finance. Various policy and fiscal incentives would encourage private sector participation;
- For effective State level coordination and implementation of RE policies, there is a need to set up separate RE departments and nodal agencies. Also a separate State level regulatory body may be set up with the structure varying from one State to another.

The MNES and the nodal agencies should lay emphasis on appropriate R&D activities and create adequate infrastructure for the same including maintenance and HRD. This would help in the implementation, regulation and monitoring of the RE policy. The Renewable Energy Policy statement is being reviewed by the Ministry.

2.3 *FINANCE FOR RENEWABLE ENERGY TECHNOLOGIES*

IREDA has been set up primarily as an institution with substantial financial base for providing loans. The innovative financial investment schemes and IREDA have made a substantial impact on RET commercialisation. Since the inception of IREDA, financing mechanism with subsidised interest rates and long repayment period has been followed. However, substantial funding through multilateral and bilateral donor agencies have increased the financial resources now available with IREDA. The World Bank has mobilised a line of credit amounting to US$ 195 million as a soft-term international finance loan to IREDA. This loan is for the implementation of "India : Renewable Resources Development Project" (RRDP) for promoting SHP, wind power and SPV. The financing plan is as under:

Table 2i *IREDA's Financial Allocation for RRDP*

Agency	US$ (millions)
IDA	115
GEF	26
DANIDA	50
SDC	1
Total	195

In order to generate private sector interest in power generation through renewable sources, the Government of India, through IREDA has provided various fiscal and financial benefits for the RETs. IREDA's project and equipment financing norms are presented in *Annexures Aa & Ab.*

2.3.1 *Wind Power*

In view of the success of private sector wind farms, the MNES has submitted a proposal for an additional line of credit for financing 115 MW private sector windfarms at a cost of US$ 165 million. This financing will be through

- a GEF grant of US$ 25 million;
- IDA loan of US$ 30 million;
- bilateral co-financing of US$ 50 million;
- IREDA financing of US$ 20 million; and
- private sector contribution of US$ 40 million.

While the Central Government does not provide sales tax and excise duty benefits, it allows free import of 10 components which are blades, gear box, brake assembly, brake hydraulics, hubs, flexible coupling, sensors, special bearings, yaw components and wind turbine controller and parts thereof. For complete import of Wind Electric Generators (WEGs), there is only 25% custom duty. In addition to the Central government incentives, the State governments have adopted different norms for fiscal incentives, banking, wheeling and buy back by the States. Tamil Nadu has increased the buyback rate from Rs. 2.00 to Rs. 2.25/kWh, and in addition it has agreed to the annual escalation of 5% as suggested by the Ministry. Karnataka has also increased the buyback by Rs 0.50 p to Rs 2.25/kWh. These fiscal incentives are listed in *Annexures Ba, Bb & Bc.*

2.3.2 *Small Hydro Power*

A Pre-investment study for the SHP sector, carried out jointly by the UNDP and the World Bank in India, under the Energy Sector Management Assistance Programme (ESMAP), in 1989-90 concluded that the existing mini-hydro schemes for irrigation have the potential for generating power. Consequent to this study World Bank offered a line of credit worth US $ 70 million for the 8th Plan, with a target addition of 100 MW. This finance scheme is targeted at the Private (more than 70%) and Public Sector Enterprises, but not the State Electricity Boards and Government

Departments. Three categories of projects are eligible for the World Bank scheme as described below

- Grid connected projects being developed at existing irrigation canals, dam toes and run-of-the-river schemes, which would generate a maximum of 30 MW, and cost less than Rs 1000 million.
- Schemes being implemented in States where grid requirements are met and adequate policies on private power generation are in place.
- Projects which can demonstrate technical soundness, least cost design, and a financial rate of return not less than 12%.

These loans can be applied for the procurement of electromechanical and hydromechanical equipment which form around 50% of the total project cost. With the promoters' contributing 25% of the cost, there is still a deficiency of 25%. Therefore IREDA provides loans at an interest rate of 16.5% for purchase of E&M equipment and civil works. In order to remove the problems in procurement procedure for the private sector the World Bank has modified the same by enhancing the threshold limit for ICB (International Competitive Bidding) from the existing US$ 3 million to US$ 5 million by replacing the LIB (Limited International Bidding) by Request for Quotation (RFQ) method and Established Commercial Practice (ECP).

The Central and State governments have provided innovative subsidy schemes to attract private sector organisations into developing power through SHPs. Under the Capital Subsidy Scheme, the Northern and hilly regions of the country enjoy a capital subsidy upto 50% of the acceptable capital cost of civil works and E&M equipment. For other regions the same stands at 25%. While in the North Eastern regions projects upto a capacity of 50 KW, implemented by the Government departments also get a capital subsidy at the rate of 25% (subject to acceptability). This facility is basically aimed at encouraging installation of micro-hydel sets.

During the last fiscal year (1995-96), the Capital Subsidy scheme was modified and an Interest Subsidy Scheme was introduced in its place. This involves an interest subsidy of upto 5% for SHP projects financed by financial institutions (FIs). This subsidy is to be released to the FIs, in the beginning itself, after capitalising the amount over the loan period. Depending on the type and location of the project, this subsidy is applicable where the project cost is not more than Rs 1.10 crore/MW. For projects in the North Eastern and hilly regions the assistance is higher. Also this subsidy is available to private sector, cooperative sector, NGOs, local bodies, SEBs and Government Departments.

Annexure Ca gives details of the various Policy Introduced/Incentives declared by the State governments for SHPs. *Annexures Cb & Cc* respectively give a statewise breakup of installed SHP and SHP sites offered to private sector.

2.3.3 *Solar PVs*

In an effort to promote eco-friendly energy sources, the World Bank has revised the interest rate on loans. For solar projects, the interest rate is now as low as 2.5%, which is 10% lower than the earlier rate. For funds through IREDA there is a moratorium of one or two years and repayments periods of up to 10 years with interest being calculated on the reducing balance of the loan. Corporates are showing a lot of interest in solar projects since the interest rates were lowered. 100% depreciation benefits manufacturers of solar power equipments.

Under a socially oriented scheme, a subsidy upto 50% of the cost of the system is extended to all categories of beneficiaries in the special category States/UTs, desert areas, islands, hilly regions and not electrified villages. The categories which can apply for this scheme are SC, ST, Fishermen, Handloom workers, Village artisans and Handicapped persons. For solar lanterns, in 1995-96 all categories of individual beneficiaries and non-profit organisations/institutions were made eligible for availing the Central Subsidy. This subsidy has been reduced from Rs 2000 to Rs 1500.

2.3.4 *Biomass*

For the promotion of Bagasse-based cogeneration, the MNES provides a capital subsidy of 30% of the total equipment cost, provided that it does not exceed Rs 7 million/MW of surplus power. Such projects should generate a minimum of 5 MW of surplus power. Soft loans are available under the Sugar Development Fund of the Ministry of Food for those industries which would produce 4 MW or more of surplus power, for their modernisation. Several international organisations are entering into this sector through joint ventures.

Demonstration biomass based power projects at the taluka level get a one time non-recurring capital subsidy of 20% of the project cost, or Rs 35 lakhs/MW of net power generation whichever is lower, subject to a maximum of Rs 3.5 crores for any one project. For non-grid connected projects not costing more than Rs 1.5 crores, an additional subsidy of Rs 10 lakhs/MW is extended to SEBs for creating evacuation facilities for the project. Under the Interest subsidy scheme, the Ministry provides a one time grant of Rs 17 lakhs/MW to FIs providing term loan for biomass based projects. The objective of the scheme is to reduce the interest rate on term lending by these FIs. But only those projects are eligible for this scheme which generate a minimum of 5 MW power.

In 1995-96, a number of States came up with innovative policy packages for the promotion of biomass based power generation. Andhra Pradesh announced its plans, while Maharashtra has issued a formal modification. The incentive package of Uttar Pradesh includes a Standard Power Purchase Agreement, Revolving Letter of Credit for payments, and Guarantee of Payments by the State government. It has announced power purchase price of Rs 2.25/Kwh, which would increase annually in the same proportion as the increase in HT tariff charged by the Uttar Pradesh State Electricity Board (UPSEB). The Tamil Nadu State Electricity Board (TNSEB) has revised its policy to provide an escalation of 5% per annum in the power purchase price. Haryana, Orissa and Gujarat governments are in the process of framing their policies. A detailed outline of the various state incentives for cogeneration and gasifier systems is given in *Annexures Da & Db.*

2.4 *MANUFACTURING BASE IN INDIA*

2.4.1 *Wind Power*

India has achieved nearly 70% indigenisation of WEGs upto 250kw capacity. There about 22 private sector companies manufacturing WEGs. They have set up some form of collaboration or joint-venture or trading agreements with foreign manufacturer. In 95-96, an additional 13 firms signed joint ventures for assembly/production of WEGs. Another 4 joint ventures were established for blade production, of which 3 have already started production. A target of achieving 100% indigenisation by the end of 1996 has been set. WEGs ranging from 400-600kw were introduced during 95-96. These have large rotor diameter and higher hub-height for better cost efficiency.

The three most active companies in this field are Bharat Heavy Electricals Limited (BHEL), RRB consultants (with Vestas) and National Energy Promotion Council (NEPC) (with Mecon). Under a MNES sponsored project, BHEL has installed indigenously developed wind turbines. As compared to BHEL, RRB-Vestas and NEPC-Mecon are small, but they provide effective installation, commissioning and maintenance services. While NEPC-Mecon has achieved significant indigenisation, RRB is producing wind turbines with partially imported components.

2.4.2 *Small Hydro Power*

There are about 15 reputed manufacturers of small hydro power (SHP) equipment. They are engaged in production of equipment for a wide range of head and flow conditions for either grid connected or stand alone systems. In 95-96 Sulzer Inc of Germany signed a JV with Flovel from India, while Ganz of Hungary signed up with Technip for manufacture of SHP equipment.

2.4.3 *Solar PVs*

Compared to the international industries, the Indian PV industry is relatively new with production of solar cells and modules starting in '83-'84 in two public sector organisations. Presently, India has indigenised technology and production facility starting from the stage of silicon material to the final PV system integration. There are 70 solar companies involved in the production of solar cells, modules and PV systems of which 13 are regular producers. Till end March '96, it was estimated that solar cell and module production was 4 MWp and 8 MWp respectively.

There is one company manufacturing feedstock and wafer, 5 manufacturing solar cells and 7 manufacturing modules. About 15 companies are involved in the Balance of System (BOS) and complete system assembly. There are 4 regular manufacturers of lead-acid PV batteries with several other small companies offering off-the-shelf lead acid storage batteries. Four of the storage battery manufacturers have included low-maintenance tubular plate lead-acid battery for PV applications to their product line.

2.4.4 *Solar Thermal **Water Heaters***

There are a total of 60 manufacturers of solar thermal water heaters in the country. 10 of the manufacturers have received certification from the Bureau of Indian Standards.

2.4.5 *Gasifier Technology*

Action Research Centres (ARCs), at the Indian Institutes of Technology in New Delhi and Mumbai, at Madurai Kamraj University, Madurai and at the Indian Institute of Science, Bangalore have been engaged in the technology upgradation, testing and monitoring of gasifier systems. They are entrusted with the responsibility of providing technical and consultancy services to the manufacturers. The R&D efforts are aimed at efficient and economically viable technology options like rotary steam and fluidised bed reactors and higher ratings in terms of feedstock flexibility and end-use applications. These ARCs are also made responsible for the prompt transfer of technology to the manufacturers.

Annexure H gives details of the experience of RETs in Industrialised nations.

3 ECONOMICS OF RENEWABLE ENERGY TECHNOLOGIES

Methodology needs clarification but appears to contain errors.

In this section of the report, detailed cost estimates consisting of investment cost and O&M costs and economics of each technology are presented. The past trend in the cost of each technology is reviewed and compared with costs estimates of other countries wherever possible. The economics of a system is determined by the following:

- total investment costs;
- lifetime of a system;
- O&M costs;
- Plant Load Factor (PLF); and
- Fiscal and financial policy (see *Section* 2 and *Annexure Aa, Ba, Ca, Da & Db*).

Based on the above information, following parameters have been calculated to determine the economic viability and feasibility of a system:

- Economic cost of generation per kWh;
- Financial / user's cost per kWh;
- Internal Rate of Return (IRR);
- Net Present Value (NPV); and
- Benefit Cost Ratio (B-C Ratio).

3.1 *CURRENT COSTS OF RETs*

In the following sub-sections, we present the cost related to various technologies and changes that have come about in the cost structure of each technology over a period of time. The total capital costs of any technology can be spilt into different cost components such as ex-factory costs of manufacturing, installation & infrastructure costs (including civil works, engineering costs, etc) and cost of grid connection,if required.

3.1.1 *Wind Energy*

Of all the renewable energy sources, wind energy appears to be the most feasible and cost-effective technology for supplementing conventional sources of energy.

Studies carried out in the past in USA and the Netherlands reported that the cost of wind turbine formed 75% of the total investment costs in Industrialised countries. In comparison, the 1988-89 MNES (the then DNES) Annual Report indicated the following with respect to capital cost of the wind turbines:

- infrastructure, installation and grid connection formed 30% to 50% of the total investment cost;

- remaining cost, i.e, from 50% to 70% was contributed by wind turbines.

In absolute terms, the US Department of Energy indicated the investment cost for 200 kWe wind turbine to be US$ 400 based on 1989 Dollar. As per IREDA, the recent investment cost per MW of wind energy is Rs 3.5 Crores. Personal communications with manufacturers reveals that the investment cost of wind energy has increased by around 35% in Tamilnadu and by 50% in Gujarat from 1992 level to 1996 level.

$200/kW

$?/kW

Though for economic analysis, life of a wind turbine is assumed to be 20 years, the experience reveals that the best turbines at present have a life of 10 to 15 years. It is recognised that further research and development work would increase the lifetime of the system.

According to studies conducted by IREDA & TERI, the O&M costs is normally taken as a percentage of total investment costs, which ranges between 2% to 2.5% in India. This estimate is similar to that estimated in an European study. Studies conducted by US DOE and SERI revealed that O&M cost was One US cent per kWh. In India, the percentage of O&M costs have remained at the same level for the last five years.

3.1.2 *Small Hydro*

A study carried out by ESMAP (ESMAP, 1991) estimated per KW investment cost (in 1990 price) of small hydel (dam based) as in the range of Rs 5426-Rs 14140 and same for small hydel (canal drops) as Rs 9848-Rs 22560. The costs of this technology are site specific. The current investment costs per MW of a small hydro system is Rs 4 crores as per IREDA. However, for the budget estimates in the Ninth Plan, MNES assumes the invest cost as Rs 7 crores per MW for North-Eastern region in the country as Rs 5 crores for any other parts of the country. A survey conducted by the World Bank [65] of technical designs of small hydel facility revealed that the capital cost of the technology could be brought down to one-third of the then capital cost which was in the range of Rs 2.5 - Rs 3.0 Crores per MW.

IREDA had formulated a Small Hydro Development Programme to supplement the MNES programme to harness the potential of this technology. Under this Programme, IREDA had sanctioned 27 projects equivalent to a capacity of 90.6 MW costing Rs 2785 Million as on 31 March 1995. Based on the above, the total capital cost per MW of small hydro works out to approximately Rs 3.1 Crores.

$?/kW

Similar to the wind technology, the O&M costs for small hydro projects is estimated to be 2% of the total capital costs (ESMAP, 1991). However, the O&M cost is site specific and in difficult terrains, the cost is likely to be as high as 3.5% to 4%.

3.1.3 *Wood Gasifier*

According to a study carried out by Mukunda *et al.* (1993) showed the capital costs of 4.4 KW and 96 KW gasifier system as US$ 1411 and US$ 1224 per KW (in 1991 US$ 1 = Rs 20) respectively. Same study worked out respective life-cycle operating and maintenance cost per KW as US$ 3037 and US$ 945 (assuming 6% discount rate and life as 40 years).

The capital costs per KW of a small wood gasifier system of 3.5 KW capacity in India (at 1993 prices) has been estimated as Rs 26,226 (Ravindranath, 1995). Detail break-up of the capital costs (at 1993 prices) is as follows:

Table 3a *Break-up of capital costs for wood gasifier system of 3.5 KW*

Items	Total Costs in Rs
Gasifier	19995
Building	10912
Engine generator	44981
Accessories	4991
Energy Forest	10912
Total	91791

Source: (Ravindranath, 1995)

A number of studies have analysed the economics of different bioenergy options in Brazil, USA and Europe. According to OTA (1992) the capital cost for small systems (5-100 KW) is in the range of US$ 420-680/kW (in 1992 US$), which is lower than the Indian examples. Small gasifiers were disseminated in significant numbers in South-East Asia during the early 1980s. The investment and operational costs of small gasifiers in the range 10-40 KW are given in *Table 3b*. The investment cost/KW for the imported gasifier was 2-4 times higher than the cost of locally produces one.

Table 3b ***Investment and Operational costs of small-scale gasifiers***

Projects	Investment cost (US$/KW)	Operational costs (US$/KWh)
Imported gasifiers		
Sebubuk	2000	0.07
Onesua	3600	0.09
Mahe	850	0.25
Dogofiri	2600	0.23
Local gasifiers		
Balong	1150	0.08
Nago	425	0.04
Bolo	300	0.03

Source: (BTG, 1993)

3.1.4 *Biomass combustion*

In India investment cost per KW for this technology lies in the range of Rs 3-4 crores per MW *(Table 3c)*. The investment cost and operating and maintenance cost in Europe is US$ 2400/KW and US c 1.1/kWh respectively (Grassi, 1992).

Table 3c *Investment Costs and Generation Costs Per Unit*

Technoloy	**Investment Costs (Rs Crores/MW)**		**Cost of Generation (Rs/kWh)**	
	1992[1]	1996[2]	1992	1996
Non-Conventional Energy				
Wind	3.50	3.5 - 4.5	2.25 - 2.75	2.00 - 2.75
Small Hydro	3.00 - 4.00	3.00 - 5.00	1.50 - 3.50	1.00 - 2.00
Spv (grid connected)	30.00	30.00	10.00 - 12.00	10.00 - 12.00
Biomass co-generation	1.20 - 1.50	2.5 - 2.75	1.20 - 1.30	1.25 - 1.50
Biomass gasifiers	1.00 - 1.50	2.5	1.50 - 2.15	1.25 - 1.50
Biomass power	-	3.00 - 4.00	-	1.75 - 2.00
Conventional power				
Thermal power	2.75 - 2.90		1.21 - 1.35 1.47 - 1.62	
Medium /large Hydro Power	2.50 - 3.50		0.75 - 1.50	

SOURCE : [1] Non-Conventional Energy Sources Schemes, Their Assessment and Implementation for committee on Energy, MNES, August 1993;
[2] IREDA

3.1.5 *Solar Photovoltaic (SPV)*

SPV is perhaps the most widely accepted solar technology. Stand-alone, with or without battery, SPV systems are more attractive for developing countries including India. In most of PV systems, the modules constitute the bulk of the investment costs. As shown in *Table 3c*, the investment costs of SPV systems have remained unchanged over the last four years. At global level, the prices of SPV modules have reduced substantially from US $ 100 per pW (peak Watt) in 1973 to US $ 5 per pW in 1990 and are further expected to go down to US $ 2-3 per pW during the neat five years. In the Indian context also there has been significant reduction in prices in recent years. Ninth Plan has set a target to bring down the price to Rs 110 per pW by 2001/02.

The operating and maintenance cost of PV system lies in the range of 2-3% of the total costs (Sinha and Kishore, 1993).

The O&M costs for SPV technology is estimated to be around 1% of the total capital investment. The cost, however, has been observed to be quite high due to the non-availability of service stations and spare parts in the past. In recent years, the availability of spare parts and repair & maintenance facility has improved.

3.1.6 *Solar Thermal*

Solar Thermal energy systems which are currently being used in India are:

- Solar water heating systems;
- Solar cookers; and
- Solar air heating systems.

There are other applications of solar thermal systems which are under development and demonstration stage, these are:

- Solar Desalination;
- Solar Pond;
- Solar Thermal Power Generation;
- Solar Refrigeration/Air conditioning;
- Solar Heat Storage;
- Solar Passive Building.

The current investment cost of domestic solar water heating system of 100 lpd capacity is in the range of Rs 15000 to Rs 18000. The investment cost for large capacity system varies from Rs 120 to Rs 140 per lpd. Operating, maintenance costs is taken as 1% of the capital costs (Kishore, 1993)

Available information show, a industrial solar water heating systems of capacity 40,000 lpd would cost Rs 1,456,900 (in 1986 prices) and operating and maintenance costs of nearly 1% of the total costs (Rao and Kishore, 1993)

3.2 *Economics of the Technology*

The Government of India is giving significant importance to the development of renewable energy sources. A key element of the new strategy for commercialisation of these technologies is to utilise the Government's limited budgetary resources to demonstrate the technical and economic viability of emerging technologies and applications, with a view to leverage private and institutional finance. The focus of the government programmes has shifted from financial incentives to fiscal incentives to attract private investment in the area of renewable energy development. In this sub-section, the economic and financial viability of the selected (refer *Section 2)* RETs is presented. Analysis has been carried out for all the RETs used for power generation, as well as stand alone solar water heating system.

3.2.1 *Methodology*

An assessment of financial and economic viability of the RETs is carried out vis-a-vis conventional coal thermal system. The economic viability is assessed based on the Levelised Annual Cost (LAC). Several financial indicators like, users cost * Internal Rate of Return (IRR), Payback period, Benefit-Cost Ratio (B-C Ratio) are used for financial analysis. The comparative analysis has been carried out for following two cases :

(For a project financed by private source of investment, user's cost indicates the minimum rate, purchaser has to pay for the output from the project. User's cost has been calculated by using the following equation: Total cost includes capital costs, operating costs, interest, taxes etc),

$$User's Cost = \frac{LifeTimeTotalCostIncurred}{LifeTimeOutput}$$

DCF approach?

- *Case I* - With special financial and fiscal incentives (like low interest rate on loan, special depreciation rate, etc) available for RETs (to be referred as *Case I* in remaining part of the report); and

- *Case II* - Without any special incentives for RETS (to be referred as *Case II* in remaining part of the report) .

Further, sensitivity analysis has been carried out on capital costs, buyback price and plant load factor (PLF). All the above mentioned economic and financial parameters have been estimated at busbar which assumes the cost of supply (transmissions and distribution cost) beyond busbar to be same for all gridable options.

3.2.2 *Limitations*

The analysis is limited to the extent that it does not take into account the:

- opportunity costs of benefits foregone during the differential lead time; and

- the economic benefits gained due to the availability of power at an earlier date in case of technologies with lower gestation period.

3.2.3 *Assumptions*

The cost data used for economic analysis is based on the information collected from various sources. The underlying assumptions peculiar to each technology are given in *Table 3d*. Certain common assumptions across all RETs are as follows:

- discount rate is taken to be 12%;
- buy back price of electricity is Rs 2.25/kWh; What is the rsc? we need least-cost comparison
- Not for economic! 18% interest rate has been assumed for working capital finances; and
- an annual escalation factor of 5% has been taken in buy back price as well as in fuel cost and O&M cost. rsc?

Assumptions for *Case II* are similar to *Case I* except for interest rate which has been assumed to be 15% (current market rate of interest) and 25% normal depreciation rate. ?

