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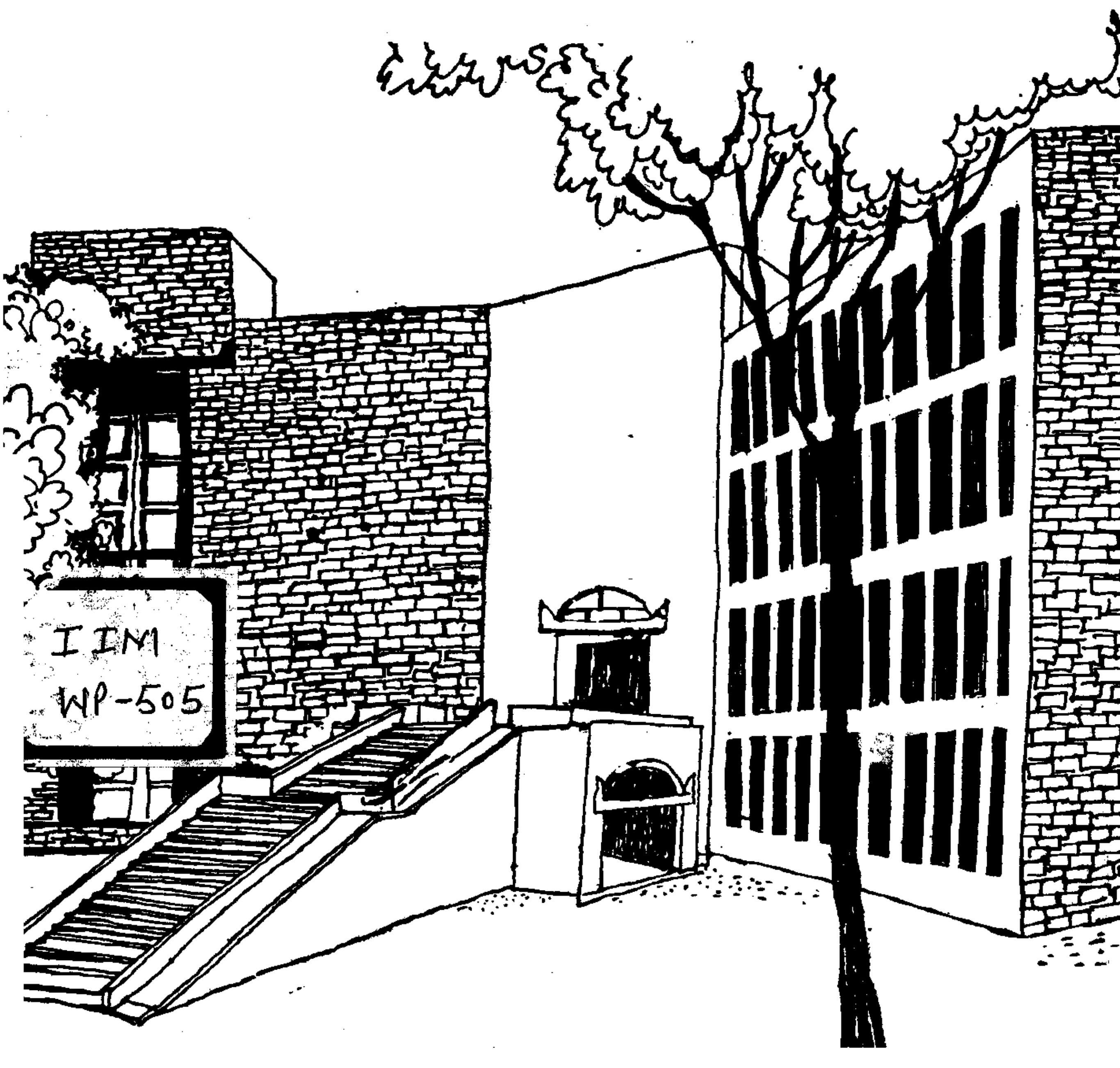

RENEWABLE ENERGY DEVELOPMENT IN INDIA: A MACRO ANALYSIS

By

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ABSTRACT

The development of renewable energy in India is not simply a technical question. The macro-analysis attempted here reviews the complexity, interdependence and the structural-systemic features of the renewable energy system and its embeddedness in larger contexts. The need for a comprehensive policy package that addresses need and supply, technology and institutions, environment and education, pricing and substitution and local conditions and standards is thus necessary but is yet to evolve. The political economy of renewable energy indicates that technological and social actions are simultaneously called for. The market, the state and the community must play balanced roles and articulation of this balance in renewable energy is a strategic question for India. The macro-analysis shows the need for structural adjustments (in terms of changes in mix of economic activities) and hence changes in energy intensity and growth rate. Technological responses like development of energy efficient and renewable energy using equipment or interfuel substitution are not sufficient to promote renewable energy use. Hence a micro or project apprach is not enough in renewable energy planning. A macro-analysis may help us to understand and possibly transcend the structural barriers. This paper explores some dimensions of this complex issue of renewable energy development and proposes some strategies.