Table 3d *Assumptions for Benefit-Cost Analysis*

Particulars	Unit	Coal	Gas	Wind	Small Hydel	SPV	Solar thermal	Cogeneration	Biomass gasification		
									Bagasse	Wood	Solid Waste
Capital Cost	Rs Crore/MW	3.50	3.50	3.50	3.50	20.1	11.00	2.36	3.50	3.50	
O&M cost	(as % of capital cost)	2.50	2.50	1.50	2.00	1.00	1.00	2.00	2.00	2.00	2.00
Insurance cost	(as % of capital cost)	1.00	1.00	1.00	1.00	0.50	1.00	0.01	0.50	0.50	0.50
Fuel cost	Rs/tonne or cum	450	1950	-	-	-	-	400	400	1200	500
PLF	(%)	68.5	68.5	25	50	25	20	162 operating days	65	65	65
Depreciation Rate	(%)	25	25	100	25	100	100	100	100	100	100
Interest on long term loan	(%)	15.0	15.0	12.5	15.0	2.5	2.5	15.0	15.0	15.0	15.0

3.3 *ECONOMIC AND FINANCIAL ANALYSIS*

3.3.1 *Case I*

Technology-wise economic as well as user's cost per kWh, IRR, payback period and benefit-costs ratios as estimated are summarised in *Table 3e* and detailed calculations are shown in *Annexures (To be attached in the Final Report)*.

Table 3e ***Economic and Financial Parameters - Case I***

Technology	Economic Cost (Rs./kWh)	User's Cost (Rs./kWh)	IRR (%)	Payback Period (Years)	B-C Ratio	Capital cost Rs Crores/MW)
Coal	1.78	3.43	14.77	8.5	2.19	3.50
Gas	1.76	2.54	14.96	7.5	1.55	3.50
SPV	13.24	7.41	3.84	-	-0.58	20.15
Solar Thermal Power	10.36	7.01	4.99	-	0.64	11.00
Biomass-Bagasse	1.69	2.85	21.22	5	2.14	3.50
Biomass-Wood	2.12	3.35	15.57	6.5	1.55	3.50
Biomass-Solid waste	1.61	2.75	22.23	4.1	2.25	3.50
Cogeneration	2.33	3.49	13.30	7.2	1.29	3.00
Small Hydel	1.43	2.25	17.89	6	1.72	3.50
Wind	2.87	2.61	14.99	6.4	1.24	3.50

What is the difference between economic and financial?

As shown in the above *Table*, in spite of substantial financial and fiscal incentives, both SPV and Solar Thermal Power are far from being economically and financially viable as compared to any other technologies. This is mainly because of very high initial capital investment. However, financial incentives provided to these technology have brought down the User's cost. It is obvious that at this stage, the technology will not be able to attract any private finance because of very low IRR and long payback period.

Overall, small hydel seems to be the most attractive option with lowest economic and user's cost of generation per kWh than other technologies including conventional coal thermal technology.

Small hydel an IRR of 17.89%, B-C ratio of 1.72 and payback period of 6 years and is rated to be second best option for private investment after biomass based gasifier which has an IRR of 22.23%, B-C ratio as 2.25 and payback period as 4.1 years. While biomass (solid waste) based gasifier ranked as first in terms of financial viability, it stood second after small hydel as far as economic viability is concerned.

According to the financial indicators, bagasse based power generation seems to be third best option with same payback period and marginally lower IRR and B-C ratio than small hydel. Wind provides an IRR of 14.99% with payback period of 6.4 years. While economic cost of generation is highest in case of wind amongst all RETs because of its low PLF (23%), present financial incentives have brought down the user's cost to Rs 2.61 per kWh. Economic and financial indicators are almost similar in case of cogeneration and wood based gasifier. Even at current level incentives wind and cogeneration are not economically and financially favourable when compared with conventional technology and other RETs except SPV and solar thermal. This low profitability in case of cogeneration is attributable to low PLF (due to seasonal operation) and higher market price of wood (almost 2.5 times and 1.5 times more than coal and gas respectively). However, user's cost of these two technologies is less than coal thermal power project.

To sum up, under the present financial scheme, small hydel, solid waste and bagasse based power generation technologies are economically and financially competitive with conventional technologies like coal and gas thermal. In case of wind, the financial and fiscal incentives have made it financially attractive but economically unviable. Calculations reveal that the user's cost which is an indicator of the price the consumer pays to buy electricity, is less than coal for all RETs except SPV and STP.

3.3.2 *Case II*

In *Case II* as defined, market rate of interest and depreciation rate are assumed for all technologies. However, financial incentives like five years tax holiday which are applicable to conventional technologies as well is assumed to be enjoyed by the RETs also. The economic and financial indicators calculated as per these assumptions are shown in *Table 3f.*

Table 3 *Economic and Financial Parameters - Case II*

Technology	Economic Cost (Rs./kWh)	User's Cost (Rs./kWh)	IRR (%)	Payback Period (Years)	B-C Ratio	Cost per MW (Rs Crores)	Coal Savings (in tones)
Coal	1.78	3.43	14.77	8.5	2.19	3.50	
Gas	1.76	2.54	14.96	7.5	1.55	3.50	
SPV	13.24	10.43	-7.64	-	-0.20	20.15	1204.50
Solar Thermal Power	10.61	7.43	-4.82	-	-0.12	11.00	963.90
Biomass-Bagasse	1.69	2.70	17.21	5.80	1.80	3.50	3131.70
Biomass-Wood	2.12	3.21	12.00	8.00	1.20	3.50	3131.70
Biomass-Solid waste	1.61	2.61	18.84	5.50	1.91	3.50	3131.70
Cogeneration	2.33	3.35	8.96	9.50	0.90	3.50	2138.40
Small Hydel	1.43	2.30	16.80	6.50	1.65	3.50	2409.00
Wind	2.87	2.68	8.92	9.5	0.77	3.50	1108.14

In this case, except SPV, solar thermal power generation technologies and wind, there is marginal change in the financial indicators and user's cost for other RETs as compared to *Case I.* In case of SPV and solar thermal power technology, which enjoy a subsidised interest rate of 2.5%, user's cost increases to Rs 10.43 and Rs 7.43 per kWh at 15% interest rate, as against Rs 7.41 and Rs 7.01 in *Case I.* IRR is negative and no payback is achieved through out the life time of the system. Financial indicators like IRR and payback period of small hydel, biomass (solid waste) gasifier, biomass (bagasse) show that financially these technologies are at par with conventional coal thermal technology. In fact, they are financially more attractive than conventional coal thermal technology. Under market conditions, in spite of having similar investment requirement per MW, wind cannot compete with conventional technology mainly because of its low PLF. Similarly, the crushing season, which has been assumed to be *162* days, constraints the commercial acceptance of bagasse based cogeneration.

3.3.3 *Stand Alone System*

Solar Water Heating system (SWH)

The analysis has been carried out for a domestic SWH system. The methodology adopted to analyse the viability of SWH system consisted of comparing the cost of heating water from alternative sources like LPG and electric geyser. Following assumptions are taken for the calculation of heating per litre of water from alternative sources:

- Cost of 100 litres solar hot water system is Rs 16000, stove price for LPG is taken as Rs 1200 and geyser price is assumed to be Rs 3200;
- Life of all three systems is assumed to be 10 years;
- Hot water demand is seasonal and is taken for 150 days per annum;
- Electricity and LPG price (subsidized for domestic consumer) has been taken as Rs 2.4 per kWh and Rs 95 per cylinder (14.5 kgs).

The results, based on the above assumptions, show that LPG is the most economical option of all three systems with a cost of heating one litre of water as Rs 0.072. Geyser and SWH are almost at par at Rs 0.21 per litre. The payback period for SWH works out to 2.6 years.

Biogas for Lighting

To be incorporated in the Final Report

3.3.4 *Sensitivity Analysis*

The results summarised in the earlier section are based on a simplistic assumption of static conditions. Sensitivity analysis takes into account uncertainty and identifies those variables which are crucial for commercial success of a technology. In this sub-section, an analysis of sensitivity of RETs based on capital cost, PLF and buy-back price of electricity is presented. The analysis has been carried out for variations in capital costs from Rs 3 crores to 5 crores per MW for all technologies (excepting solar) and buy-back prices ranges from Rs 2.1 to Rs 2.5 per kWh. Ranges of PLF associated to the different technologies (only RETs) as assumed in the analysis has been presented below:

Technology	**Plant Load Factor (%)**			
Biomass-bagasse	35	40	45	50
Biomass-wood	35	40	45	50
Cogeneration	30	35	40	45
Small Hydel	30	35	40	45
Wind	15	20	25	30

Sensitivity analysis has been carried out for Case I. Variations in economic as well as user's cost of generation for all the technologies against increasing capital costs are shown in *Figure 1 and 2 (Annexure E)*. *Figure 3-5 (Annexure E)* present the variation in user's costs, IRR and benefit costs ratio for different technologies. Economic and user's costs of generation vis-a-vis PLF for different technologies are shown in Figure 6-10.

Level Playing Ground

As discussed in earlier Sections, at 15% rate of interest and uniform rate of depreciation, except for SPV and Solar Thermal Power, other RETs are almost at par with conventional coal and gas based technologies. In fact some of the technologies like small hydel, gasifier are financially more attractive than conventional technology. SPV and STP are far from being attractive even at the current level of interest rate (2.5%) enjoyed by these two technologies.

4 ENVIRONMENTAL IMPACTS

The RETs are considered to be environmentally benign causing little or no damage to the environment. In terms of atmospheric emissions, RETs are rated to be more superior than conventional fossil fuel based energy generation technology. However, there are some environmental externalities associated with the use of renewable resource based energy supply options. In this section of the report, such externalities are discussed in detail. In the absence of any identification/quantification study in India, ERM India has, wherever possible, used studies carried out in other countries.

4.1 WIND

4.1.1 Noise

There are two sources of noise in the wind turbine, namely, machinery in the nacelle, and the swishing sound from the rotating blades. While the former can be avoided by good design and acoustic insulation the latter is unavoidable and is the dominant source of noise. This noise results from a combination of aerodynamic and mechanical noise.

The value of the aggregate noise externality is site specific and mainly depends on the population density in the near vicinity of the wind farm. Studies carried out in UK have revealed the best estimates for Delabole and Penrhyddlan and Llidiartywaun to be 1.1 mECU/kWh (million European Currency Unit/kWh) and 0.07 mECU/kWh respectively. In the most UK wind farm locations, the damage is estimated to be less than 1 mECU/kWh.

Similarly, a study of a giant 2 MW turbine, called MOD-1 having a 200 foot rotor and 131 foot tower, at Howard's Knob in Boone, North Carolina at the National Aeronautics and Space Administration (NASA), USA, noticed that a shivering low frequency noise wafted downwind from the turbine. Investigations revealed that the rotor of MOD-1 rotors blades were moving at 250 mph while the wind passing the tower developed a defect called "wake". Each blade during its downward swing passed through this "wake" which resulted in added vibration and noise. The study reported two other factors responsible for noise. The affected houses were located in a small valley near the wind turbine, thereby the valley sides shielded not only the residents from the pleasant murmur of the natural wind which masks noise but also amplified the sound from the wind turbine. The engineers solved the problem by reducing the speed of rotation and downrating the wind turbine to 1.5 MW. Since then it has been established that the rotors which operate up-wind of the tower make less noise.

4.1.2 Visual impact

Opposition to wind energy on the grounds of loss of visual amenity is one of the biggest problems faced by wind industry in many developed countries.

This has resulted in a consensus amongst the wind industry that installation of wind electricity generators in areas designated to be of national scenic value should be avoided.

The flicker effect of direct sunlight passing through the rotating blades has potential impacts but only over a very restricted area. Furthermore, counter-measures are relatively straightforward and therefore the impacts are negligible. The dominant visual effect is the intrusion of the turbines and associated equipment.

In India, research is required to assess the externality as a function of landscape type and other variables. However, studies carried out in other countries have revealed that proper land use planning system can control and minimise the amenity externality effectively.

4.1.3 *Wild Life*

Major studies on the effects of wind turbines on birds have been undertaken in the Netherlands and USA. The US studies found some significant impacts on raptor species. The Dutch study found more limited effects, mainly on gulls and small song birds. A study (1992) was conducted (11) at Blyth Harbour Windfarm (UK) having a significant population of the rare purple sandpipers along with several other species. The study reported around 1000 dead birds which were recovered from the search areas adjacent to the windfarm. The death of these birds was attributed to natural reasons and not to the existence of the windfarm. The bird watchers of this study have observed that in course of time the birds learn to avoid the wind turbines. The study concluded that the impact of the windfarm on birds is less than the impact caused by roads or powerlines. The impacts on birds can be minimised if the wind farms are located away from important ornithological sites.

4.1.4 *Land use*

For a 20 MW windfarm, the area of the land taken out for use by turbine and access roads is about 5 hectares which is 1% of the land-spread of the windfarm. After construction and commission, 99 per cent of the land is available for its original use or newer activity [13]. However, the use of the land is restricted and limited for agriculture or pasture but not for plantation of trees. It should be noted that in India majority of the potential sites are near the seashore, or mountain ridges where there is no premium on land and land is mostly barren.

The land occupied by wind turbines within a wind farm is very small, and therefore only the effects of construction activities may have an impact on the terrestrial ecosystems. Even these will, in general, be small and reversible.

4.1.5 *Television Interference*

The rotating blades of wind turbines scatter electromagnetic signals, and can therefore cause interference in a range of communication systems. Primarily, impacts on television reception close to the wind farm are possible. These are normally confined to a small area, typically 2 km by a few hundred meters.

4.1.6 *Accidents*

Accident data collected in UK indicates that the accidents take place in manufacturing, construction and operational stages of the life cycle. Additionally the accidents are also associated with home to work travel which is the only source of accidents to the public apart from operational accidents. The other accident categories are occupational, and therefore the damage may well be internalised, at least partly, through wage or insurance costs.

4.2 *SMALL HYDRO*

There are almost no atmospheric emissions from small hydro fuel cycle. Though on a very small scale, the main impacts are on land use, aquatic and terrestrial ecosystem. The impacts of small hydro are very site- and project-specific. This makes it difficult to generalise the impacts of small hydro projects. No study has been carried out in India for assessment of these impacts.

4.3 *BIOMASS BASED ENERGY*

4.3.1 *Deforestation*

The sustainability of use of biomass resources is a function of its utilisation rate versus rate of regeneration. When the utilisation rate exceeds regeneration rate, this phenomenon is referred to as deforestation. Use of biomass as energy source contributes to deforestation and degradation of forest resulting in soil erosion and loss of biodiversity. A study conducted in India [54] reveals that if 19 mt (as reported by Forest Survey of India) of fuelwood use is met through forests, it would result in clearfelling of 150790 ha of forests annually. This would result in considerable amount of deforestation and degradation of forest. The total use of fuelwood in India in the 1991 was 227 mt which has increased continuously ever since with an increase in population.

The use of fuelwood by stripping land of vegetation leads to soil erosion due to wind and water effects (especially in dry areas). Such loss on a world wide basis is estimated to contribute to 7% of the soil degradation (*Source: World Resources 1992-93*). At global level, according to FAO study, tropical deforestation for the decade 1981-90 was estimated to be 15.4 Mha/year. This has indirect implications on emissions of C:

- 1.6 +/- 1.0 Gt C (Carbon) annually, accounting for 21% of global C (IPCC, 1992);
- 1.1 - 3.6 Gt of C annually (Houghton 1991);
- 0.9 Gt of C annually (Dixon *et al.* 1994).

The *Table 4a* depicts the area under forest and changes in forest area statewise.

Table 4a ***Area under forests and changes in forest area statewise base on satellite assessment of forests (10^3 ha)***

State/Union territories	1982 assessment (1981-83)	1986 assessment (1985-87)	1988 assessment 1987-89)	1990 assessment (1989-91)
Andhra Pradesh	5019.4	4791.1	4279.0	4725.6
Arunachal Pradesh	6050.0	6876.3	6875.7	6866.1
Assam	2638.5	2605.8	2475.1	2450.8
Bihar	2874.8	2693.4	2666.8	2658.7
Goa (including Daman and Diu)	128.5	130.0	125.3	124.7
Gujarat	1357.0	1167.0	1190.7	1204.4
Haryana	64.4	56.3	51.3	51.3
Himachal Pradesh	1288.2	1337.7	1178.0	1250.2
Jammu and Kashmir	2088.0	2042.4	2006.4	2044.3
Karnataka	3226.4	3210.0	3219.9	3234.3
Kerala	1040.0	1014.7	1029.2	1033.6
Madhya Predesh	12774.9	13319.1	13578.5	13539.6
Maharashtra	4741.6	4405.8	4404.4	4385.9
Manipur	1767.9	1788.5	1768.5	1762.1
Meghalaya	1651.1	1569.0	1587.5	1576.9
Mizoram	1909.2	1817.8	1885.3	1869.7
Nagaland	1435.1	1435.6	1432.1	1434.8
Orissa	5316.3	4713.6	4720.5	4714.5
Punjab	76.6	116.1	134.3	134.3
Rajastan	1247.8	1296.6	1283.5	1309.9
Sikkim	283.9	312.4	303.3	311.9
Tamil Nadu	1838.0	1771.5	1771.3	1772.6
Tripura	574.3	532.5	553.5	553.8
Uttar Pradesh	3144.3	3384.4	3360.9	3396.1
West Bengal	881.1	839.4	801.5	818.6
Other territories	786.6	785.9	1235.7	786.0
Total	64203.9	64013.0	63918.2	64010.7

Source : Ravindranath et al. (1992)

A study was carried out in India to estimate the carbon flow (*See Table 4b*) resulting from combustion of fuelwood, decomposition and short term and long term use of wood. The study also took into account the C sequestration in forests due to afforestation measures.

Table 4b Carbon flows in India from deforestation and forest degradation for the year 1986 (Mt C)

1	Carbon stored		
	forest:	Vegetation	4179.00
		Soil	5399.00
	Total carbon stored		9578.00
2	Carbon emission from:		
	shifting cultivation		1.56
	combustion[c]		26.90
	past long-term use[a]		1.38
	past short-term use[b]		3.10
	current short-term use		2.84
	release from soil		3.91
	biomass decomposition		18.92
	Total Carbon emissions		58.61
3	Carbon uptake (annual)		
	Forest plantations and succession in forests		68.87
4	Total annual Carbon uptake		68.87
5	Net annual Carbon uptake		10.26

Source : Ravindranath *et al.* (1992)

[a] Longterm use : timber used in furniture or housing, where carbon is stored for over 30 years. Timber used 30 years ago is expected to emit C during the reference year.

[b] Short-term used: timber used in pulp, container boxes, etc. where carbon is stored for short periods, 2-3 years. C emission during the reference year takes place from timber use during 3 years, including the reference year.

[c] Combustion : fuel wood obtained from clearfelling and forest degradation used as fuel.

4.3.2 *SPV and Solar Thermal*

The solar thermal power plants require about the same land area as a coal-fired plant and the solar PV plant requires about 12% less. However, both these require substantially more area than the wind electric power plant.

Despite their large land area requirement, solar photovoltaic power plants have an advantage not possessed by any other renewable energy source. In a distributed and stand-alone form, which is projected to be its largest application area, SPV can be installed and used in small load-specific capacities on roof tops and unutilized small nooks and corners of the site. Therefore, despite the fact that the total land area required per unit energy output is substantially high for SPV, the required land area can be sectioned and divided into smaller fragments, right at the load centre, by using small stand-alone PV systems. This advantage may not be of much value to the industrially advanced countries, but it is of vital significance to many developing countries, including India, where much of the small rural loads themselves are highly dispersed and utility grid lines are not available everywhere.

5 RENEWABLE ENERGY SUPPLY CURVE

Under the new Strategy and Action Plan of the Ministry of Non-Conventional Energy Sources (MNES), considerable progress has been achieved on the development of renewable energy sources. The total installed capacity of RETs has reached 1000 MW which is 1.5% of the total generation capacity in the country. This includes wind technology of 815 MW, 128.69 MW of micro hydel and 43 MW of biomass power etc (*Source : MNES, 1995/96*). The government has targeted an additional capacity of 3000 MW in the Ninth Plan (1997-2002). A document on Renewable Energy Policy[67] which includes the amendment of the legislation in the present electricity sector is proposed in favour of promoting renewables. The main aim of the policy is to augment the share of renewable to 6% of the grid system by the year 2012. The present study assesses the penetration of the RETs for power generation over the period 1996-2012 (covering IXth, Xth and XIth Five Year Plans). The technologies under consideration are wind, small hydel, bagasse based cogeneration, power generation based on biomass combustion as well as gasification and solar thermal power generation. The study does not include solar PV in the grid system since present prices of photovoltaic modules are in the range of US$ 4-5 per peak watt (Rs 11 crores per MW) as against Rs 3.5-4.5 crores/MW (1 crores = 10^7) of the conventional and other RETs. However, government has a target of developing 50 MW in the Ninth Plan in decentralised manner for both commercial and rural applications. A least cost analysis has been carried out to estimate the penetration level of RETs in the grid system of the country for the years 2001/02, 2006/07 and 2011/12 (respective terminal years for IXth, Xth and XIth Five Year Plan).

5.1 *ELECTRICITY DEMAND PROJECTIONS*

The electricity demand in the country has been projected by correlating the past electricity consumption with the GDP. For the future projections of electricity demand, GDP growth rate during the Ninth Plan period has been assumed as 7% (as projected by the Government of India) and beyond year 2002 as 8%. The electricity demand at the consumer end from the utility has been estimated as 439.9 TWh, 686.5 TWh and 1048.8 TWh respectively for the years 2001/02, 2006/07, 2011/12. This is as against the consumption of 238 TWh in 1993/94.

5.2 *SUPPLY ANALYSIS*

To assess the supply options, a linear programming model has been used. Model output provides the capacity requirement to meet the demand and supply mix for various power generation technologies. Other conventional technologies considered in the study are thermal power generation based on coal, gas (combined cycle), gas (open cycle), large hydel, nuclear and pump storage. For coal and gas, supply from domestic as well as imported fuel sources has been considered. Further, it has been assumed that the capacity based on the RETs under consideration meets base load demand.

5.2.1 *Scenarios*

Assessment of penetration level of RETs has been carried out for two cases:

Case I - This case makes the assessment of penetration of RETs in absence of any incentives. Economic costs (refer *Section* 3) for power generation have been used to carry out the analysis; and

Case II - The continuation of the present Government policy throughout the time horizon of the study has been considered in this case. User's costs (refer *Section* 3) for power generation which include the Government's present fiscal/financial incentives provided to the power generation technologies have been used.

Further, two scenarios have been developed to capture the impact of variations in capital costs and plant load factor of the RETs on the penetration level. Different capital costs per MW as assumed (only for RETs) in Scenario I are Rs 3 crores, Rs 4 crores, Rs 4.5 crores and Rs 5 crores. average for all RETs ? Scenario II considers variations in Plant Load Factor (PLF). Four different sets of PLF as assumed for different RETs (denoted by A, B, C, D) are shown in *Table 5a*. Each scenario has been developed for *Case I* as well as *Case II*.

Table 5a Sets of PLF (%) assumed in Scenario II

	A	B	C	D
Wind	15	20	25	30
Small Hydel	30	35	40	45
Biomass (Combustion)	35	40	45	55
Biomass (Gasifier)	35	40	45	55
Cogeneration	44	44	44	44

5.2.2 *Assumptions*

The assumptions regarding the RETs considered in the study are discussed below:

Wind

During the Eighth Plan period (1992-1997), wind power capacity in India has increased from 40 MW at the beginning of the plan to 815 MW (as on September 1996). In the Ninth Plan, the Government has set a target of adding 2000 MW capacity using this renewable energy resource. According to a first order estimate, the country has a wind power potential of nearly

20,000 MW. Ninety eight locations in eight states, with an estimated potential of around 5000 MW have annual mean wind speeds of 18 kmph or more which can offer relatively better plant load factor. Reviewing the performance of the country's manufacturing capability *(See Section 2)* and achievement in the installation front (average capacity addition of 200 MW per annum during last five years), present study assumes an upper limit on exploitation of this source at 5000 MW for the next 15 years time horizon.

Small Hydel

The country has a potential of 10,000 MW for small hydel capacity. During the Eighth Plan, the Small Hydro Power (SHP) programme was declared a thrust area by the Ministry. At the beginning of the Eighth Plan, the installed capacity in the country was 93 MW. As of March 1996, capacity of 128 MW has been installed and 248 MW is under implementation. It is expected that another 50 MW of capacity will be commissioned during the year 1996/97. Thus the total installed SHP capacity in the Eighth Plan would be 178 MW. Also, near commercialisation of the technology has been achieved during this period. The Ninth Plan has a target of initiating new projects aggregating to 350 MW. However, installation of 266 MW capacity is envisaged during this period and rest will spill over to the Tenth Plan period. The present study takes into account complete commercialisation of the technology during the Ninth Plan period and an upper limit on achievable small hydel capacity as 2500 MW over next 15 years time horizon.

Bagasse based Cogeneration

MNES Task Force has worked out a power generation potential of around 3500 MW based on bagasse based cogeneration. The potential for its exploitation over the next ten years is estimated as 2600 MW. Several policy measures taken by the Ministry in the last three years have created widespread awareness and an environment favourable for cogeneration technology. As a result, a capacity of 42 MW has already been installed and an additional 50 MW is under construction. With co-operative approach between the Government, SEBs and the sugar industry, it might be feasible to exploit the entire potential of 3500 MW by the year 2011/12.

Biomass based Power Generation

India has a potential of 32,000 MW of biomass based power generation (Ravindranath, 1995) capacity using combustion or gasification technology. The Government has created several favourable measures to ensure a level playing field and conducive environment for biomass power generation technology. One rice straw combustion based power project of 10 MW was commissioned in Punjab in 1992/93. However, it ran into technical and operational problems related to the combustion of straw, immediately after the installation. Bharat Heavy Electricals Limited (BHEL) carried out major modifications in the boiler and then operated successfully for 15 days in early 1994, before handing it over to the Punjab State Electricity Board (PSEB).

However, PSEB could not operate the plant thereafter because of the inability of collecting adequate quantities of straws to feed the plant. Presently, two pilot projects in Andhra Pradesh and Madhya Pradesh with respective capacity of 6 MW and 5 MW are under construction. Both are likely to be commissioned in April 1997. The gasification technology for power generation by converting wood/non-wood biomass into producer gas is still at the development stage. Further, gasifier designs are available with the capacity ranging from 5 to 100 KW. The megawatt size unit with high conversion efficiencies is likely to be commercially available in late 1990s (Larson 1993). Also large size plants might have constraints on raw material availabilities due to the lack of efforts/concepts on development of large scale energy plantation project. Since both the technologies are still not commercially (gasification technology is not technically also) mature, present study assumes introduction of biomass based power generation in the grid in Xth Plan and onwards. An upper limit of 100 MW and 200 MW based on each of these technologies have been assumed for the year 2006/07 and 2011/12.

Solar Thermal

Economics of solar thermal power generation are still very unfavourable. However, the MNES has developed a project of 35 MW in Rajasthan for demonstrating the techno-economic viability of a large scale solar thermal power generation. The project is expected to cost US$ 100 million. Per MW cost is worked out as Rs 10 crore, as against the conventional and other RETs cost of Rs 3.5-4.5 crores. Due to the very high costs, the study does not assume any further capacity addition apart from this project. Moreover, capital cost of this project has been treated as sunk costs in the analysis.

5.2.3 *Results*

Supply options as obtained from the exercise in two cases and different scenarios as defined earlier are discussed below:

Figure 5.1 (*Annexure F*) presents the total capacity requirement vis-a-vis capacity contributed by the RETs in *Case I* and *Case II* for each of the year under consideration. The total optimal capacity requirement has been estimated as 131,300 MW, 198,700 MW and 286,000 MW in *Case I* and 133,200 MW, 200,100 MW, and 292,600 MW in *Case II* for the years 2001/02, 2006/07, 2011/12. Slightly higher capacity requirement in *Case II* is because of higher addition of nuclear and wind technology capacities which offer low Plant Load Factor (PLF). Contribution from RETs for the respective years in *Case I* are 3960 MW, 5330 MW and 8560 MW. This implies that without any subsidy/incentives, the above-mentioned exploitation levels may be economically feasible to balance the huge demand-supply gap of power generation capacity for the country which is facing increasing scarcity of reserves of conventional fuel sources.

The share (%) of RETs in total capacity has been worked out as 3%, 2.7% and 3% in *Case I* for the years 2001/02, 2006/07 and 2011/12. Although, percentage share of RETs in 2006/07 has gone down from 3% in 2001/02 to 2.7%, but it has gone up in absolute unit. Capacity addition from RETs in *Case II* has been estimated as 5920 MW, 8280 MW, and 11,400 MW in 2001/02, 2006/07 and 2011/12 which is higher than respective year in *Case I*. This shows that the Government's present policy to provide subsidy/incentives for exploitation of renewable energy sources has a considerable impact on accelerating its penetration level. Figure 5.2 and 5.3 (*Annexure F*) show the break-up of total RETs capacity technologywise and the share (%) in total RETs capacity. In *Case I*, the model does not pick up any new wind capacity which can be explained by its higher economic cost of generation as compared to the other options. However, higher amount of wind capacity has been added in *Case II* than in *Case I*. This is because wind technology which offers higher economic cost of generation, becomes cheaper when financial/fiscal incentives are considered in the financial costs of generation. However, capacity based on other RETs such as small hydel, cogeneration, etc can be completely exploited to their upper limit level even without any subsidy/incentives.

Table 5.2 (*Annexure F*) presents the penetration level and capacity mix for RETS in the Scenario I. *Figures 5.4a, 5.4b and 5.4c* (*Annexure F*) shows that the total penetration level in *Case I* declines with the increasing capital costs. However, in *Case II*, total contribution of RETs in 2006/07 and 2011/12 remains constant at 8275 MW and 11435 MW even at capital costs of Rs 5 crores (*Table 5.2 in Annexure F*).

Model results indicate full exploitation (at upper limit level) of small hydel capacity in the absence of any subsidy/incentive scheme even at a capital cost of Rs 5 crores/MW. On the other hand, in absence of any subsidy/incentive scheme, considerable amount of new capacity based on wind technology can be added at capital costs of Rs 3 crores/MW.

Table 5.3 (*Annexure F*) presents the total contribution and technology mix of RETs as obtained from the model in Scenario II. Figure 5.5a, 5.5b and 5.5c (*Annexure F*) show that in *Case I*, contribution level increases with rising PLF of the technologies. However, in *Case II*, penetration level is not affected even at a PLF of 30% for small hydel and 15% for wind (Table 5.3 in *Annexure F*). Model results indicate that at PLF of 30%, wind technology becomes viable even in the absence of any subsidy/incentive scheme.

6 CONSTRAINTS TO EXPANDED USE OF RENEWABLE ENERGY

The Government of India has given significant importance to the development and promotion of renewable energy technologies (RETs) for nearly one and a half decade. India is perhaps one of the few countries in the world to have drawn up a comprehensive strategy and an action plan and set specific goals for renewable energy based capacity addition for power generation in the country. In spite of the Government's serious efforts towards rapid development of RETs based power, there are still a number of constraints and problems which need to be overcome in order to tap the vast potential of Renewable Energy in India. The constraints are discussed in this sub-section of the report.

6.1 INSTITUTIONAL CONSTRAINTS

Favourable institutional structure may have considerable impact on the promotion and development of RETs.

6.1.1 Approach

A top-down, centralised government initiative does not serve as an effective measure for the promotion of renewable energy technologies which is highly decentralised in operation. Bureaucratic red-tapism to get clearance of the project is one of the major constraints to attract private entrepreneurs. Presently, clearances (technical, financial, environmental etc.) required from concerned ministries and agencies complicate the entire process and lengthen the gestation period of a project.

6.1.2 User Education

User education and appropriate training on the operation and upkeep of renewable energy systems are not being practised with the seriousness deserved. The little that is undertaken has been either based on theoretical class-room teaching methodologies or publicity speeches by specific manufacturers. There have been very few field-level education and training programmes which address and deal with problems and questions brought by the participants themselves. There is a lack of simple but well written and profusely illustrated documents in local languages, to tell prospective users about renewable energy sources.

6.1.3 Outlook of SEBs

The existing institutional structure for power generation does not facilitate the use of renewable energy as an energy resources. In general, the State Electricity Boards (SEBs) have shown little interest in encouraging the sugar factories to cogenerate surplus power. Only certain SEBs like Karnataka, Tamil Nadu allow banking and wheeling of power. Other SEBs are yet to formulate policies on purchasing the power generated through wind, small hydel, etc. Further, there is a lack of flexibility on Third Party sale of power generated through the RETs. The unwillingness of state utilities to buy the electricity at economic prices and not permitting private utility to sell electricity in the market at commercial rates was observed to be a crucial factor for the commercial non-viability of the rice-husk based power generation system at Dhuri in Punjab [Ravindranath, 1995].

6.1.4 *Lack of Awareness*

The concept of renewable energy has not been very well promoted and marketed in the country. The information flow has been very limited which has led to a pre-conceived notion among masses that RETs are fit only for demonstration projects, and are not a long term feasible option for power generation. This lack of awareness on advantages, techno-economics and the availability of RETs and mindset has proved to be a major hinderance in the promotion of RETs. IREDA/MNES has been advertising in the newspapers/TV/Technical Magazines, etc. for promotion of RET based products/systems especially solar thermal. Individual manufacturers are also promoting these products through advertisements, however, lot more needs to be done in this aspect.

6.1.5 *Mis-utilisation of Incentives*

Also, incentives provided to the promoters of RETs are related to investment rather than performance. Very often, this encourages the entrepreneurs to design the plant to capture more tax savings than generate power.

6.2 *Technological Barriers*

6.2.1 *Resource Definition*

All renewable energy sources are site specific and the magnitude of energy availability or its potential depends on the local site conditions. Therefore, in order to optimise its use and tap its full potential, authentic and dependable resource data - in particular, the daily, seasonal and annual energy variations is must. A comprehensive understanding of all local conditions in different parts of the country does not exist today resulting in poor planning of power system.

6.2.2 *Technology*

Technology is a major bottleneck in most of the developing countries. Excepting a few (e.g small hydel), most of the currently available technologies are not fully mature and are relatively expensive. For instance, in India, efficient designs of gasifier based on biomass are still in the development stage. High efficiency large- scale gasifier systems are also not yet commercially available. Another major drawback of most of the RETs is their low energy density. In case of wind technology, capacity utilisation factor (CUF) is in the range of 15-30% whereas it is less than 25% in case of solar thermal and SPV. This has led to higher costs of energy production. Continuous development and upgradation of the technology is required keeping in view the Indian conditions. However, limited fund allocations from the government curtails the Research and Development (R&D) activities. Industrial R&D activities are required to enhance indigenisation which would help in reducing the capital costs.

Technical problems associated with conversion of wind energy into useful power relate to the peculiar nature of wind as a resource. The output of the wind energy conversion devices is proportional to the cube of the wind speed. The siting of the wind farms assumes great importance due to the high variability in wind speed from site to site. A survey conducted in 1985 65 reported that 106 of the 177 water pumping windmills were installed at locations with inadequate wind and water.

For decentralised and stand alone systems in the capacity range of 1 - 20 kW power is fairly complicated and expensive. This results from the requirement of a large and expensive capacity for storage of electrical energy which depends on sophisticated storage techniques and battery control and regulation facilities. This problem is associated with most stand alone power generating systems such as wind turbines, SPV systems, etc and the stand alone systems in this capacity range are yet to establish their viability and reliability.

6.2.3 *Site Specificity*

Wind technology is very site specific as wind power can be harnessed only at those places that experience sufficient wind speeds. Apart from the above wind is also very inconsistent in nature - its strength and direction vary with time and so does its output. Hence, it does not have the features of a conventional power source, the most significant being that it cannot be used (on a large scale) as an independent power source.

The penetration level of wind technology in existing state/regional grid is limited. Certain studies conducted in this regard in India and aboard have revealed a feasible penetration level of up to 25 percent. At a particular site, the grid parameters keep fluctuating. The Wind Electric Generator (WEG) would feed power into the grid only if its output parameters synchronizes with the (corresponding) grid parameters. The WEG would hence feed power into the grid within a given range (of fluctuation) of these parameters. In places where the grid is weak, grid interfacing of the generator becomes a problem and the annual energy generation would be affected by the low grid availability.

6.2.4 *Cogeneration Technology - constraints*

As far as cogeneration technology is concerned, the key to a successful bagasse cogeneration program would be the penetration of high pressure boilers in the sugar mills. It is believed that high pressure boilers would make cogeneration efficient and much more attractive for the units opting for cogeneration. Most Indian sugar factories use low or medium pressure boilers. The high pressure boilers are new to the sugar industry and are associated with increased risks in operation and resultant higher costs. Most sugar factories in public and cooperative sectors are on small scale and there is a shortage of sound technical management required to maintain such type of boilers.

6.2.5 *Lack of Technical Information*

Lack of easy accessibility of technology related information and documentation to the entrepreneur as well as consumer is yet another constraint. In India, technical experience is limited to demonstration projects. Though there is technical expertise available for writing project reports, identification of sites for windfarms and small hydel, to carry out the implementation of large scale projects is envisaged to be a constraint to the widespread dissemination of RETs.

6.3 *INFRASTRUCTURAL CONSTRAINTS*

6.3.1 *Land Availability*

Land availability for housing power generation facilities can emerge as a major constraint on future development. Land rates in the prime areas have shot up. Shortage of wood biomass may be the major constraint for the use of the gasifier technology. Absence of land tenurial securities, information on potential benefits of using degraded land for energy plantation etc discourages farmers from establishing energy plantations.

6.3.2 *Grid Connection*

Grid availability to evacuate the generated power is an essential requirement. Poor grid availability and reliability are risks that have to be borne by the developers. So far, development of private transmission/distribution system is not allowed in India but this Policy is changing in some States like Orissa.

6.3.3 *Repair & Maintenance*

Lack of proper maintenance and servicing facilities at local level is another serious constraint for successful operation of RETs. This is particularly true for stand alone decentralised systems such as lighting systems, SHW, etc whereby the spare parts are not readily available in the market and repair and maintenance systems is not properly developed. This has lead to unacceptability of the system among large numbers of potential consumers in urban and rural areas. The manufacturers should provide reliable service contracts for operation and maintenance of the equipment they sell. Empowerment of local communities with proper technical training on operation & maintenance may be a long term solution to this problem. Also, there is a lot to be desired from Indian manufacturers and suppliers on their approach to the vital components of after-sales services and appropriate documentation. Indian renewable energy products are not yet rugged or reliable enough to dispense with maintenance and after-sales services completely.

6.4 ECONOMIC/FINANCIAL BARRIERS

6.4.1 Hidden Subsidy

In India diesel and electricity is subsidised for agriculture and rural domestic sectors. Many of the State Governments provide electricity free of cost for agricultural activities. Very often, existing subsidies provided for renewable energy technologies are inadequate to compete with highly subsidised electricity/diesel for water pumping or subsidised kerosene/LPG for domestic use. In such a situation, it is impossible for any renewable energy options to compete with and be viable. No industrialist/entrepreneur would invest money in a renewable energy project if the output has to compete with highly subsidised energy supplies.

6.4.2 Funds Constraint

Funds available for the promotion of RETs are very low as compared to the funds available for the conventional energy sector. In the Eighth Plan (1992-97) allocations for renewable energy was Rs 857 crores (GOI, 1992) which was only about 0.8% of the total funds allocated to the energy sector (TERI, 1996). If a goal of 10000 MW renewable electric capacity has to be achieved by the year 2010 (which would amount to a 5% share in the total anticipated installed capacity), it would involve an investment of nearly Rs 53500 crores (US$ 15 billion) (Gupta, 1995). Without a much greater involvement of multilateral funding agencies/private sector/financial institutions, this target may not be achievable.

6.4.3 High Initial Investment

Costs of renewable energy systems/devices are higher as compared to the conventional energy systems/devices. The generation cost per unit in case of RETs would become attractive, if following were quantified and included in the costing of conventional power systems.

- direct and indirect subsidy made available to fossil fuel based technology at various stages; and

- environmental degradation and health hazards caused by extensive use of fossil fuels.

6.5 *POLICY MEASURES TO REMOVE CONSTRAINTS*

As economic development in the country cannot be constrained, it becomes necessary for the policy-makers to come up with a sound alternate energy development plan. In order to keep pace with the growing energy demand and covering the gap between demand and supply, efforts should be made to accelerate the pace of renewable energy development. There are various levels at which work needs to be done. These levels and the work plan that they need to follow are enumerated below.

6.5.1 *Government Agencies and their Functions*

Development plans for renewable energy is the ultimate responsibility of government agencies. This should be shared with other stakeholders in the development process, thereby encouraging them to take further interest in the process. Since the government is represented by numerous agencies, working at many different levels, their functional roles have to be clearly identified. Some of the functional roles that can be adopted by governments are listed as under:

- Develop long-term strategies and a set of developmental criteria to measure the contribution of energy systems to economic advancement.

- Formulate a policy which would cover the following issues: investment incentives, pricing, taxation, market infrastructure development, consumer information and education, technology transfer, development of local manufacturing capability and other areas.

- They should address the issue of implementation by selecting appropriate instrumental agencies which will not only implement, but also monitor the renewable energy projects. These agencies should be provided government support for developing infrastructure and human resource.

- The governments have to develop a good energy data base, on the basis of which they can mobilise funds required for direct investment or route it through financial institutions. The projects should be able to attract foreign funding agencies.

- Apart from financial and institutional support the governments should provide a legal framework for encouraging private sector participation. This legal framework should also provide for monitoring and enforcement mechanisms, to ensure environmental accountability of all private and public sector participation.

6.5.2 *Utilities and their functions*

Power/electricity utilities responsible for electricity, coal and petroleum supplies are state owned/controlled. They are responsible for conventional energy system distribution and maintenance. Environment protection has pressured them to promote renewable energy/decentralised energy options. Some of the policy measures which would be forthcoming for electric utilities where renewable energy options are concerned are mentioned below:

- The investment portfolios of utilities should be diversified to include decentralised power generation options, which would use least cost criteria with an optimal mix of supply facilities. This should be followed by a detailed cost-benefit analysis to evaluate the decentralised options.

- They should provide grants to R&D institutions to develop appropriate decentralised options.

- Where these options have been developed by other agencies like local authorities, or other public and private sector agencies, the utilities should ensure them with complementarity of their grid usage and provide them connections at a cost. The utilities can also formulate a policy for power purchase from these agencies.

- To allow private sector and user communities to overcome investment constraints, innovative options should be looked at to define the relationship between utility and non-utility power generation. These options could include equipment leasing, franchising, BOOT (build, operate, own and transfer) etc.

- In order to maintain and operate decentralised power generation options, the electric utilities should provide training to non-utility persons.

- Adequate functional and financial autonomy should be provided to decentralised power plants, which should make a come-back with reasonable return on investment.

- The utilities should establish demand side management programmes to promote end-use efficiency by financing energy-efficient irrigation pump-sets, lighting systems and other electrical appliances.

6.5.3 *Private sector and its functions*

A recent article in the Financial Times (London), states that by the year 2007, India would need to add an estimated 130,000 MW of new power generation capacity. Of this a maximum of 40,000 MW can be added by the public sector but the balance will have to come from the private sector.

The Government of India has taken adequate steps to promote private sector participation in the field of renewable energy development by launching innovative financing schemes. These include

- 100% depreciation allowance
- Soft loans
- Reduced customs duties on imported materials and equipment
- Exemption from excise duty and sales tax
- Remunerative price for power fed into the grid, and
- Facilities for wheeling and banking of power

On their part the private sector should be given the following responsibilities:

- Conduct market surveys to establish market potential and feasibility of these technologies, and on the basis of the study they should provide help to the governments for drawing appropriate area classification and policy formulation.

- They should strive for technology indigenisation by investing in assembling and manufacturing technology.

- They should come up with a suitable market strategy targeting all potential customers to promote decentralised energy systems use.

- The private sector should invest in spare parts and servicing networks, so as to build user confidence in the technology.

- They should enter into a partnership with public utilities on a profit sharing basis for renewable energy decentralised systems.

6.5.4 *Financing Institutions and Donor Agencies and their functions*

Financial institutions (FIs) for renewable energy include national and commercial banks, credit and loan financing organisations, development banks and specialised lending agencies. The financing requirements pertain to acquisition of user-operated energy systems and end-uses, costs of R&D, training and data base development costs and support for infrastructure development. For renewable energy programmes the loans are relatively small, as compared to loans required for conventional energy systems. But the promotion of environment friendly renewable energy technology has made it necessary for FIs to finance such small loans. This can be done by taking the following measures into consideration:

- FIs should diversify their credit portfolios to finance those systems which have shown commercial success. For the purpose they should develop in-house expertise to help process RET loan proposals.

- They should evolve innovative financing schemes by adding line of credit, revolving fund and hire-purchase to the conventional loan schemes.

- FIs should act as intermediaries accessing and distributing international loan funds. They can put together several small projects in an attractive package to place as a proposal before the international bodies for funding.

- FIs specialising in development should provide investment linked technical assistance in developing cost-effective technologies, and ensure viability of investments made by monitoring progress.

- Going by their experience in technical assistance programmes, donor agencies should concentrate more on the viable technologies, ad work in close association with the FIs to develop investment in mature technologies.

- Both these agencies should pay more attention to developing local manufacturing expertise, for which a well-supported R&D base is essential. Financial assistance to R&D agencies should be encouraged so as to bring down technology costs and improve technical efficiency factors.

- Adequate attention must be paid by donor agencies and international FIs to policy reforms and institution-building efforts. They should provide support for increased technology absorption capability, promotion of venture capital markets, environmental and social impact assessments, innovative project implementation mechanisms, and other measures to enhance feasibility of renewable energy projects.

6.5.5 *Research Institutions and their Functions*

Renewable energy R&D has to be country-, as well as area-specific, because of the wide variation in physical and socio-economic conditions. Primarily it is the universities, other academic institutions and some selected specialised institutions which conduct R&D activities. But these agencies are faced with limitations pertaining to lack of focused long-term research programmes, ad hoc nature of studies undertaken depending on availability of funds, insufficient links with the government at the planning and implementation stages. The research institutions should therefore take the following measures in relation to renewable energy development:

- They should assess energy needs, local resource availability and technology absorption capability through field surveys, desk research and other means. This exercise would generate data base for energy development and management.

- Research effort should incorporate planning methodologies, project evaluation techniques and project implementation mechanisms on a demonstrative basis.

- They should take part in field-tests conducted on RETs jointly with foreign manufacturers and research institutions, so as to identify improvement/adaptation needs and they should also be actively involved in the pilot project stage.