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1. Introduction

Renewable energy has been in use for centuries. It was estimated to consist of 66 per cent of the total energ consumed in 53-54 in India. Presently its share may be around 40 per cent. Most of it is non commercial (not sold through a market place). With the energy crisis of the seventies and the depletion of fossil fuel resources, renewable energy is getting increased attention. It has many positive advantages as well. Its potential to meet a large part of India's growing energy needs in the future is rated to be high. In this paper, we want to examine the macro-framework in which renewable energy development can take place in India. This analysis would survey the economic environment, renewable energy's role in national energy balance, technology, institutional structure and public policy options.

2. National Energy scene and the role of Renewable Energy

Energy consumption is growing in India rapidly, over the last thirty years, at a rate higher than the growth of GNP. The use of non commercial energy is declining and is now around 40 per cent of total energy. Renewable energy sources have been traditionally non commercial but they are slowly becoming commercial. This important structural feature needs considerable emphasis. As the mix of economic activities and the economic base becomes complex and interdependent, the incremental energy consumption required to bring about 1 per cent increase in GNP growth rate declines. The elasticity of commercial energy consumption (the ratio of % of growth of energy to % of GNP growth) is changing in India in the following manner:

1953 - 61	-	1.55
1961 - 71	-	1.17
1971 - 81	-	1.30

There is, however no clear pattern. If we combine non commercial energy also, the overall elasticity of energy consumption is definitely going down and is probably lower than one, now.

Table 1 indicates the overall energy situation in the country and how it is changing. The structure of the energy sector, the reliance on scarce sources and the differential growth rates presents us with a comprehensive energy profile. As energy demand is a derived demand, the varying pattern indicates a varying sectoral growth picture.

Table 2 and 3 tells us more about the growth rate and shares of market by different fuels and different sectors. Coal is declining in importance as its share is taken by oil and power. Industry and agriculture consume relatively more energy than transport and domestic/commercial sectors, as compared to ten years ago. These are important trends that tell us about the nature of change in the energy economy.

Table 4 indicates the rapid rate of energy growth (about 10 per cent per annum) in the agricultural sector. The next fastest growing (in energy terms) is the Industrial Sector. Table 5 portrays the per capita energy consumption changes. Over the last ten years, as shown in Table 5 National Sample Survey data, per capita energy consumption has slightly decreased. The share of commercial energy is growing, particularly in urban areas. NSS data shows, paradoxically, that per capita energy in rural areas is higher than in urban areas. This may be due to some unreliability in data or incorrect measurement.

These trends in energy tell us about the present role and the future of renewable energy. Projections about the future of renewable energy must derive from futures of sectors, the inter se economics and resource evaluation of other energy sources and where renewable energy can be applied for new uses or in substitution. As the existing data base about non commercial energy in rural areas which is primarily renewable, is very weak, demand analysis in this area becomes very difficult. We do know that it is very important to assess this need in rural areas, to forecast renewable energy requirements.

TABLE 1

National Energy Balance in India

(in million tonnes of coal equivalent - mtce)

Primary Energy Supply	1970-71	1975-76	1980-81
Production	73.4	98.3	116.3
Imports (+)	18.1	22.4	33.9
Exports (-)	1.0	0.8	0.5
Change in stock (-)	1.1	5.3	5.5
Total Primary Energy Supply	89.4	114.6	144.2
Transformation (-)			
(Conversion losses; Transmission and Distribution losses; Internal use in Energy Sector)	24.6	32.7	43.2
Final Energy Demand	64.8	81.9	101.0
Final Energy Consumption			
Coal	35.1	43.7	48.5
Oil products	23.2	29.0	40.1
Gas	0.5	1.1	1.3
Power	6.0	8.1	11.1
Total Final Energy Consumption	64.8	81.9	101.0
Non Energy use (-)	3.9	5.2	8.4
Energy use	60.9	76.7	92.6

Source: T.R. Satish Chandran's address to the Institution of Engineers, India 1982.

TABLE 2

Fuelwise Energy Consumption

Fuel	1970-71		1975-76		1980-81	
	mtce	%	mtce	%	mtce	%
Coal	35.0	57.5	43.6	56.8	46.7	50.4
Oil	19.4	31.9	23.9	31.2	33.5	36.2
Gas	0.5	0.8	1.1	1.4	1.3	1.4
Power	6.0	9.8	8.1	10.6	11.1	12.0
	60.9	100.00	76.7	100.0	92.6	100.0

Source: Ministry of Energy, Government of India, 1982.

TABLE 3

Sectorwise Energy Consumption

Sector	1970-71		1975-76		1980-81	
	mtce	%	mtce	%	mtce	%
Industry	32.4	53.2	44.6	58.1	54.3	58.7
Transport	19.3	31.7	21.6	28.2	24.4	26.3
Domestic+ Commercial	7.9	13.0	8.3	10.8	10.5	11.3
Agriculture	1.3	2.1	2.2	2.9	3.4	3.7
	60.9	100.0	76.7	100.0	92.6	100.0

Source: Ministry of Energy, Government of India, 1982.