- Research institutions should maintain contact with foreign research agencies in order to keep an update on latest technology options, performance parameters, future cost economics, resource requirements and other relevant information.

- During the technology commercialisation stage, the research institutions should work in close association with government implementing agencies, utilities and the private sector. This would enable them to assess technology performance and improvement based on market feedback.

- They should make efforts to develop new technologies to meet future energy needs.

6.5.6 *Training institutions and their functions*

At present training is provided by research institutions in order to disseminate information on technical research and for specific projects by government organisations or technical consultants. These training programmes lack funds and proper organisation and may be repetitive. In case of government bodies, this training is lost when a person is transferred to another unrelated field. Therefore the training programmes have to be well managed and organised in order to scale up renewable energy options for electricity. An assessment of training needs should be made at the national level which can then be provided through specialised institutions or through existing agencies after providing them with the necessary capabilities. The training institutes can have the following functions:

- Assess training needs at the national, state, district and village levels, covering areas of policy analysis, planning methodologies, data collection survey techniques, technology evaluation, technical operation and maintenance, project implementation, R&D management, preparation of loan proposals etc.

- They should identify the trainees by level and location, covering governmental policy-makers and planners, personnel of governmental implementing agencies and utilities, private sector manufacturers and equipment dealers and FIs.

- They should develop a standardised training manuals and guidebooks, in local languages, for use at decentralised levels and organise training of trainers for downstream delivery.

6.5.7 *Other Measures*

Measures discussed below have been resourced from a Working Paper prepared by ERM India on National Renewable Policy for Ministry of Non-Conventional Energy Resources.

Resource Mobilisation

Till date, promotion of RETs is mainly funded by the Government and subsidy driven. However, it is realised that it would be difficult for government exchequer to continue finance promotion and development of RETs. The exchequer cannot be expected to bear this burden entirely on its own. In the context of paucity of funds/resources with the government and to bridge the gap between rapidly growing demand and supply a policy to encourage greater investments by private enterprises is required in RET sector. To attract private investment, an attractive package of incentives needs to be provided to them so as to make investment in RETs a profitable venture. In this background, the National Renewable Energy Policy suggests:

- Extra Rupee could be charged from consumers of LPG cylinders
- A levy of surcharge @ 1.00 paisa/litre on consumption of diesel & petrol
- Collection of Rupee 1 from every Govt/public sector employee
- Large scale companies consuming power should utilise 10% of their total requirement through renewable.

With the available resource, a National Renewable Energy Revolving Fund could be created.

It is important for a private promoter to have access to less time consuming and easy finance through one window. A major step in this direction is making IREDA an independent financial institution like ICCI, IFCI, IDBI etc. It should function as an apex financial/banking institution and its linkage with the MNES should be minimised so that it can come out of the shadow of MNES. The National Renewable Energy Revolving Fund should be created and controlled by IREDA.

IREDA should provide refinance facilities to various commercial banks and non banking financial companies at a rate of interest which is attractive for these financial intermediaries to promote commercialisation of RETs.

The main reason for the commercialisation of RETs has been the provision of various financial and fiscal benefits especially depreciation allowance. These incentives should continue in future as the viability of already installed projects would lead to demonstration effect and replication. However, as the installed capacity of RETs increases the burden on exchequer will also increase if incentives like 100% depreciation are continued. Thus this too should be phased out gradually with technology improvements and increasing commercialisation.

With the increasing share of RETs in the total power sector the government and SEBs will have to ensure that they are in position to take the electricity supplied to them by private energy generating units. Necessary policies and efforts should be undertaken in this direction.

Least cost rural energy market necessarily means decentralised and stand-alone market for energy. Decentralised sources of energy are biogas plants, smokeless chullahs and solar hot water systems. They are designed to cater specifically to the needs of rural population. Presently, they fall under the ambit of MNES. Promotion and development of decentralised sources of energy should be made a part of the Rural Development Programme under the Ministry of Rural Development. Funds should directly flow to the Panchayat and a better interface should be developed with NGO's and various development agencies liasoning with KVIC, health programme of Ministry of Health & Welfare, etc can be done at centre and capabilities of panchayats should be geared up to take up such programmes. Nodal agencies should play a supporting role and provide technical assistance to agencies implementing the schemes for least cost rural energy supply.

Rural Electrification Corporation should take up the task of promoting decentralised power technologies like mini-hydel, wind mills and gasifier for meeting decentralised power requirements. An amount equivalent to the avoided cost of installing transmission line should be utilised for supporting the rural electrification programme based on renewable sources of energy.

Rural Energy Co-operatives should be created to supply decentralised energy in its command area and manage the decentralised system. All the beneficiaries would be the member of these co-operative and a price will be charged for the energy supplied to them.

7 CONCLUSIONS

In the previous sections, various renewable energy technologies and their current development status were individually discussed. Additionally, the current government policy, manufacturing base and R&D infrastructure has been discussed.

The renewable energy programmes in India were initiated after the first oil shock came in 1973. From that time till about 1996, there has been concerted government effort to develop various renewable energy sources throughout the country. Considerable progress has been achieved during these 20 years in almost all renewable energy fields. Details of developments and status of various renewable energy sources have been discussed individually in the previous sections. Major obstacles against their large-scale use have also been discussed. These obstacles finally lead to two conclusions: (i) the currently ruling fossil oil prices are low, and quite steady, that do not take into consideration the immense damages being done to our environment due to their unbridled use; and (ii) enough resources for further R&D on renewable energy sources are just not available to reduce their investment costs. Unless more R&D resources are made available to reduce the renewable energy costs, and the oil prices take into consideration their deteriorating effects on our environment, it would be quite difficult to push these sources for mass-scale applications.

7.1 FINANCIAL AND ECONOMIC VIABILITY

From the discussions which have been brought out so far, it can be concluded that in India, excepting SPV and STP, all other technologies are financially almost at par with conventional technology. Some of the technologies like wind, small hydel and gasifier based on solid waste and bagasse are more attractive than conventional one. Interestingly, these technologies can sustain even without any incentives as specially provided to them. In case of SPV and STP, serious R&D effort is required to bring down the capital cost. Without drastic capital cost reduction, it is impossible to bring the technology at par with others.

7.2 SUPPLY CURVE

Above study concludes that RETs capacity of amount 8560 MW is feasible in 2011/12 even in the absence of any subsidy/incentives scheme. This will contribute nearly 3% to country's total power generation capacity. Though this share is not significant at present, it is nevertheless relevant to bridge the huge demand-supply gap resulting from increasing scarcity of conventional energy sources. Continuation of Government's present policy can give a further boost to the penetration of RETs to 11440 MW in 2011/12. Sensitivity analysis on capital costs show that 7235 MW of capacity is economically viable even at a capital cost of Rs 5 crores/MW and this further goes up to 11440 MW in case present subsidy/incentive scheme continues. Variations in PLF have considerable impact on the penetration of RETs in absence of any policy intervention. However, under the present policy, variations in PLF does not affect the penetration level.

7.3 *POWER GENERATION*

Because electricity is a clean and highly versatile form of energy, a major renewable energy R&D goal has been generation of electric power. As a result, the installed electric power generating capacities, due to renewable energy sources, have been increasing steadily, *albeit* at a less-than-optimum rate. Estimates on installed renewable energy power generating capacities show that largest growth during the last few years was observed in the wind sector. This is because of the private sector participation on a build-operate-own (BOO) basis in many energy-starved States in India. The growth rate of solar PV has also been significant during the 1992-1994 period, but has lately slowed down a little. Here, private sector participation is also significant in system manufacturing. However, Indian solar PV market is controlled by the government and the demand has mainly been due to the service-sector government organisations dealing with Telecommunications, Televisions, Railways, Defence, and so forth. The rural applications market is also sponsored by the government.

7.4 *LAND REQUIREMENT*

There is a common belief that since most renewable energy resources are highly disperse, the land requirement per unit energy generation may be substantially large. *Annexure G* (Figure 1) shows the land requirement for unit energy generation using various power plants based on renewable energy sources and coal. As is shown in the figure coal-fired power stations require maximum land area, if the coal mining area is also considered. On the other hand, geothermal energy requires about nine times less land area. Wind generators have the next highest land requirement. However, one major advantage of wind energy is that the installed land can also be used for other purposes, such as agriculture, farming or minor industrial activities. The solar thermal power plants require about the same land area as a coal-fired plant and the solar PV plant requires about 12% less. However, both these require substantially more area than their cousin, the wind electric power plant.

In case of wind energy, other impacts discussed in the previous sections are related to noise, visual, and wildlife. However, since most of potential wind sites are located in isolated sites either on the seashore or hills, these impacts are not very significant.

7.5 *CONSTRAINTS*

The development of renewable energy sources as an energy supply options has suffered from many institutional, technical, financial & economic constraints. The most significant of these constraints is the lack of adequate resources necessary for the highly essential research and development, lack of awareness and proper institutional support. This calls for effective financial incentives and administrative support.

Annex Aa

IREDA's Project Financing Norms

IREDA'S FINANCING NORMS AT A GLANCE

PROJECT FINANCING :

Sl. No.	Sector	Interest Rate (inclusive of Interest Tax)*(%)	Repayment Period including Moratorium (Maximum) (Years)	Moratorium (Maximum) (Years)	Minimum Promoter's Contribution (%)	Term Loan/Lending Norms of IREDA
1	**Small Hydro**					
	(a) World Bank Programme	16.50	10	3	25	100% of eligible equipment cost under World Bank norms limited to a maximum of 75% of project cost
	(b) Non-World Bank component	19.00	10	3	25	
2	**Wind Farm**					
	(a) DANIDA Funds	18.00	7	1	25	100% of eligible equipment cost limited to a maximum of 75% of project cost.
	(b) IREDA Funds (above 1MW capacity)	19.00	7	1	25	
3	**Bio-mass Co-Generation** (including Sugar Industry)	18.00	10	3	25	Upto 75% of total project cost.
4	**Bio-mass Power Generation**					
	i) Municipal Waste	10.50	10	3	25	Upto 75% of total project cost.
	ii) Other than Municipal Waste	16.50	10	3	25	Upto 75% of total project cost.
5	**Bio-mass Gasifier for Power Generation** (Above 500 KW)	18.00	5	2	25	Upto 75% of total project cost.
6	**Bio-Methanation from Industrial Effluents**	18.00	8	2	25	Upto 75% of total project cost.
7	**Bio-mass Briquetting**	12.50	10	2	25	Upto 75% of total project cost.
8	**Solar Thermal Systems****					
	- Users (Direct)					
	- Institutional (non-profit making i.e. not claiming 100% depreciation)	5.00	10	2	25	Upto 75% of total project cost.
	- Industrial & Institutional (Profit making and claiming 100% depreciation)	8.30	10	25	25	Upto 75% of total project cost.
	- INTERMEDIARIES					
	- Intermediaries (Domestic) $$$	2.50	5	1	25	Upto 75% of total project cost.
	- Intermediaries (Other than domestic) $$	8.30	10	2		Upto 75% to total project cost.
9	**Biogas plants utilizing animal dung.** Human Excreta and Night Soil (20-100 cum/day) $					
	- Financial Intermediary***	16.50	8	2	20	Upto 80% of total project cost.
	- Direct Users	10.50	8	2	20	Upto 80% of total project cost.

Annex Ab

IREAD's Equipment Financing Norms

EQUIPMENT FINANCING :

Sl. No.	Sector	Interest Rate (inclusive of Interest Tax)* (%)	Repayment Period including Moratorium (Maximum) (Years)	Moratorium (Maximum) (Years)	Minimum Promoter's Contribution (%)	Term Loan/Lending Norms of IREDA
1	**Micro Hydel Sets** (upto 100 Kw capacity) (a) For hilly Areas (b) Others	17.00 17.50	6 6	1 1	20 20	Upto 80% of the cost of eligible equipments(s). Upto 80% of the cost of eligible equipments(s).
2	**Wind Energy Equipment** (upto 1Mw per party per financial year)	19.00	7	1	35	Upto 65% of the cost of eligible equipments(s). WEG, Tower, Control Panel and Transformer)
3	**Wind Energy Auxiliary Equipment**	19.00	8	1	25/50	Upto 75% of cost of cranes/monitoring equipments (new) or 50% of cost of second hand cranes.
4	**Gasifiers (upto 500 Kw)**	17.50	4	1	20	Upto 80% of the Cost of eligible equipments(s).
5	**Battery Powered Vehicles & Vehicles based on alternate fuels such as ethanol etc.**	17.50	5	1	20	Upto 80% of the Cost of eligible equipments(s).
6	**High efficiency energy saving/conservation systems through renewable systems/fuels.**	17.50	5	1	20	Upto 80% of the Cost of eligible equipments(s).
7	**Solar Photovoltaics** (Direct/Intermediaries)					
i)	Domestic & Farm Systems of all Categories					
	a) For rural applications b) Other than for rural applications	2.50 5.00	8 8	1 1	15 20	Upto 85% of the Cost Upto 80% of the cost
ii)	SPV Pumping	2.50	10	1	15	Upto 85% of the cost
iii)	Power Generation of all Categories.	5.00	10	2	15	Upto 85% of the cost

NOTES :

*	Rate of interest would be reduced by 0.50% in the event of borrower furnishing security of Bank Guarantee.
**	Rebate of 0.50% in interest rate is given to the beneficiaries who use ISI marked collectors for Solar Thermal Heating Systems.
***	The financial intermediaries can have spread of 3% over and above IREDA's interest rate i.e. 19.50% (16.50 + 3.00)> The requirement of margin/spread of 3% has no application where financial intermediaries give equipments on lease basis.
$	Projects costing upto Rs.50.00 lakhs could only be considered for IREDA's financing
$$	Are eligible for spread upto maximum of 4%
$$$	Are eligible for a spread of 2.5%

Annex Ba

Policy Incentives For Wind Power Projects

Table *Policy Introduced/Incentives Declared by the State Governments For Private Sector Wind Power Project*

Items	Andhra Pradesh	Tamil Nadu	Karnataka
Rates/charges for:			
Wheeling	2% of energy fed into the grid	2% of energy generated	2% of energy generated
Banking	12 months for captive use, 8 months (August to March) for third party sale at 2% charges)	12 months with 2% Banking Charges	12 month (July-June) +1 month grace-period
Buyback by SEB	Rs 2.25\kwh	Rs 2.75\kwh with 5% annual escalation	Rs 2.25\kwh
Third Party Sale	Allowed	Not allowed	Allowed
Incentives:			
Capital Subsidy	20% of the project cost subject to maximum Rs 25.00 lakhs	10% of project cost subject to maximum of Rs 15.00 lakhs	As extended to other industries
Allotment of Land	Long lease for projects upto 20 MW	--	By K s Ind Area Dev Board for 40 years +10 years (renewable)
Other Concessions	Industry status	Exemption of generation fax	Exemption of electricity tax for 5 years for new units
Promotional Supports:			
Single Window Agency	NEDCAP	TEDA/TNEB	KEB/KPCL
Publication of Brochure (Detailing Policies/ incentives, etc)	Published	Published	Published

Table *Policy Introduced/Incentives Declared by the State Governments For Private Sector Wind Power Project*

Items	**Kerala**	**Uttar Pradesh**	**West Bengal**
Rates/charges for:			
Wheeling	2% of energy generated	2% of energy generated	2% of energy wheeled
Banking	6 months with 2% banking charges	One year	12 month (July-June) +1 month grace-period
Buyback by SEB	At mutually agreed rates	Rs 2.25/kwh	To be decided on case to case basis
Third Party Sale	--	Allowed with 2.5% wheeling charges	Not Allowed
Incentives:			
Capital Subsidy	15% of the installation cost subject to a ceiling of Rs 5.00 lakhs	As extended to other industry	
Allotment of Land	--	Lease for a period of atleast 35 years	
Other Concessions	(i) Financial assistance from State Ind.Dev Corpn (up to Rs 90 lakhs) (ii) Consultancy Services		
Promotional Supports:			
Single Window Agency	ANERT/KSEB	NEDA	
Publication of Brochure (Detailing Policies/ incentives, etc)	Published	Published	

Table *Policy Introduced/Incentives Declared by the State Governments For Private Sector Wind Power Project*

Items	Gujarat	Madhya Pradesh	Maharashtra
Rates/charges for:			
Wheeling	2% of energy generated (upto June, 1996)	2% of energy generated	Allowed
Banking	6 months	Under Consideration	Allowed for 20% of energy generated
Buyback by SEB	Rs 1.75/kwh	Rs 2.25/kwh	Rs 2.25/Kwh with 5% escalation after 3 years
Third Party Sale	Not allowed	Allowed to H T consumers	Allowed
Incentives:			
Capital Subsidy	--	As extending to other industry	
Allotment of Land	On lease 15 years (Renewable)	Lease for a period of 5 years at a token rent of Rs 1/- per annum and therafter on Government prescribed rates.	
Other Concessions	(i) Sales Tax benefit exemption/deferment/composite benefit towards eligible investment ii) Exemption from Electricity duty	(i) Exemption from Electricity Durty for 5 years ii) Plant & machinery exempted from State Sales Tax iii) Exemption from Demand Cut to the extent of 30% iv) Sales Tax exemption/deferment/ composite benefit on the eligible capital investment upto 100% v) Industry Status	
Promotional Supports:			
Single Window Agency	GEDA	MPUVN	MEDA/MSEB
Publication of Brochure (Detailing Policies/ incentives, etc)	Published	Published	Not Published

Annex Bb

Statewise Ongoing / Installed Wind Power Projects

Table Stauts of Windfarm Projects as on 31-12-1995 Demonstration Projects

State/location	Capacity Installed (MW)	Under Instllation (MW)
Tamil Nadu		
Kayathar	10.30	-
Muppandal	4.00	-
Tuticorian	1.555	-
Puliyankulam	1.59	-
Kethanur	2.00	-
Sultanpet	0.09	-
NHW Project	-	2.00
	19.355	2.00
Gujarat		
Lamba	10.20	-
Okha Madhi	3.30	-
Okha	0.66	0.44
Mandvi	1.49	-
Tuna	0.695	-
Dhank	-	2.00
	16.345	2.44
Andhra Pradesh		
Tirumala	1.05	-
Ramagriri	2.00	-
	3.05	--
Maharashtra		
Deogarh	1.10	---
Vijayadurg	1.50	--
Chalkewadi	--	2.00
	2.60	2.00
Madhya Pradesh		
Kheda	0.59	--
Orissa		
Puri	1.10	--
Karnataka		
Talacauvery	0.550	--
Kappataguda	2.025	--
	2.575	--
Kerala		
Kanjikode	2.025	--
Kottathara	--	2.00
	2.025	2.00
Others (Individual grid connected WEGs)	0.465	--
Total	**48.105**	**8.44**

Table Wind Power: Installed Capacity (in MW) at a glance (As on 31-3-1996)

State	**Demonstration Projects**	**Private Sector Projects**	**Total**
Tamil Nadu	19.355	537.035	556.390
Gujarat	16.345	99.328	115.673
Andhra Pradesh	3.050	41.850	44.900
Karnataka	2.575	--	2.575
Kerala	2.025	--	2.025
Maharashtra	2.600	--	2.600
Madhya Pradesh	0.590	6.300	6.890
Orissa	1.100	--	1.100
Others	0.465	--	0.465
	-----	------	--------
Total	**48.105**	**684.513**	**732.618**

Annex Bc

Wind Monitoring Stations With Mean Annual Wind Speed Greater Than 18 Kmph

Table *Wind Monitoring Stations with Mean Annual Wind Speed Greater than 18 KMPH*

Station	Mean Annual Wind Speed	Station	Mean Annual Wind Speed	Station	Mean Annual Wind Speed
Tamil Nadu		**Karnataka**		Okha	19.43
Alagiyaandiyapuram	20.88	B B Hills	26.78	Okha Mandhi	19.05
Andipatti	18.96	Bommanahalli	18.06	Surjabari	19.53
Arsampalayam	20.18	Chikodi	24.00	**Maharashtra**	
Ayikudy	21.35	Godkere	19.80	Chalkewadi	20.17
Edayarpalayam	22.43	Gokak	18.93	Gude Panchagani	20.01
Ennore	19.18	Hanamsagar	20.23	Katholi	19.69
Gangaikondan	18.15	Hanumanhatti	20.08	Panchgani	18.39
Kannankulam	21.57	Hardenahalli	18.16	Vijaydurg	19.61
Kattadimalai	23.66	Horti	21.05	**Andhra Pradesh**	
Kayathar	20.29	Jogimatti	29.85	Badhrampalli Kottala	21.46
Kethanur	21.91	Khamkarhatti	21.47	Bhimunipatanam	19.11
Kumarapuram	24.61	Khanderayanahall	20.48	Jamalamaduge	18.81
Mettukadai	18.00	malgatti	19.32	Kadavakallu	23.08
Muppandal	25.48	Sangundi	18.56	Kotturu	19.13
Nettur	20.89	**Madhya Pradesh**		MPR Dam	19.85
Omnakulam	20.40	Jamgodrani	18.44	Muspikovala	20.16
Ottapidaram	18.22	**Gujarat**		Narasimha Konda	20.08
Pongalur	19.43	Bamanbore	20.72	Nazeerabad	20.98
Poolavadi	21.16	Bhandaria	20.18	Pampanoor Thanda	19.56
Poosaripatti	20.39	Dhank I	24.53	Payalakuntla	20.09
Puliyamkulam	18.93	Dhank II	25.32	Ramgiri I	19.52
Rameswaram	23.91	Harshad	20.02	Singanamala	23.40
Sankaneri	22.06	Jamanvada	20.02	Tallimadugula	22.13
Sembagaramanpudur	21.69	Kalyanpur	22.21	Tirumala	20.43
Sultanpet	18.96	Kukma	90.19	**KERALA**	
Talayathu	20.51	Lamba	19.47	Kanjikode	22.32

Station	Mean Annual Wind Speed	Station	Mean Annual Wind Speed	Station	Mean Annual Wind Speed
Lakshadweep		Limbara	20.02	Kotamala	18.41
Agathi	18.22	Mundra	19.54	Kottathara	19.40
Kadmat	18.00	Navadra	20.33	Kuttikanam	18.14
Minicoy	18.29	Navibander	19.46	Panchalimedu	20.61
				Ponmudi	18.10

Annex Ca

SHP Sites Available To Private Sector

Policy Introuced/Incentives Declared By the State Government for small Hydro Power Project

Item	Andhra Pradesh	West Bengal	Karnataka	Kerala	Uttar Pradesh	Madhya Pradesh	Punjab	Himachal Pradesh
Participation permitted (other than Govt. Sector)	Private	Private	Private	Private	Private	Private	Private	Private
Rates/Charges for :								
Power Wheeling	8.5 % of energy generated	2 % of energy generated	2 % upto 1 MW 5 % upto 3 MW 10 % above 3 MW	12 & of energy Generated	2% of energy generated 2.5% for sale to third party	2% of energy generated	2% of energy generated	2% of energy generated
Power Banking	Not allowed	for 6 month	-	Atmutually agreed rate	Allowed for one year	Not Allowed	Not Allowed	Allowed with additional charges
Buyback by SEB	Atmutually agreed rate	Atmutually agreed rate	-	-	Rs.2.25/unit	Rs.2.25/unit	Rs.2.25/unit	Rs.2.25/unit
Third Party Sale	Not allowed	allowed	Allowed	-	Allowed	Allowed	Allowed	Allowed
Incentives :								
Capital Subsidy	-	-	As extened to other industries	-	-	-	-	-
Other concessions	-	-	Exemption for 5 years for electricity tax for captive use	-	-	Plant & machinery used for generation free from State sale tax Exmption from electricity duly for 5 years Exemption from demand cut upto 30 % for delf use	Exempted from demand cut Sale tax benefit for the project owner	-
Promotional Supports :								
Opening of co-ordination Cell/Single Window Agency	Opended under APSEB	Opended under Sec (NCES)	Opened under Chief Secy.	-	NEDA upto 3 MW UPLJVN>3 MW	MPUVN	PSEB/PEDA	HPSEB/HIMURJA
Publication of Brochure (Detailing polices/incentives, etc.)	Published	Published	Published	Published	Published	Published	Published	Published
Royality on water	as fixed by the Govt. from time to time	-	10 % of prevailing electricity traiff	Chargeable rate to be fixed	10 % of electricity generated	-	-	Exempted upto 1 MW capacity

Annex Cb

Statewise Ongoing / Installed SHP Projects

Table *State-wise list of Installed/On-Going Micro/Mini Hydel Projects upto 3 MW Capacity*

State	Projects Installed		Projects Under Construction	
	No.	Capacity (MW)	No.	Capacity (MW)
Andhra Pradesh	7	7.01	36	42.10
Arunachal Pradesh	29	19.15	12	21.60
Assam	2	2.20	-	-
Bihar	-	-	4	2.45
Goa	-	-	2	2.90
Gujarat	1	2.00	2	2.60
Haryana	1	0.20	1	0.10
Himachal Pradesh	14	9.47	4	11.00
Jammu & Kashmir	11	4.35	9	11.19
Karnataka	5	4.70	22	30.64
Kerala	3	0.52	7	17.00
Madhya Pradesh	4	2.25	9	15.40
Maharashtra	3	3.58	5	8.70
Manipur	6	4.10	4	3.50
Meghalaya	1	1.51	2	0.20
Mizoram	9	5.36	9	8.80
Nagaland	5	3.17	4	5.50
Orissaa	3	1.26	7	9.92
Punjab	4	3.90	8	9.50
Rajasthan	5	4.30	2	1.04
Sikkim	14	9.66	2	3.20
Tamil Nadu	3	4.75	4	6.40
Tripura	2	1.01	1	0.10
Uttar Pradesh	46	26.78	28	22.60
West Bengal	5	7.46	5	9.70
Andaman & Nicobar	-	-	1	2.52
Total	**183**	**128.69**	**190**	**248.39**

Annex Cc

Policy Incentives For SHP

Table *Details of SHP Sites offered to Private Sector*

Name of State	No. of Sites	Capacity (MW)
Himachal Pradesh	139	155.00
Uttar Pradesh	57	161.50
Punjab	22	20.00
Madhya Pradesh	74	53.00
Maharashtra	6	8.70
Andhra Pradesh	30	36.00
Kernataka	24	34.80
Kerala	29	34.70
West Bengal	63	66.00
Total	**444**	**569.70**

Annex Da

Amount of Incentives For Gasifier Systems

Table *Amount of Incentives given by MNES for various ratings and modes of Gasifier Systems of 1995-96*

Mode of Application	Rating	Maximum Financial Incentive (Rs)
Mechanical	5 HP	9,000
	10 HP	12,000
Electrical	3 KW	15,000
	5 KW	24,000
	10 KW	39,000
	20 KW	60,000
	40 KW	1,14,000
	100 KW	2,64,000
	200 KW	3,60,000
	300 KW	4,68,000
	500 KW	6,87,000
Thermal	7,500 Kcal/hr	7,500
	12,500 Kcal/hr	10,500
	25,000 Kcal/hr	17,000
	50,000 Kcal/hr	28,500
	1,00,000 Kcal/hr	45,000
	1,20,000 Kcal/hr	54,000
	2,50,000 Kcal/hr	97,500
	5,00,000 Kcal/hr	1,55,000
	7,50,000 Kcal/hr	2,00,000
	12,50,000 Kcal/hr	2,95,000

Annex Db

Policy Incentives For Cogeneration

Table *Policy Introduced/Incentives Declared by the State Government for Cogeneration Power Projects*

Item	Maharashtra	Tamil Nadu	Karnataka	Uttar Pradesh	Madhya Pradesh	Punjab	Andhra Pradesh
Participation permitted (other than Govt. Sector)	Cooperative	Private	Private	Private	Private	Private	-
Rates/Charges for:							
Power Wheeling	Allowed rate will be decided	15% of energy enerated 2% of sister concern	6 % of energy generated	12% of energy generated	2% of energy generated	2% of energy generated	15% of energy generated
Power Banking	*Allowed for 20% of energy generated	2% of energy generated	2% of energy generated	Allowed for one year	-	-	2% of energy generated
Buyback by SEB	Allowed @ 2.25/KWh beyond 4 MW & Rs. 2/KWh below 4 MW Escaled @ 5% per anum after 3 years	Allowed at Rs 2.25/KWh Escaled @ 5% per anum for 5 years	allowed @ Rs. 2.00/kwh	Rs.2.25/KWh to be increased in the same proportion as increase in H.T.Traiff	Rs.2.25/unit	allowed at Rs.1.50/unit	Allowed at the average price of power purchased from Central government
Selling to 3rd Party Sale	Allowed	Allowed	Allowed	Allowed within a radius of 5 Km	Allowed	Allowed	Allowed
Incentives :							
Capital Subsidy	Participation in equity upto 60% by MSEB for Coop. Mills	-	subsidy @ Rs. 25 lakh/MW	-	-	As extended to other industries	-
Other concessions	Exemption from electricity generation tax for captive use	Exemption from electricity generation tax for captive use, TNEB,3rd party	Exemption for 5 years from electricity tax for captive use	-	Exmption. from sale tax and other concessions applicable to new industries	Exempted for eletricity duty etc	-
Coordinating Agency	MSEB	TNEB	KEB/PCL	Deptt. of Additional Sources of energy/NEDA U.P.	MPUVN	PEDA	NEDCAP

Annex E

Economic & Financial Analysis Of RETs

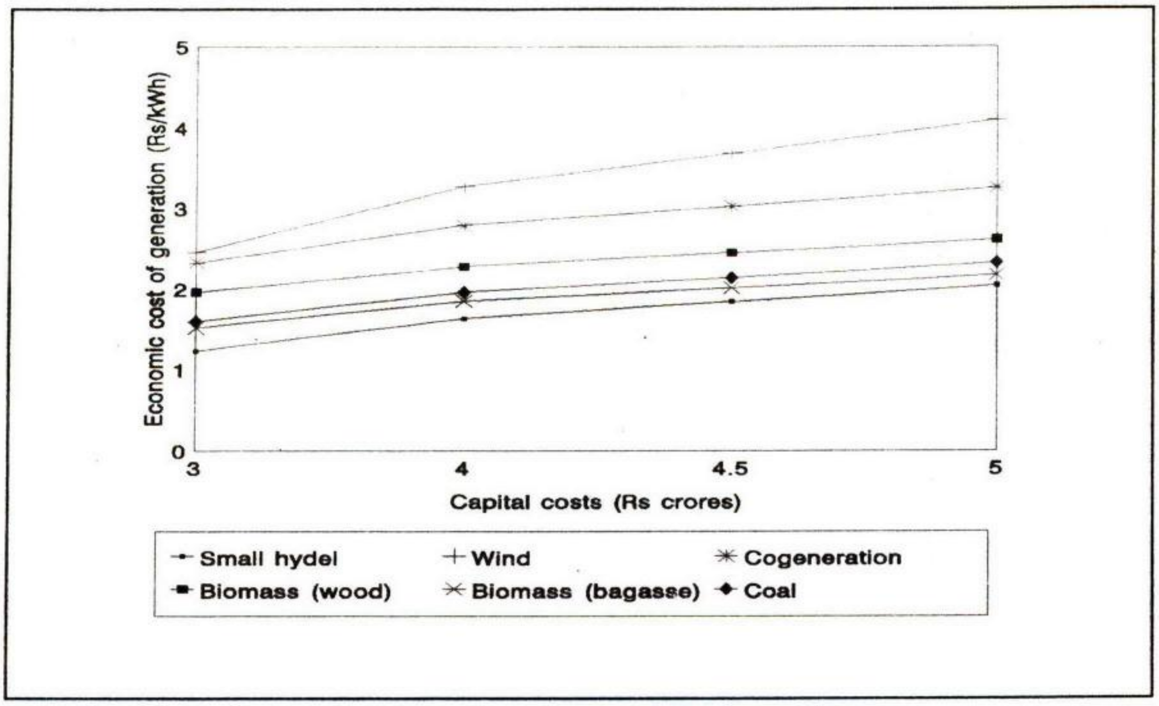

Figure 1: Economic costs of generation at different capital costs

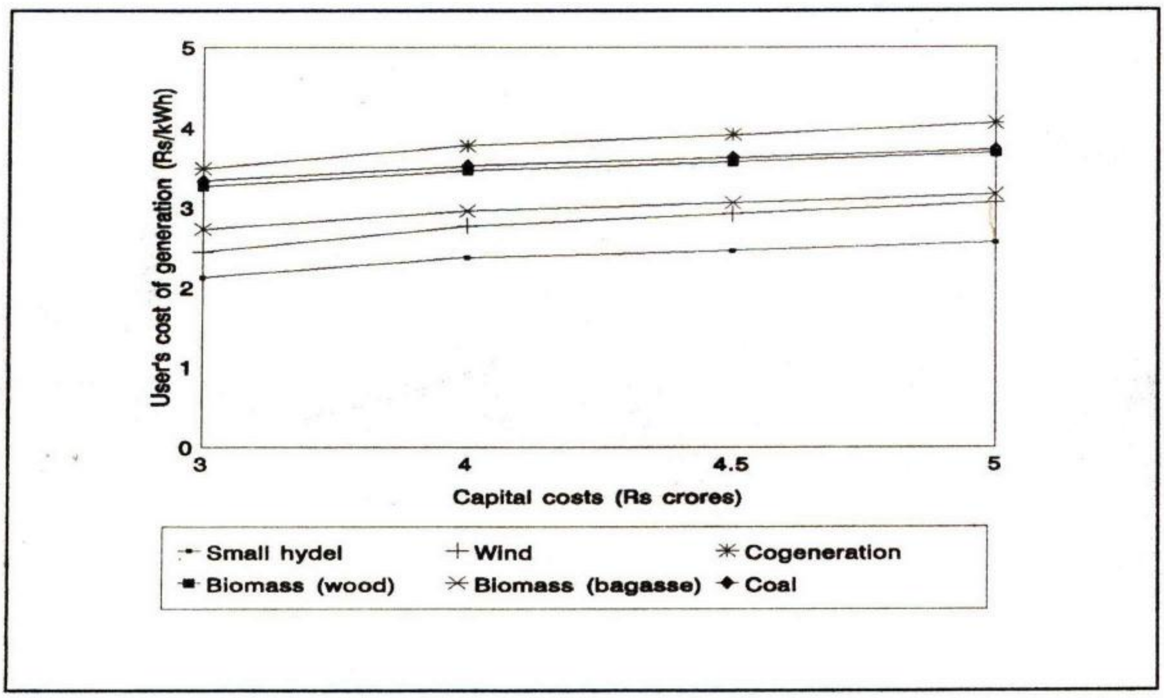

Figure 2: User's costs of generation at different capital costs

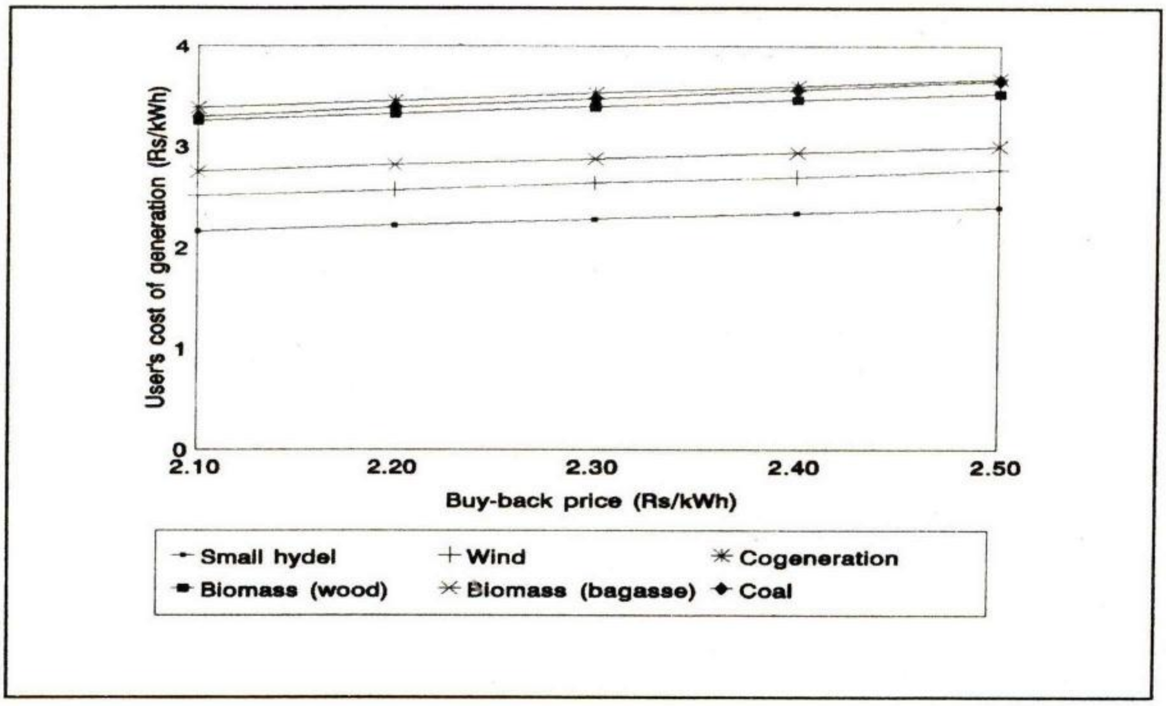

Figure 3: User's costs of generation at different buy-back prices

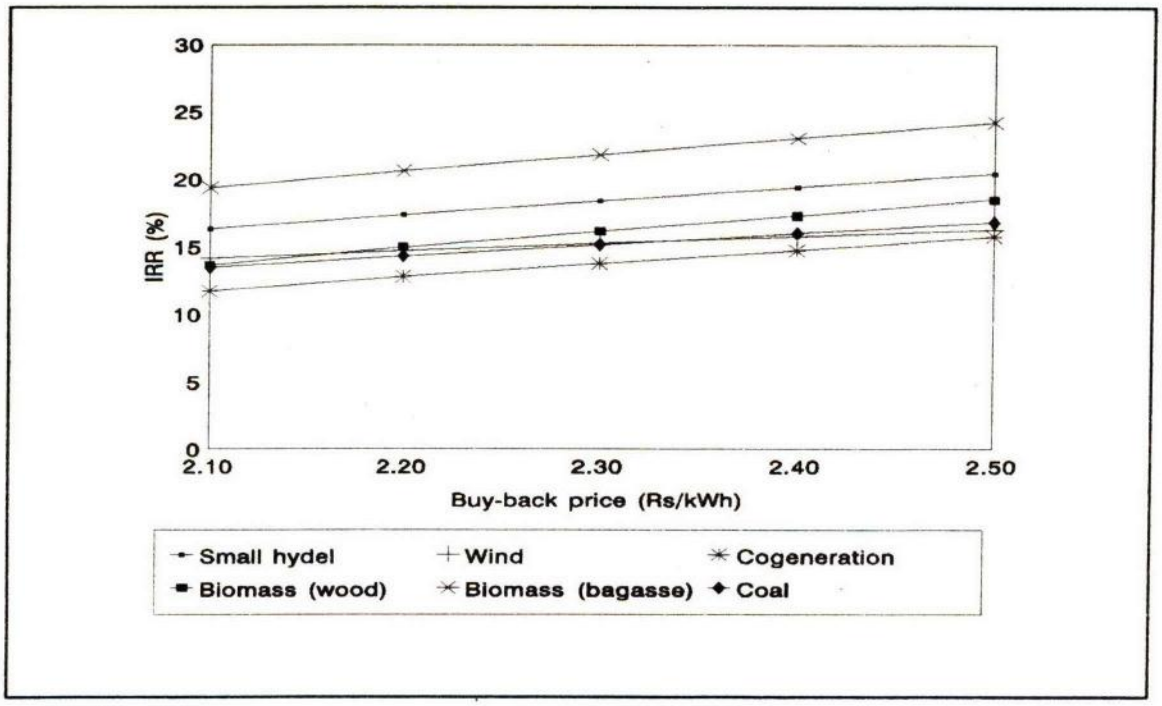

Figure 4: IRR (%) at different buy-back prices

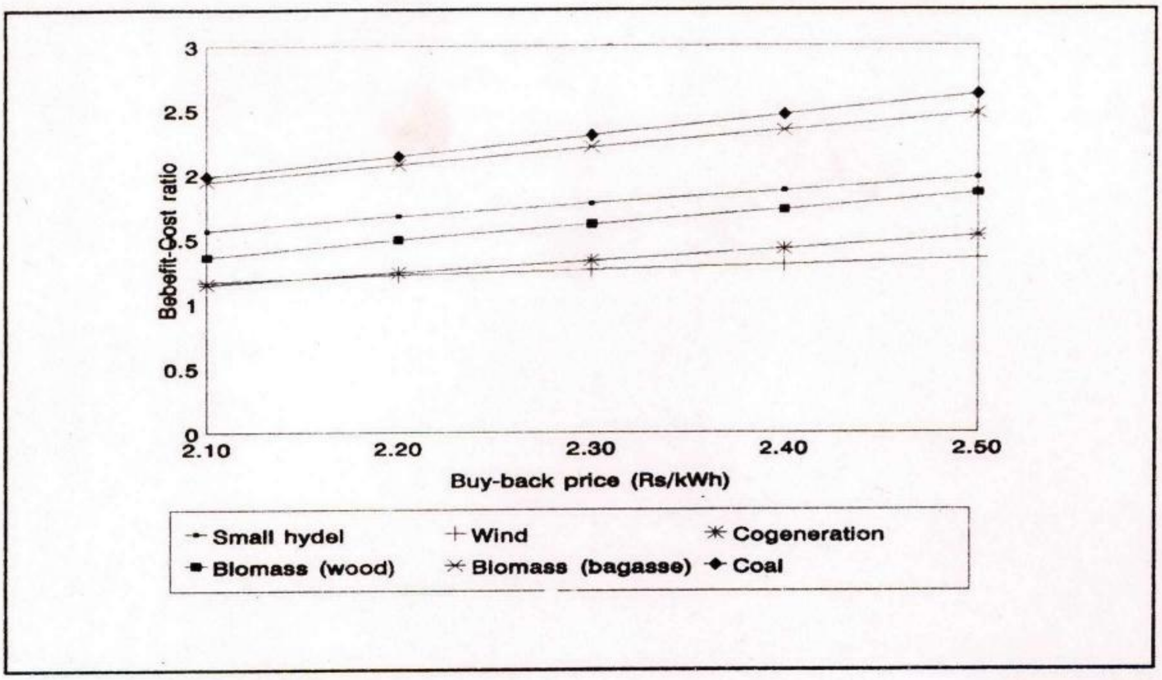

Figure 5: Benefit-cost ratio at different buy-back prices

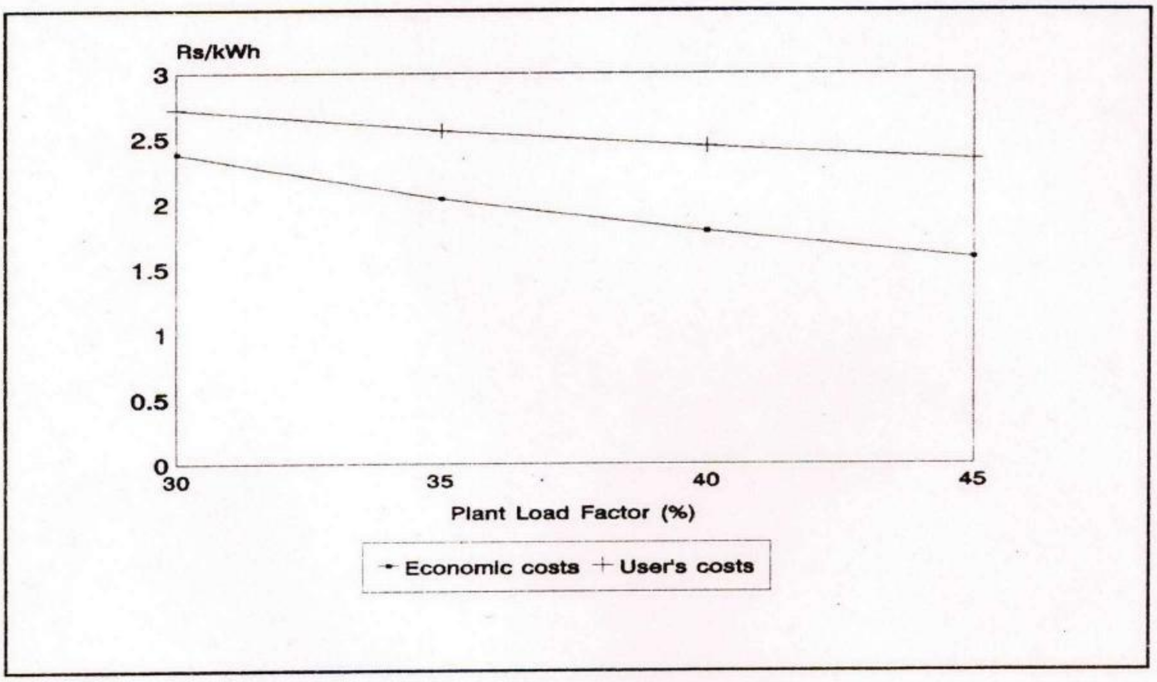

Figure 6: Economic & User's costs for Small Hydel at different PLF

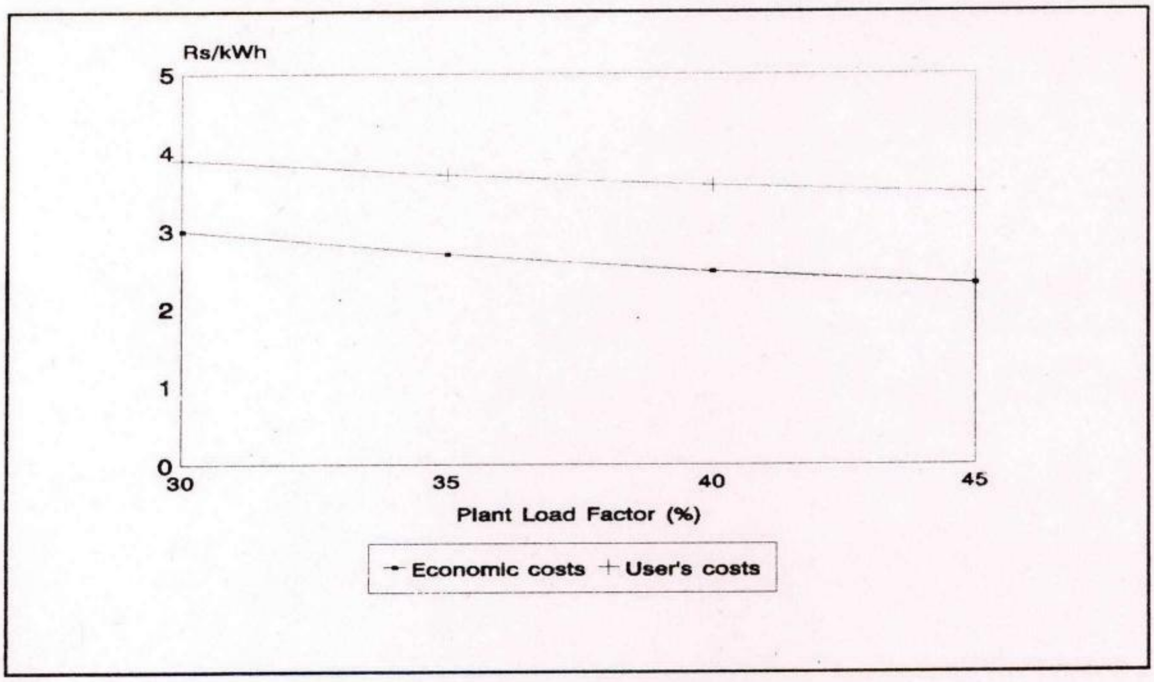

Figure 7: Economic & User's costs for Cogeneration at different PLF

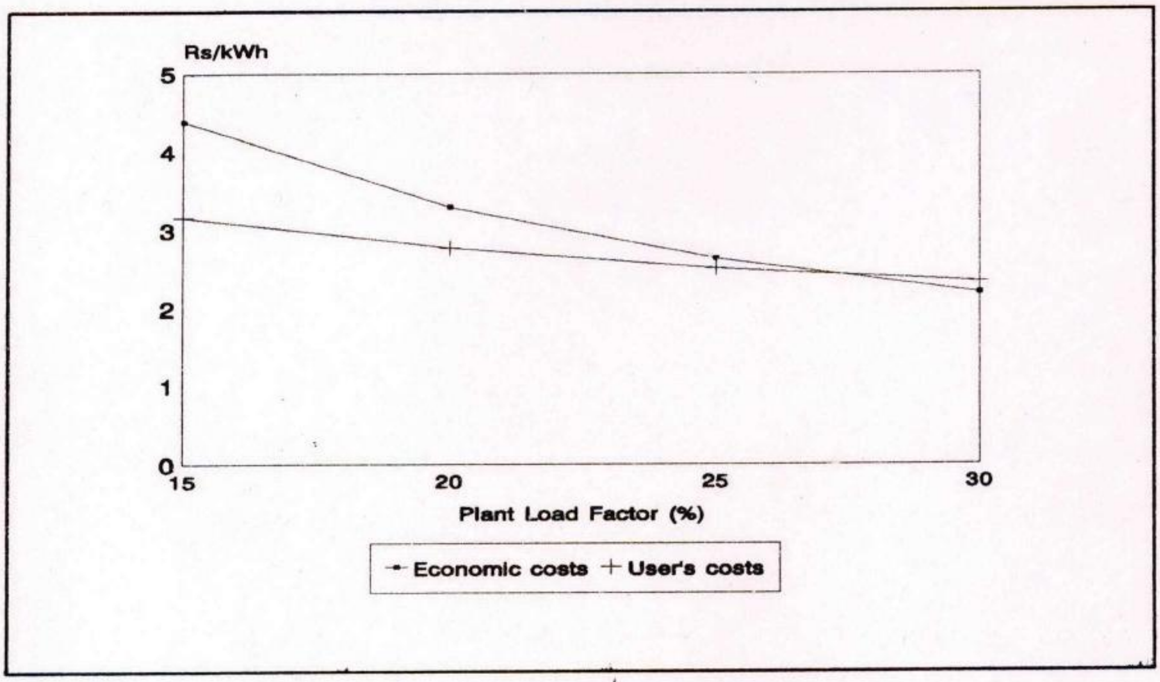

Figure 8: Economic & User's costs for Wind at different PLF

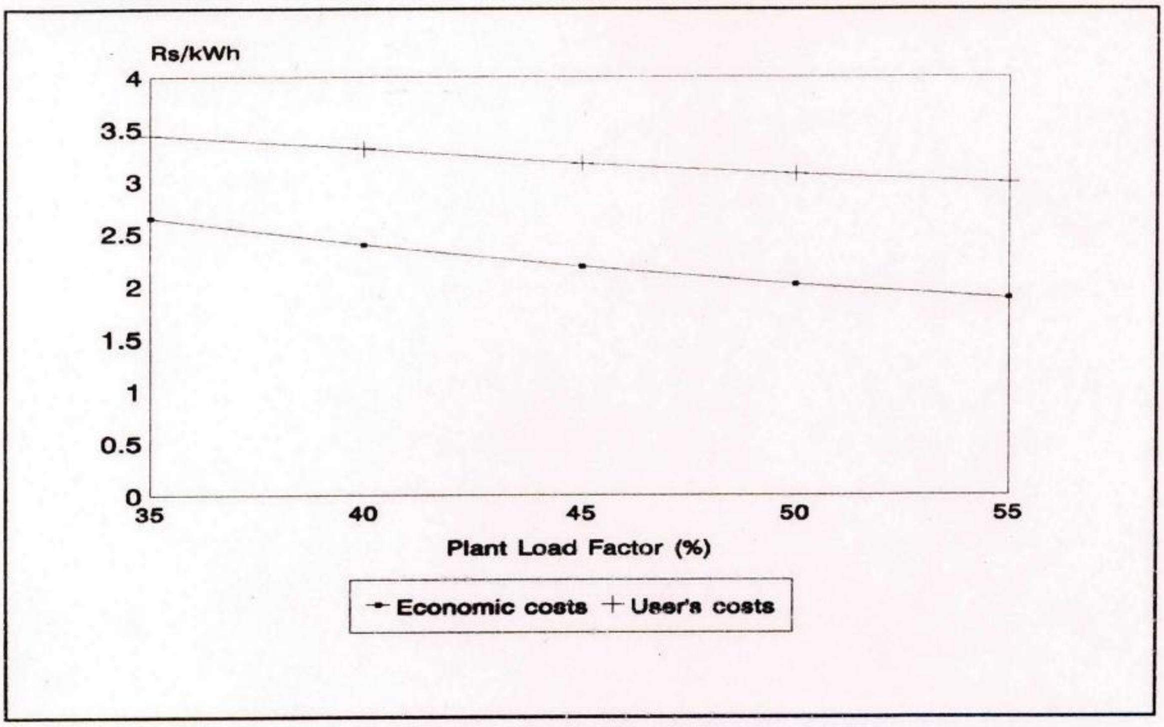

Figure 9: Economic & User's costs for Biomass-wood at different PLF

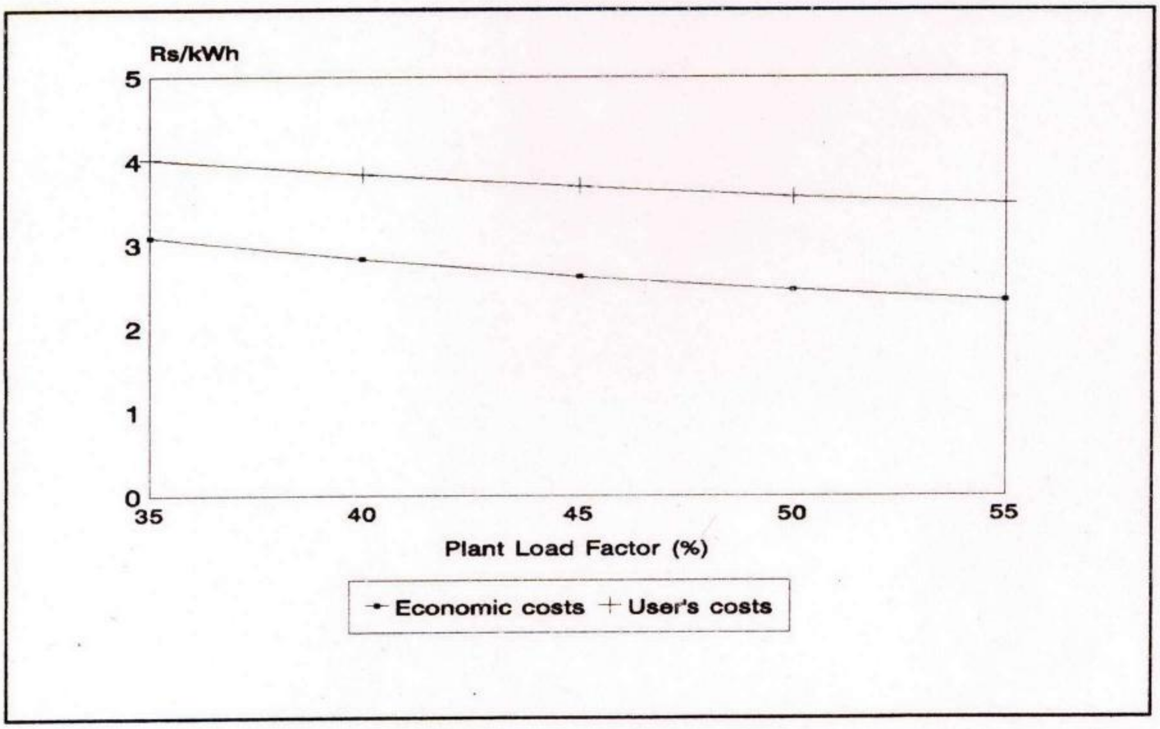

Figure 10: Economic & User's costs for Biomass-bagasse at different PLF

Annex F

Supply Curve

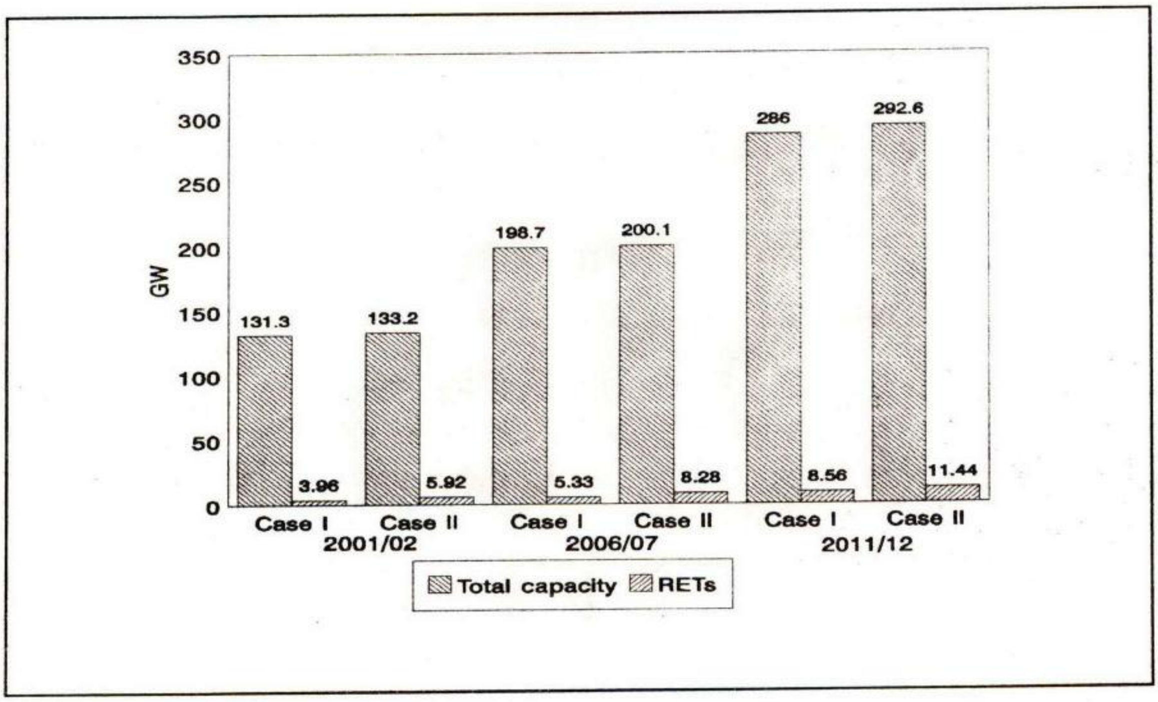

Figure 5.1: Requirement for power generation capacity and contribution by RETs in Case I & II (2001/02, 2006/07 and 2011/12)

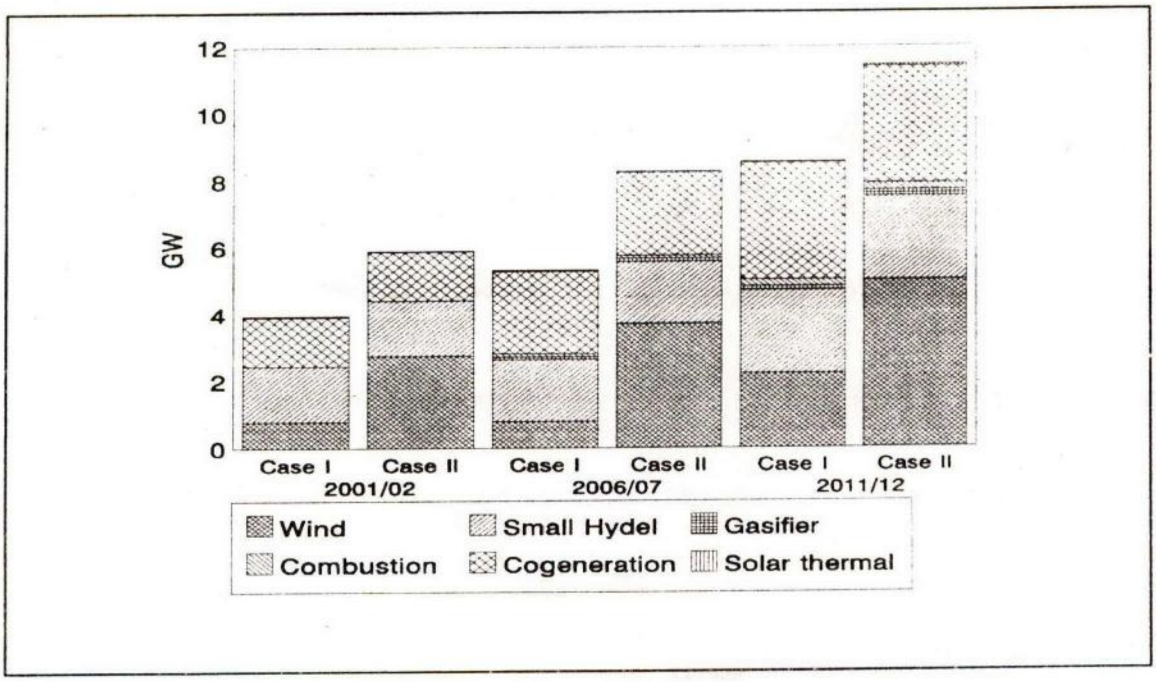

Figure 5.2: Capacity mix for RETS in Case I & II (2001/02, 2006/07 & 2011/12)

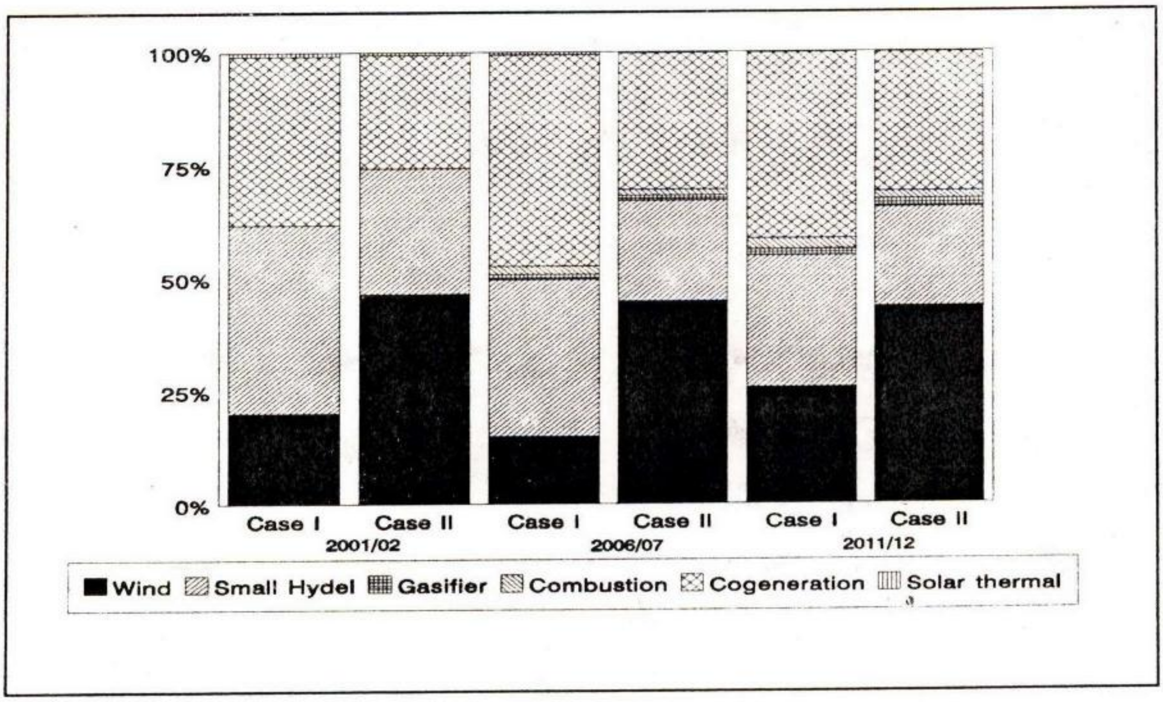

Figure 5.3: Capacity mix (%) for RETs in Case I & II (2001/02,2006/07 & 2011/12)

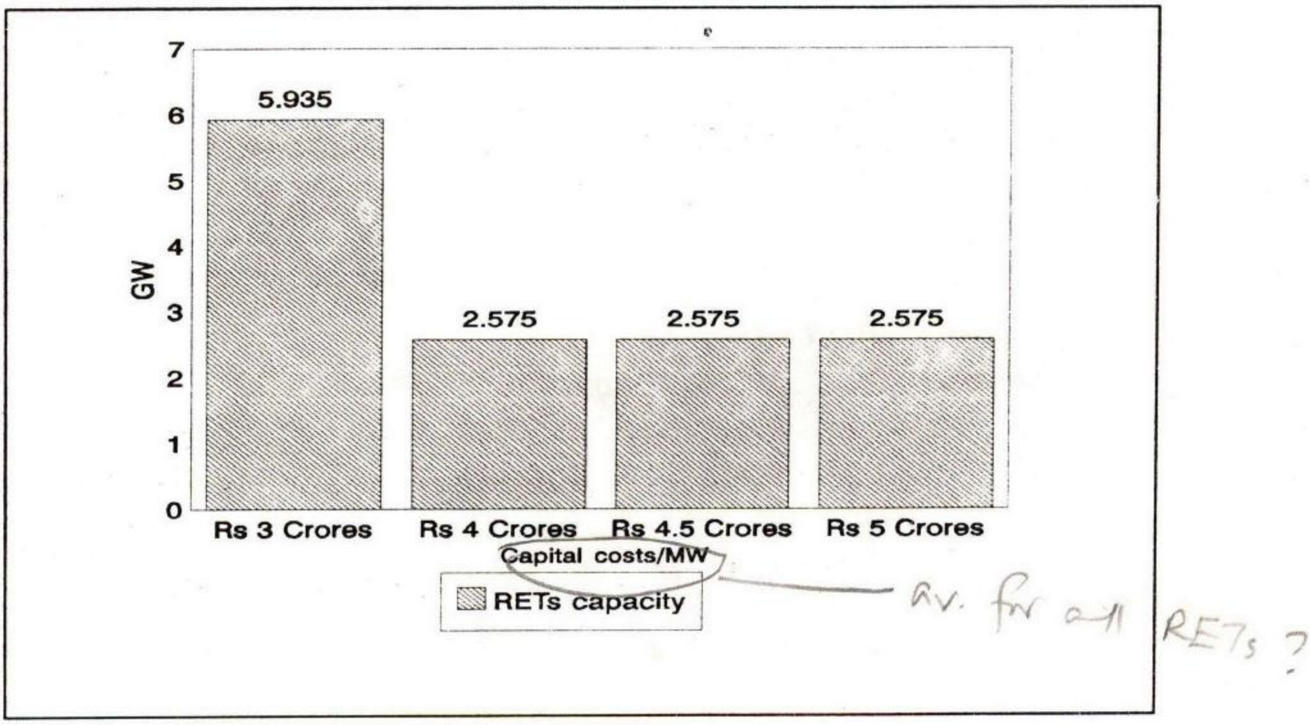

Figure 5.4a: Total RETs capacity in Case I under Scenario I (2001/02)

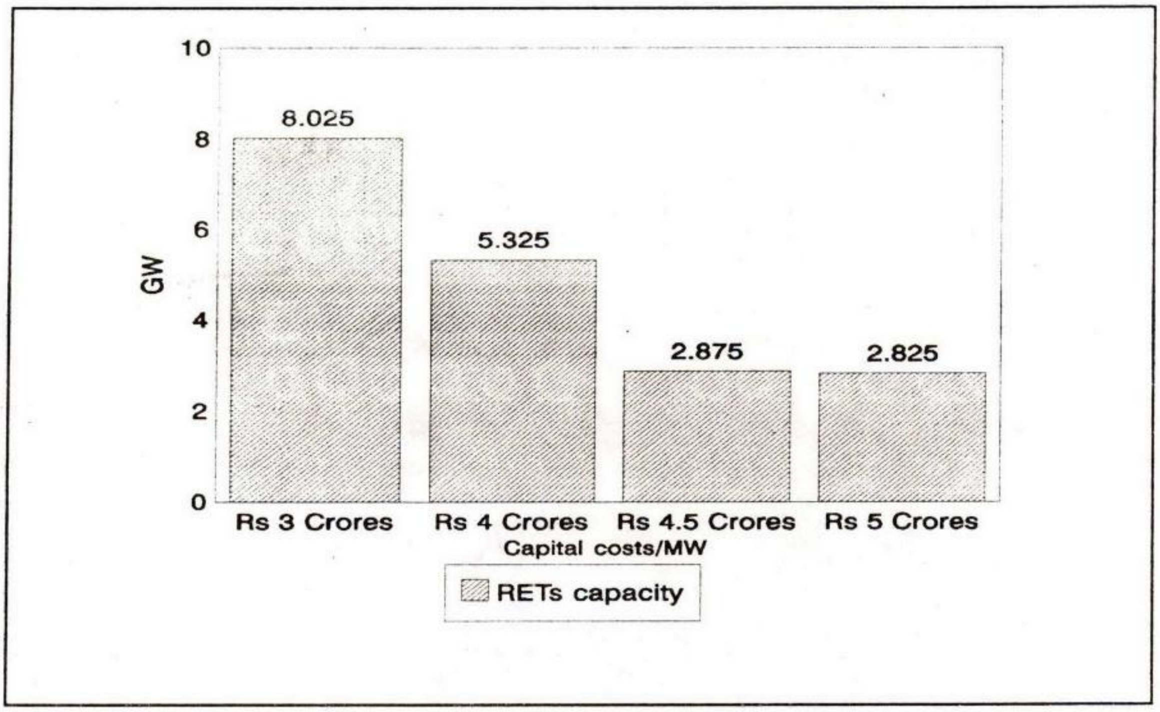

Figure 5.4b: Total RETs capacity in Case I under Scenario I (2006/07)

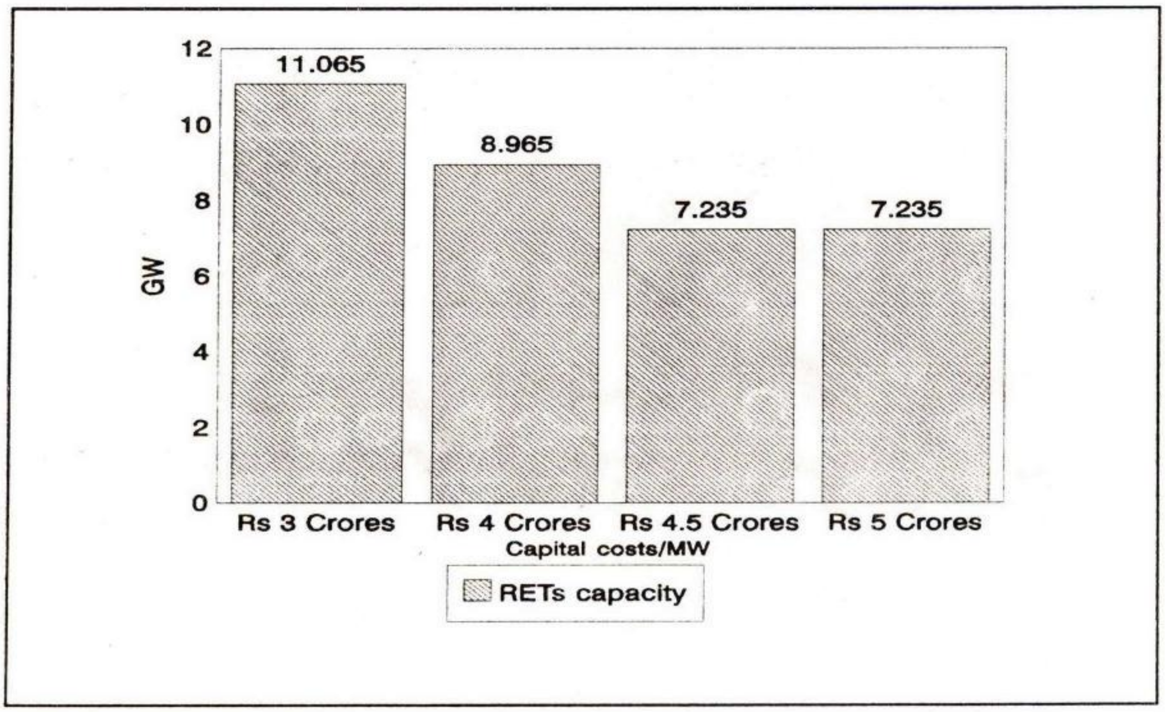

Figure 5.4c: Total RETs capacity in Case I under Scenario I (2001/02)

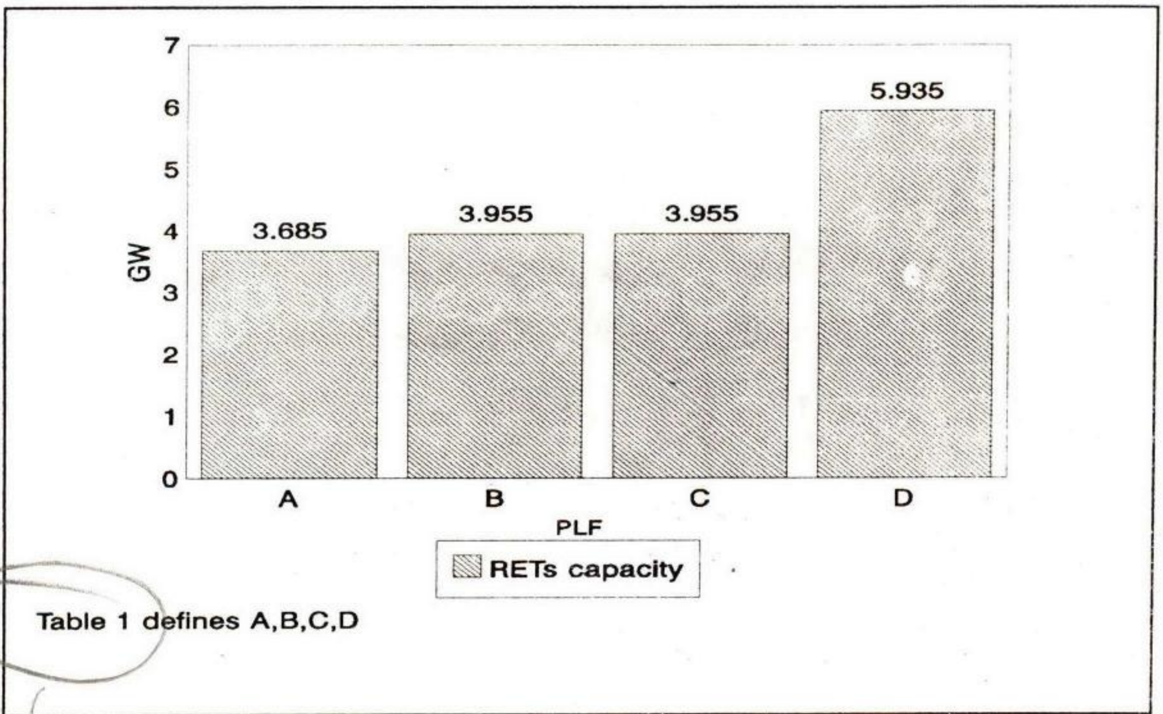

Figure 5.5a: Total RETs capacity in Case I under Scenario II (2001/02)

5a ?

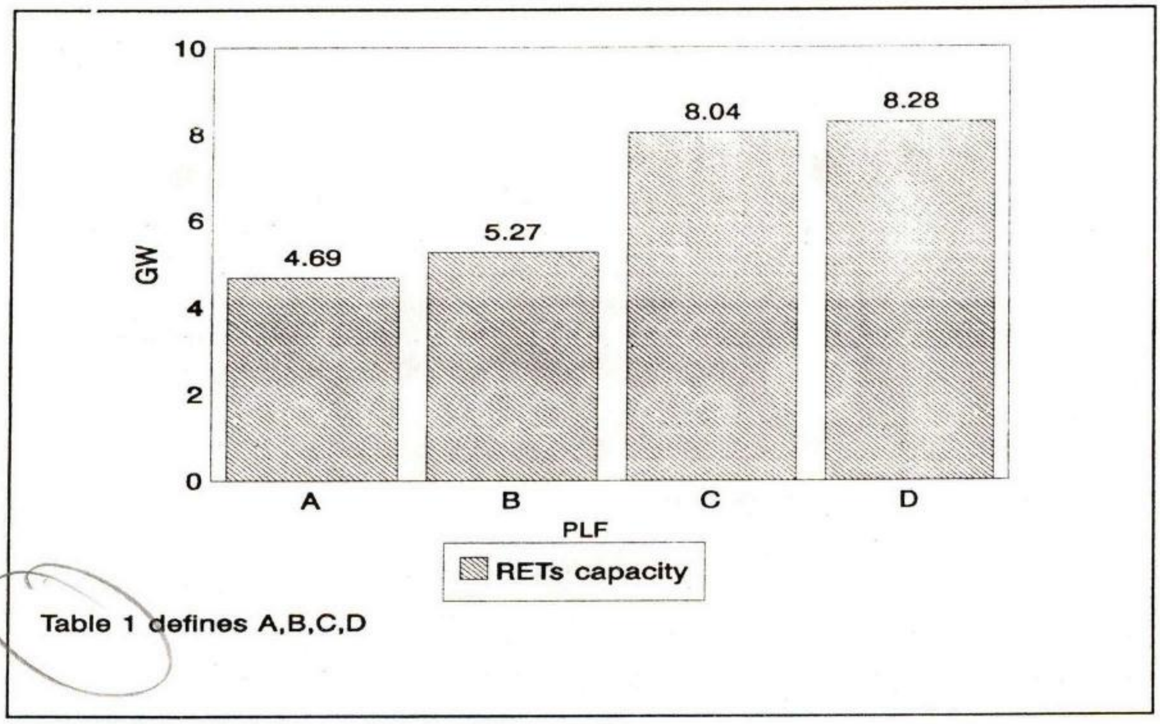

Figure 5.5b: Total RETs capacity in Case I under Scenario II (2006/07)

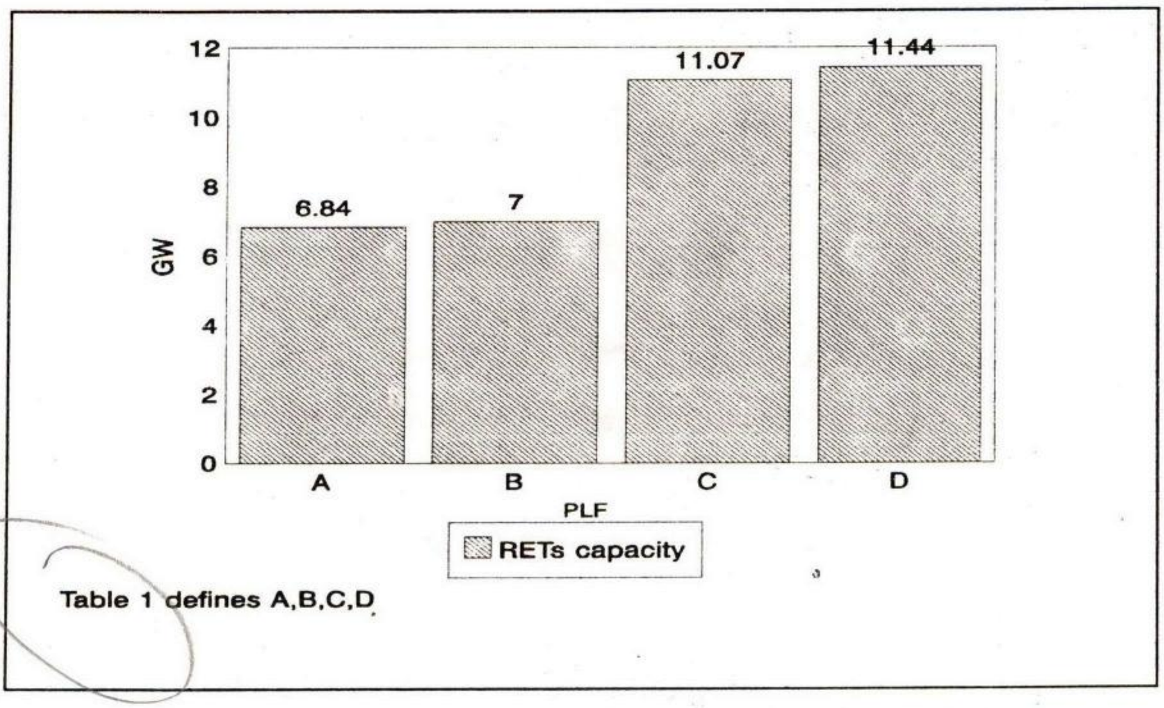

Figure 5.5c: Total RETs capacity in Case I under Scenario II (2011/12)

Table 5.2: Capacity mix (in GW) for RETs in Scenario I (2001/02, 2006/07 and 2011/12)

Year	Technology	Capital cost Rs 3 crores/MW		Capital cost Rs 4 crores/MW		Capital cost Rs 4.5 crores/MW		Capital cost Rs 5 crores/MW	
		Case I	Case II	Case I	Case II	Case I	Case II	Case I	Case II
2001/02	Wind	2.78	2.78	0.8	2.78	0.8	2.78	0.8	2.78
	Small Hydel	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
	Gasifier	0	0	0	0	0	0	0	0
	Combustion	0	0	0	0	0	0	0	0
	Cogeneration	1.47	1.47	0.09	1.47	0.09	0.09	0.09	0.09
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	5.935	5.935	2.575	5.935	2.575	4.555	2.575	4.555
2006/07	Wind	3.46	3.71	0.8	3.71	0.8	3.71	0.8	3.71
	Small Hydel	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
	Gasifier	0.1	0.1	0.06	0.1	0	0.1	0	0.1
	Combustion	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.1
	Cogeneration	2.48	2.48	2.48	2.48	0.09	2.48	0.09	2.48
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	8.025	8.275	5.325	8.275	2.875	8.275	2.825	8.275
2011/12	Wind	4.63	5	2.53	5	0.8	5	0.8	5
	Small Hydel	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Gasifier	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Combustion	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Cogeneration	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	11.065	11.435	8.965	11.435	7.235	11.435	7.235	11.435

Table 5.3 : The total capacity and mix (in GW) for RETs in Scenario II (2001/02, 2006/07, 2011/12)

Year	Technology	A		B		C		D	
		Case I	Case II	Case I	Case II	Case I	Case II	Case I	Case II
2001/02	Wind	0.8	2.78	0.8	2.78	0.8	2.78	2.78	2.78
	Small Hydel	1.38	1.65	1.65	1.65	1.65	1.65	1.65	1.65
	Gasifier	0	0	0	0	0	0	0	0
	Combustion	0	0	0	0	0	0	0	0
	Cogeneration	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	3.685	5.935	3.955	5.935	3.955	5.935	5.935	5.935
2006/07	Wind	0.8	3.71	0.8	3.71	3.47	3.71	3.71	3.71
	Small Hydel	1.37	1.85	1.85	1.85	1.85	1.85	1.85	1.85
	Gasifier	0	0.1	0.04	0.1	0.1	0.1	0.1	0.1
	Combustion	0	0.1	0.06	0.1	0.1	0.1	0.1	0.1
	Cogeneration	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	4.69	8.28	5.27	8.28	8.04	8.28	8.28	8.28
2011/12	Wind	0.8	5	0.8	5	4.63	5	5	5
	Small Hydel	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	Gasifier	0	0.2	0.06	0.2	0.2	0.2	0.2	0.2
	Combustion	0	0.2	0.1	0.2	0.2	0.2	0.2	0.2
	Cogeneration	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
	Solar	0.035	0.035	0.035	0.035	0.035	0.035	0.035	0.035
	Total	6.84	11.44	7.00	11.44	11.07	11.44	11.44	11.44

Annex G

Land Requirements By Different Energy Sources

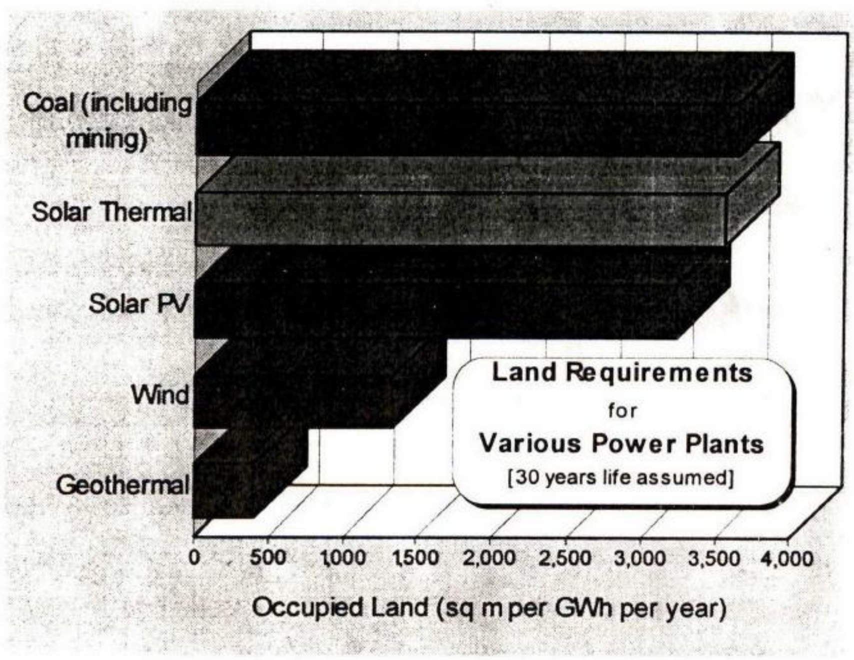

Fig. 1 Land requirements by different energy sources.

Annex H

RET Experience In Industrialised Nations

1.0 Energy Strategies for Sustainable Development

1.1 It is an inalterable fact that energy provision is the critical and vital necessity for every natural and social development. It is therefore not surprising that the energy sector represents a large fraction of national and international economies. Globally, energy accounts for 25 to 30 percent of present investments in development and economic growth.

1.2 It has now been increasingly realized that the energy provision sources of the 20th century have nearly all been fatal sources - oil, natural gas, nuclear power and a rapidly increasing depletion of vegetation by the exploding human population. It is the ways and means of using energy by the present civilization that created not merely a sectoral problem but a problem of sustainability of the earth itself. Maintaining current patterns of fossil fuel use will cause unprecedented rates of climate change and other environmental/ecological problems.

1.3 It is therefore clear that energy strategies should be used as instruments for sustainable development and preserving the environment. Increasing the share of renewable energy sources in total world energy supply and improving energy efficiency are the essential elements of a strategy for making this happen.

2.0 Potential of Renewable Energy Sources and Maturity of Renewable Energy Technologies

2.1 Before discussing the strategy, let us briefly examine the available renewable energy sources and technologies. For, a renewable energy strategy would largely depend on the availability of relevant renewable energy sources and reliable renewable energy conversion technologies. We know that the flow of renewable energy to the Earth's land surface is thousands of times greater than mankind's present rate of total energy use. Of these the most significant renewable source are: Solar, Wind, Hydro, Geothermal and Biomass. Utilization of these sources appropriately and efficiently would depend on the development of mature and reliable conversion technologies.

2.2 What are the available mature renewable energy technologies available to us for immediate applications. There are already some technologies for utilizing renewable energy sources which are mature and fairly economically competitive Table 2.0 shows the ratings of the RETS. These mature RETS are diffusing on the market even under present conditions characterized by the absence of level playing ground vis-a-vis the established conventional energy sources. As a result, out of the eight giga tonnes of oil equivalent (Gtoe) per year of present total commercial energy supply in the world, renewable energy sources contribute about 7 per cent, most of which is large scale hydropower. If we include in it non-commercial energy sources, the contribution of renewable energy sources comes to 14 to 20 percent of total primary energy supply.

Table 2.0: Degree of Maturity of Various Renewable Energy Technologies and Applications
(1. Technically mature for market and possibly with need of optimization; 2. Application experience still missing (for example lifetime of equipment); 3. Research and development needed for alternative solutions; 4. Development needed; 5. Research needed)

Technology		Degree of Maturity				
		1	2	3	4	5
Solar Energy						
	Solar Absorptions		×			
	Solar collectors (low temperature)	×		×		
	Solar collectors (process heat)	×	×	×		
	Solar thermal electricity (troughs)	×	×			
	Solar thermal electricity (other technologies)				×	
	Passive solar in buildings	×	×	×		
	Photovoltaic (PV) electricity (crystal silicon)	×	×	×		
	PV electricity (amorphous silicon)				×	×
	PV electricity (other materials)				×	×
	Solar production of fuels (e.g., hydrogen), photochemistry				×	×
Wind energy						
	Installations up to 400 kilowatts (kW)	×	×	×		
	Larger installations					×
Hydro energy						
	Large-scale hydropower	×				
	Small-scale hydropower	×				
	Tidal energy		×			
	Wave energy				×	
Biomass energy						
	Combustion	×	×		×	
	Gasification	×	×		×	
	Alcohol	×	×			
	Anaerobic digestion (biogas)	×		×		
	Vegetable oil		×		×	×
	Other energy crops				×	×
Ambient heat						
	Electric heat pumps	×				
	Absorption heat pumps	×	×	×		
Application and components						
	Photovoltaic (PV) application technologies (e.g. pumps and lights)	×	×		×	
	Batteries, fuel cells	×	×	×	×	×
	Control system	×			×	
	Heat storage	×		×	×	
	Hydrogen (electrolysis, storage, handling)	×		×		

Based with modifications on: "Forderung und Nutzung 'erneuerbarer Energiequellen' in der Bundesrepublik von Deutschland", Deutscher Bundestag, Drucksache 11/2684 (July 1988).

2.3 It is estimated that in the near-term (1990-2000) the global economic potential to supply energy based on renewable sources comes to about 3.3 Gtoe per year i.e., 2.5 times the 1985 contributions. Tables 2.1, 2.2 and 2.3 give the details of the estimated potential of the RETs. What are the major constraints in achieving the potential at a faster rate ? In the long run, it is not the availability of resources or cost-effectiveness of the technologies that is likely to be constraining the rapid progress of the utilization of renewable energy sources. It is the political and administrative strategies regarding energy policies and legislation that are the primary constraints.

Table 2.1: Annual Economic Potential for Primary Electricity for the Year 2000 (Terawatt hours) (Twh)

REGION	HYDRO	WIND GRID	WIND REMOTE	SOLAR GRID	SOLAR REMOTE	TOTAL	1985 PRODUCTION
North America	767	75	0.1	60	0.7	903	2,980
Europe	793	63.4	0.5	13	1.6	872	1875
Japan, Australia and New Zealand	155	44.8	0.3	19	0.3	219	795
Soviet Union and Eastern Europe	816	8	0.7	24	0.8	850	1,170
Latin America	656	5	2.9	37	10.8	712	525
North Africa and the Middle East	34	0	1.2	21	9.5	66	200
Africa	111	1.5	3.6	15	25.8	155	185
India	80	5.2	18	13	63	179	260
China	325	9	18	13	33.6	398	450
Asia & Oceania	252	0	15.4	12	55	334	320
TOTAL (World)	3990	212	61	227	200	4690	9300

Based on : B. Dessus, F. Pharabod and B. Devin, Renewable energies "actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche No. 1 (January 1992).

Table 2.2: Annual Accessible Supply Potential for Hydropower and solar, wind and biomass Energy by Region and Technology for the year 2000 (Megatons of Equivalent [Mtoe])

				BIOMASS				
REGION	**HYDRO**	**SOLAR**	**WIND**	**WOOD (COM.)**	**WOOD (NON COM.)**	**PLANTATION**	**WASTE**	**TOTAL RENEWABLE**
North America	169	17.5	16.4	204	7.5	13.6	67	495
Western Europe	174	6.5	14	43	5	5.3	52	300
Japan, Australia and New Zealand	34	6.5	9.8	1.7	0	3.9	16	87
Soviet Union and Eastern Europe	189	7.5	1.8	218	15.5	15.4	56	494
Latin America	144	17	1.8	324	158	15.7	55	716
North Africa and the Middle East	7.5	11	0.1	10	11	0.9	6	47
Africa	24.5	19.5	1.2	70	200	3.9	24	343
India	17.5	43	5.3	9	66	5.2	69	215
China	71.5	32	6.3	17	48	3.2	84	262
Asia & Oceania	56	39.5	3.3	68	162	2.8	65	396
Total Developing	321	162	18	498	645	32	313	1,989
TOTAL (World)	878	200	60	980	673	70	504	3,365

Based on : B. Dessus, F. Pharabod and B. Devin, Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche No. 1 (January 1992).

Table 2.3: World Energy Conference Estimates of the Contribution of Renewable Energy to the Global Energy Supply in 1985 in Megatons of Oil Equivalent (Mtoe)

Energy source	Industrialized countries (Mtoe)	Developing countries (Mtoe)	Total (Mtoe)	Share of total energy (%)	Share of total renewable energy (%)
Hydraulic	312	133	445	5.8	33
Solar	8	5	13	0.2	1
Wind	0.8	0.2	1	0.01	0.07
Commercial fuelwood	98	77	175	2.3	13
Non Commercial fuelwood	22	583	605	8	45
Energy Plantation Biomass	2	8	10	0.1	0.7
Waste Biomass	10	80	90	1.2	7
Total Renewable	453	886	1339	17.5	100
Total energy	5352	2317	7669		
Share of total energy (%)	8.5	38.2	17.5		

Based on : B. Dessus, F. Pharabod and B. Devin, Renewable energies: actually accessible regional potentials and environmental impacts analysis for the nineties", La Houille Blanche No. 1 (January 1992).

3.0 A Brief Review of Strategies in some Industrialized Countries

3.1 It is important to know how appropriate political and legislative strategies for energy sector undertaken by some countries have made the entry of the RETs into energy market possible on a competitive basis. What follows is a brief review of some of these strategies adopted by different countries. This review would hopefully provide guidelines for formulating India's strategy for renewable energy programme

3.2 Wind Power

3.2.1 Perhaps in the field renewable energy, Denmark exhibits a compelling example Like many oil-dependent countries, Denmark received a rude shock in the seventies' energy crisis. But while other nations responded to oil crisis by investing in nuclear breeder reactors or synthetic fuels, Denmark turned to energy source that has been central to its agricultural economy, from the 12th into the early part of the 20th century - wind power. With a tradition of political decentralization and locally owned farm co-operatives, Danes insisted on indigenous resources and its own technological ingenuity by focusing on wind power and biomass energy.

3.2.2 Danish engineers had developed the world's first electricity generating wind turbine in the 1890's and continued advancement as late as the fifties, when wind power was abandoned in favour of cheap oil. Building on earlier work, it took Danish engineers only a few years to develop the technology that today dominates the global wind power industry. Starting in the early eighties, a series of wind power co-operatives were formed in Denmark allowing groups of people and later even individuals to purchase a turbine, lease a site for it, often on the property of a co-member or on individual property. The national government played a crucial role by paying 30 percent of the cost in the first nine years and by requiring utilities to purchase the electricity generated at a fair price.

3.2.3 The results are now visible throughout the Danish countryside. Altogether, Denmark had roughly 3,600 turbines in operation by 1994, with a capacity of 500 megawatts. This makes Denmark the world's second (to USA) largest user of wind power, which provided more than 3 percent of the country's electricity in 1994 which is projected to reach 10 percent in 2005. Denmark has effectively led the way to be first intermittent renewable energy technology to be integrated in sizeable numbers into the world's electric power systems

3.2.4 The wind power got a second boost in California, USA, in the early eighties The 'wind rush' followed the 1978 publication of a state government study that unexpectedly found that California has a large wind energy potential. The study coincided with the adoption of state and federal tax credits intended to spur wind power development and with the passage of the federal Public Utility Regulatory Policies Act (PURPA), which required electric utilities to purchase renewably generated electricity at the "avoided cost" of power from conventional sources.

3.2.5 By 1993, California's wind farms generated nearly 3 billion kilowatt-hours, about 1.2 percent the states' electricity, or enough to meet the residential power needs of San Francisco. It is interesting to note that when a number of small manufacturers in response to the surge in development of wind power rushed their turbines to market indiscriminately and failed, the Danish wind turbine industry came to California's' rescue, supplying 7,500 turbines to the State developers (twice as many as the installed capacity in Denmark itself). In 1993, the American wind Energy Association set a goal of pushing US windpower capacity to 10,000 megawatts by 2000.

3.2.6 While the combined efforts of Danish and US manufacturers, with continuing government support, have led to steady improvements in wind generating technology both in terms of efficiency and cost, more than a dozen American and European companies are pursuing advanced wind technologies, many with government assistance, that are believed capable of closing the remaining cost gap with fossil fuel plants.

3.2.7 Despite the surge in wind power in the US, the nineties are beginning to shape as the decade of Europe and Asia (India and China) in this field. Several European governments stepped up their efforts to promote carbon-and-sulphur-free renewable energy source in the late eighties' including increased R & D support and additional subsidies. In northern Germany, for example, where wind power purchase price and a generous government subsidy allow private wind power developers to receive 13 cents per KWH for their electricity. In the Netherlands, an integrated wind power development programme is a prominent part of the country's National Environmental Policy Plan. And in the UK, the newly privatized power industry is required to reserve a portion of new power contracts for non-fossil sources, an obligation originally intended for nuclear power, but now used to promote wind energy

3.2.8 As noted above, the key strategy for wind power development has been to ensure a favourable stance of the utilities, most of which are unfamiliar with the technology and resist anything new. Opening the grid to independent wind developers and giving them attractive but fair prices for the power they provide is the key strategy for boosting the industry and attracting the capital needed to develop the next generation of wind turbines. In addition, small, declining subsidies and tax breaks (as now used in Germany) can spur wind power development. Finally, governments can help utilities form consortia that commit to building large numbers of turbines, thereby allowing manufacturers to scale up production and bring down the price. Several countries have adopted some or all of these strategies in recent years as a way of encouraging the development of less polluting wind power.

3.3 Solar Power

3.3.1 Solar Thermal

3.3.2 Broadly there are two categories of solar energy technologies: thermal/solar thermal and solar photovoltaic (PV). Let us first examine the status of solar thermal applications. It is interesting to note that solar water heating actually got its modern start in Palestine in 1940, nearly a decade before the Jewish state was founded. However, it was Levi Yissar of Israel who contributed significantly in making solar water heating a success story in his country. With his box-like, roof-mounted solar collector made of copper and glass Yissar demonstrated that solar heating was reliable and would pay back the initial investment in just two years. By 1953, he had established a full-fledged solar collector manufacturing company. While other countries were left wondering as to how to respond to the 1973 oil crisis, Israel responded by increasing its support of solar hot water and spurring development of the solar industry. The government eventually required all residential buildings upto nine stories high to use solar energy for water heating. As a result, today, Israel has the world's highest density of solar collectors. Some 900,000 solar hot water systems were in place in Israel by 1994, providing business for 30 solar companies.

3.3.3 Solar hot water system gained popularity in California, Florida and Australia at the turn of the century and faded with the advent of cheap oil and natural gas. In the late seventies solar water heating made a strong comeback propelled by tax credits and the desire to achieve energy independence. In the USA alone, dozen of companies installed more than 1.5 million solar heating systems during this period. The market however collapsed in the mid eighties with the expiration of the tax credit. Japan, on the other hand, expanded its reliance on solar water heating and is now the world leader with some 4.5 million buildings having solar hot water system in 1992. In Netherlands some 10,000 solar hot water heaters had been installed by more than 10 companies by the end of 1993, spurred by subsidies to be phased out as the industry becomes stronger in the late nineties. The technology has also caught on in a number of developing countries often with little government support, e.g. Gaborone, the capital of Botswana, for example, has purchased and installed 3,000 solar water heaters displacing nearly 15 percent of the country's residential electric demand, while 30,000 solar hot water system were installed in Columbia, 17000 in Kenya and nearly 1000 in Malaw and in Jordan 26 percent of the country's households use solar hot water systems.

3.3.4 In order to expand the solar collector market and help manufacturers to scale up production, a few electric utilities have begun to help customers install solar water heaters. The Sacramento Municipal Utility District (SMUD) in California financing the conversion of electronic water heaters, chalking up more than 1800 systems by early 1994. In 1993 the utility offered a performance based rebate upto $ 863 on systems that cost less than $ 3000. Customers pay the remainder through their bills over 10 years. SMUD's goal is to have more than 20,000 solar systems in place by 1999 covering half the homes in the area that heat water with electricity

3.3.5 Although the idea of an orbiting power station has been abandoned, several caricature to this vision of large scale solar thermal energy were built in the eighties in France, Japan, Italy, Spain, Ukraine and the USA. Among the large solar thermal generators that got the most attention was Solar One, a 77 meter high, tower-mounted receiver built in Southern California's Mojave Dessert, in the early eighties with a 10 megawatt generator. Although Solar One turned out to be an expensive and unreliable power plant, the engineers are working on a Solar Two 100 MW version with a new design.

3.3.6 The generous power purchase contracts and solar tax credits offered in California are the attraction of the solar entrepreneurs. Luz International, for example, has lined up several large contract to deliver electricity to the Southern California Edison Company and was at work on a series of solar power generators. Between 1984 and 1990 Luz installed nine plants with a capacity of 354 MW. It is also interesting to observe that Luz's fortunes took a bad turn when the falling natural gas price drove the company's power purchase price lowered and tax credit facility renewed for only 9 months instead of 12 months. On the other hand, a solar power generating system based on parabolic dishes designed at the Australian National University and an initial 2 MW plant was being built in 1994 in Australian remote Northern Territory. The project is being funded by a consortium of electric utilities under pressure to reduce their heavy reliance on coal. Twenty five dishes will feed steam to a turbine to produce power for the isolated community of Tennant Creek.

3.3.7 As a source of baseload and peak electricity in relatively sunny, dry climates, Solar Thermal Power is likely to have few rivals. One possibility that is being explored in the US Southwest is to convert existing coal-fired power plants into Solar Thermal Power stations that use natural gas for back-up - already close to being economical for plants that face legal requirements to cut the amount of Sulphur and NO_2 they emit. Another possibility is to link a field of solar troughs or dishes a gas turbine power station, allowing the solar collectors to substitute for the boiler in a combined-cycle plant, which would increase the overall efficiency [1]

3.4 Solar Photovoltaics

3.4.1 In early 1954, the scientists at the Bell Laboratories in New Jersey discovered that a silicon device produced electricity when exposed to sunlight. Within a few months the Bell Scientists made a breakthrough when they pushed the cell's efficiency to 6 percent. By 1980, the efficiency of commercial photovoltaic (PV) modules had risen to more than 10 percent and the price had fallen to roughly $12 a watt ($21 in 1993 dollars) as shown in Figure 1. The technology continued to advance during the next decade, and by 1993 the average wholesale price of PVs had dropped between $3.5 and $4.75 a watt, or roughly 25-40 cents a KWH. As costs fell, sales rose to 60 MW in 1993 (see figure 2)

Figure 1

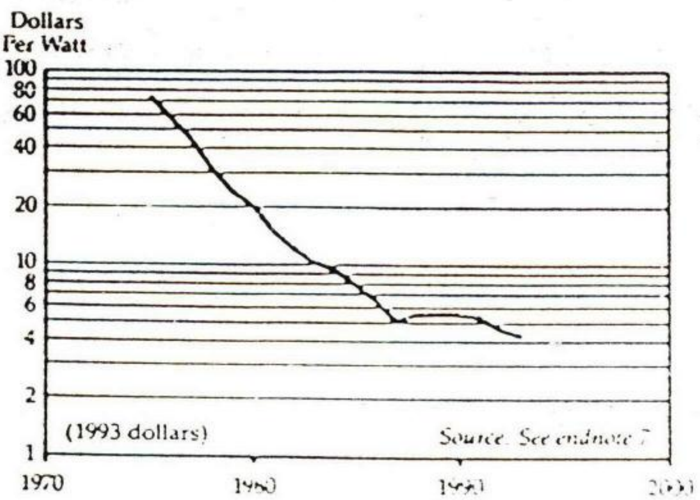

FIGURE 1. *World Price for Photovoltaic Modules, 1975–93*

[1] Beasinger, Clarks. "Solar Thermal Repowering : A Technical and Economic Pre-Feasibility Study", The Energy Foundation, San Francisco, Calif., draft revised version 2.0, 1993

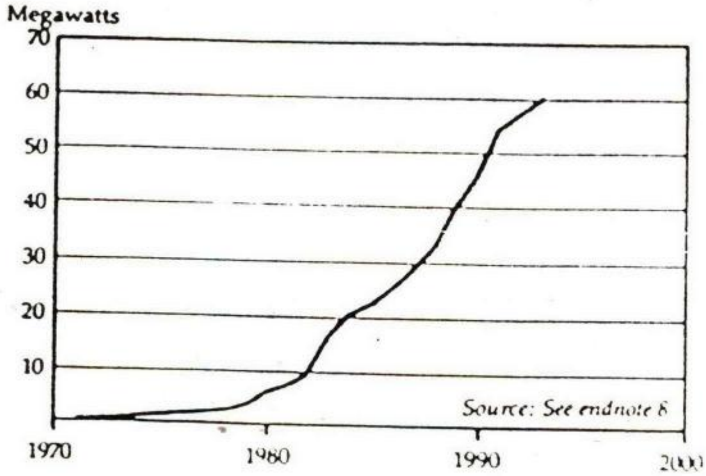

FIGURE 2. *World Photovoltaic Shipments, 1970–93*

Figure 2

3.4.2 Although still too expensive to compete head-to-head with conventional generating technologies, PV cells have found ever-larger share in the global energy markets. By the early nineties thousands of villagers in Africa, Asia, and Latin America were using PV cells to power lights, televisions, and water pumps - needs that were otherwise met with kerosene lamps, rechargeable batteries, and diesel engines. Interestingly most of these efforts have been promoted by NGOs and private business, with limited support by Government and aid agencies. Still, solar electrification projects using PV cells start with a large disadvantage because of its high initial cost compounded by the hidden subsidy to grid electricity. By levelling the playing field in reducing the subsidies to conventional power or providing equivalent funding for solar energy could lead a boom in Solar Electrification. World governments and international aid agencies, particularly GEF have begun to respond to this need, mainly by setting up new ways of funding Solar Power Projects.

3.4.3 In order to move into larger markets and continue the downward trend in prices, PVs will need both a push and pull from Governments and institutions. In response, some governments have adopted a strategy aimed at stimulating the market for PVs - to encourage utility investment and at the same time allow private manufacturers to scale up production. US Government support, for example, rocketed to $ 260 million (in 1993 dollars) in 1980 but then fell to just $ 38 million in 1990

Government R & D funding was steadier in Germany and Japan during the eighties exceeding US outlays by the end of the decade. Much of the early Government support in all these countries was skewed toward large demonstration projects. On the other hand, the wild swings in US Government support made it difficult to attract private capital needed to advance the technology both in terms of costs and efficiency.

3.4.4 Between 1990 and 1994, Governments have shown better understanding of the needs of the PV industry. US Government, for example, doubled its R & D support during this period, reaching $78 million, while Germany's plateaued and Japan's grew modestly. R & D programs have been reoriented so as to work with private efforts and Governments have also begun working to spur commercial development. Some of the most effective programs are in Europe where Governments began offering tax incentives, low interest financing, and cash rebates to entice building owners to install Solar Electric systems in the early nineties. Thousand Roofs program was launched in 1990 in Germany and was soon upgraded to 2,500 roofs. Switzerland aims to place at least one PV system in each of the country's 3029 villages by the end of this decade. The Netherlands is planning to install 250 MW of PVs by 2010, with the expectation that it will contribute for more power after that. Austria and Denmark are preparing their own stimulus programs. Japan, meanwhile, has devised a strategy to install some 62,000 Building-integrated PV systems, with combined capacity of 185 Megawatts by the end of nineties. Government support will be in the form of a subsidy that initially will cover half the cost of the systems but then decline gradually until it reaches zero after seven years. In the US, on the other hand, federal and state tax credits have been used to spur PVs since the late seventies, a subsidy that was still continuing in the mid-nineties. In 1993, coalition of more than 60 US utilities announced plans, in conjunction with the federal government, to install 50 MW of Solar Cell between 1994 and 2000.[2]

[2] Utility Photovoltaic Group. "Electric Utilities Serving 40% of US Consumers Propose $513 Million Program to Acclarate Use of Solar Photovoltaics. Washington, D.C., September 27, 1993.

3.5 Biomass Energy

3.5.1 Recent advances in combustion engineering bio-technology and silviculture are making it economical to turn a variety of plant forms into usable liquid and gaseous fuels or even into electricity. A study commissioned by the United Nations for the 1992 Rio conference found that if crops were grown specifically for this purpose, the equivalent of 55 percent of today's total world energy use could be met with biomass by 2050.[3] In 1992, biomass is estimated to supply 13 percent of the world's energy (see table 3.5). If the contribution of biomass to the world energy is to grow, what will be required is technological innovations, so that biomass can be converted to usable energy in ways that are more efficient, less polluting, and economical. Gains in conversion efficiency are already being achieved starting from cookstoves and biogas plants to electricity generation.

[3] Johansson, T.B. et al. "Renewable Fuels and Electricity for a growing World Economy : Defining and achieving the potential", in T.B.Johansson et al. eds. Renewable Energy Sources for Fuels and Electricity, Washington D.C. : Island Press, 1993

Table 3.5

Biomass Energy Use in Selected Countries, 1987

Country	Biomass Use (petajoules)	Share of Total Energy Consumption (percent)
United Kingdom	46	<1
United States	3,482	4
Denmark	84	9
Thailand	206	20
Brazil	1,604	25
China	9,287	28
Costa Rica	31	32
Zimbabwe	143	40
India	8,543	56
Indonesia	2,655	65
Tanzania	925	97

3.5.2 Besides conversion efficiency, there are essentially two main strategies to increase the level of biomass energy use: reliance on residues from crop and forestry production, and development of new, sustainably grown energy crops. How are these strategies presently followed ? In the US, for example, the paper industry meets roughly half its energy needs using sawdust, scrap wood and pulping waste to fuel its boilers for heat and electricity generation. US grid-connected, biomass-fuelled electricity capacity - all of it based on residue products - rose from 200 MWs in 1979 to some 6,000 MWs by 1993. The catalyst behind the increase was the 1978 passage of PURPA, which required electric utilities to buy power produced by independent companies at fair prices. Recently, US utilities have shown interest in burning wood, which is very low in sulphur, along with coal in order to meet sulphur emission standards, spurring R & D by governments and industry. Surveys indicate that an additional 8000 MW of biomass energy potential can be harnessed in the US paper and wood products industry alone.[2]

[2] Preston, J.L. et al, "Article : Energy Efficiency in the Manufacturing Sector", Monthly Energy Review December 1992, Washington D.C. : GPO, 1992. The current US biomass generating capacity shown above, however, excludes roughly 1,800 MWs of municipal solid waste incineration projects.

3.5.3 Denmark, a country with extensive cropland but few large forests has made straw into an important energy source. Existing straw surpluses can meet more than 7 percent of the country's energy needs. Following the decentralised approach in developing wind energy the Danish Government has helped spur the construction of 12,000 small-scale straw burners that provide heat for on farm use. Since 1980, more than 60 district heating systems have been modified to rely on straw for an average of 90 percent of their fuel. With help of higher taxes on fossil fuel Denmark plans to increase straw combustion from 800,000 tons in 1991 to 1.2 million tons in 2000. Also, following the example of wind turbines, it hopes to make biomass technology in to an important export.[5]

3.5.4 Bagasse, the residue of sugarcane after extraction has been traditionally used for burning in boiler to produce steam to fuel the extraction process of the sugar mills. Some sugar mills also produce electricity with the steam to fuel the plants' operation. With the development of modern steam turbines and the technology for converting the solid biomass into gas, the prospect of generating electricity manifold as against earlier standard boiler technology is conclusively demonstrated. In fact, there is an international effort supported by GEF and the Brazilian Government, sponsoring a design competition for a 25-30 MW biomass fuelled gas turbine in Brazil's north-east state of Balvia. It is expected that with such technology development, the cost of biomass electricity can be brought down to 5 cents/Kwh from 8 cents/Kwh and therefore make it competitive with conventional coal fired units. Pending this development, the sugar mills have started selling electricity by using the existing technologies to local power companies in Costa Rica, Cuba, Fiji, Guatemala, Mauritius, Thailand, the US and Zimbabwe. The key strategy in this is to require electric utilities to pay fair prices for surplus power within the legal framework of policy.

[5] Denmark already sold a straw-fired district heating system in the former East Germany - for details of Denmark program see "The Centre of Biomass Technology "Straw for Energy Production Technology-Environment-Economy", Aarhno, Denmark, 1992

3.5.5 Other biomass residues, such as dung from livestock and humans, are gasified in anaerobic digestors, with remaining nutrient-laden material returned to the land as rich fertiliser. Methane created by microbes that decompose landfilled garbage are also collected and burned to produce heat or electricity. China, Denmark, India and the Netherlands, among other countries, are using large and small anaerobic digestors, while the UK has 51 landfill plants, which capture 8 percent of the amount of the methane generated and released into the atmosphere each year. And in western Germany, a quarter of the landfills are equipped to convert the gas to heat and power. In all these cases it is the government subsidy which is one of the important fiscal strategies employed. In fact, in a few cases, heavy government subsidies have spurred reliance on biofuels as a substitute of oil. In the US, for example, nearly a tenth of the motor fuel used in the mid-nineties is a 10 percent blend of corn-derived ethanol and gasoline, a product that has been made economically attractive through exemptions from federal and state level taxes. The case of Brazil using alcohol from sugarcane to power about half the fuel of the country's automobiles has been well known.[6] A caveat should be entered here regarding increasing use of biomass energy. For, energy derived from biomass will continue to have less value than many other uses of biomass, such as, fodder, construction materials, feedstocks etc. This may leave energy near the bottom of the biomass "food chain". Biomass energy technology promotion therefore could take one of two paths in the future : an intensive, environmentally destructive path or one that could enhance local ecosystems.

3.6 Summary of Learnings

3.6.1 We have deliberately concentrated our focus in reviewing the strategies followed in the industrialized countries in the North. There are clearly two specific reasons for concentrating our focus on these countries: first, development of renewable energy technologies in these countries are faster and therefore provides a future direction in this field world over. Secondly, apart from wide scale of operations of

[6] In Brazil costs of alcohol have fallen by roughly half since the late seventies, though the least expensive cane ethanol still costs more than gasoline - roughly double the world price in 1994. It must be emphasised, however, that either corn or sugarcane derived alcohol will be economically and environmentally justifiable, particularly, in land-scarce highly populated countries like India. Globally also, there is simply not enough land to fuel automobiles of the world.

RETA, these countries have fully documented and well-laid out policies including legislations for RETA. The most significant point of contrast to be emphasized here is the fact that while the policies and legislations of these industrialised countries of the North in relation to RETA have largely been in response to environmental considerations, for most countries of the South, particularly India, the concern remains to be alternative or supplementary source of energy production first and then environmental considerations. This is one reason why we see these industrialised countries almost solely concerned with fossil fuel based electricity generating systems or utilities, which is the major source of environmental pollution. All the policies and legislations regarding subsidies, tax credits, buy-back rate etc. which affect production of renewable energy technologies in these industrialized countries are essentially to ensure that the costs imposed by emissions of various kinds of pollutants are put directly on the electricity generating utilities. Basically, there are two strategic policies proposed to address these issues : environmental costing and set-asides. When new generating options are being evaluated, the cost of pollution is counted, which gives renewables a boost. Alternatively, the renewables are given subsidies, tax credit and other financial incentives in order to bring them in level playing ground with the conventional fossil-fuel based energy generation. The second strategy is a simple set-asides for renewables, in which a minimum share (10 - 20 percent) of the market for 'new' power is reserved for 'non-fossil' generating technologies. Either one of these strategies are followed, while in some cases a combination of the two are also in practice. Still a <u>third</u> alternative strategy being experimented is to allow selling of renewably generated electricity at a slightly higher 'green' price. It is also to be noted that whatever the strategies followed in these countries, the governments had to set the rules for these strategies. But once regulations are in place, there are declining need for intervention and a less adversarial relationship between utilities and regulators in which market mechanism play the 'gatekeeping' role.

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