TABLE 4

Energy Consumption Growth rate by Sector (%)

Sector	1970-1971 to 75-76	1975-76 to 80-81	1970-71 to 80-81
Industry	6.6	4.0	5.3
Transport	2.3	2.5	2.4
Domestic and commercial	1.0	4.8	2.9
Agriculture	11.1	9.1	10.1
Total Energy consumption	4.7	3.8	4.3

Source: Working Group on Energy Policy, Planning Commission, 1981.

TABLE 5

Per Capita Energy Consumption (Kgce)
National Sample Survey Estimates

Fuel Type	Estimates in NSS 1963-64		Estimates in NSS 1973-74	
	Rural	Urban	Rural	Urban
Kerosene	7.1	12.9	11.5	17.8
Electricity	0.1	1.1	0.3	2.2
Coal	2.6	9.3	2.5	12.4
Coke	1.4	14.1	2.5	12.7
Charcoal	0.5	3.2	0.1	1.7
Firewood	183.2	114.9	166.2	98.2
Dungcake	35.7	11.8	24.9	8.7
LPG	-	-	0.3	1.2
	230.6	167.3	208.3	154.9

Source: National Sample Survey Organization.

3. Renewable Energy Needs and Markets

More quantitative estimation of renewable energy is not adequate. The quality of renewable energy, its reliability, its variability and its contextual relevance are very important. One bundle of wood can be very different from another bundle of wood. Biogas from one plant may be quite different from biogas from another. Moreover matching sources and uses of renewable energy is very critical as the verstality of renewable energy is lower than conventional sources like electricity. It is certainly self-reliant, pollution free, decentralised and is sustainable over time. Context, however is more critical in renewable energy, making aggregation of renewable energy, a difficult task in energy planning. By context, we mean, resource endowment (forests, cattle heads, climate, soil conditions etc.)and user needs and priorities and external market linkages. In other words, renewable energy is not simply physical, to be measured in joules or millions of tonnes coal equivalent. It has a social meaning which is contextual. The demand-supply analysis for renewable energy in this sense is made difficult by this localising feature. We cannot, like in conventional economic analysis, conclude that the relative price advantage of renewable energy will make it more popular. Historically, the contextual use of renewable energy has been characterised by multiple forms, small scale, remote areas, non commercial use, decentralization, local control and matching of sources and uses. Commercialization of renewable energy might mean a significant change in all these features. Yet, if we have to plan for renewable energy to replace non renewable energy, reliance on efficiency, price advantage and market processes seem inevitable. How to resolve this profound dilemma will be explored later, in this paper. Let us now look at the sources of renewable energy.

Bioenergy sources are wood, grass, agricultural residues, human and animal wastes, municipal wastes and sewage and some plants like water hyacinth. The methods to extract energy from these sources, usually are, direct combustion, gastification in the presence of air or oxygen, pyrolysis, anaerobic digestion, fermentation followed by distillation.

With growing population and scarce land resources, firewood and agricultural wastes are very difficult to obtain. Commercialization of firewood and charcoal and growing urban demand for these fuels have made them inaccessible and expensive for the rural poor. The ecological problems (desilation, soil erosion, flooding, droughts) due to deforestation are also becoming severe. Energy plantations of fast growing species like Subabul, Eucalyptus are being extensively developed to improve self reliance in energy. While there is some conflict between food and energy in land use, energy plantations have been successful in a number of places, notably Gujarat and Tamilnadu, improving energy supply, employment and economic conditions.

Biogas plants from animal wastes to provide gas and fertilizer are becoming common. India has presently about 1,00,000 such plants. While small family plants are common, experiements in larger, community plants are being attempted. The generation of gas is maximum at 30-35^{0}C and a lot of present R & D efforts are focussed on material development, maintaining productivity in winter etc. As a decentralised energy source, biogas holds great promise to meet the local needs of nearly 15 million rural households, potential customers of biogas.

Wind energy is another important source. It is location specific and has a narrow market size. It can be harnessed in coastal areas, mountainous regions and other places where the wind velocity is significant. Gujarat, Rajasthan and coastal areas appear to have high potential for wind energy development. Different geographical areas, however, are yet to be systematically explored. Most such areas have a potential of more than 3 KWH per square km per day for more than six months a year. Current R & D efforts are in design of different types of wind mills and making them more productive. Multiple type wind mills for minor irrigation and drinking water supply have been installed in 250 places, all over India.

Solar Energy appears to have significant potential in India where it is estimated that each square km. receives 1650-2100 Kwh. per day for about 250-300 days in a year. This energy is renewable, pollution free and intensive. Solar drying of crops and fish and indirect use of solar energy through photosynthesis (crops and trees) have been common in India for thousands of years. However, the traditional technologies have been relatively inefficient and our developmental efforts have been focussed in harnessing solar energy in new ways and in upgrading traditional technologies (Daval. 1982).

Solar thermal devices like solar coolers, solar water and air heaters, solar desalination systems, solar refrigeration and airconditioning systems, solar pumps and power generating systems have a lot of applications in the country. Solar water and air heaters for low temperature applications have been developed and manufactured by several industries. Solar coolers have also been developed and used. Present R & D focusses on development of new materials to increase the range of working temperatures and efficiency of systems (selective coating materials for absorbing, glazing systems, insulation material, reflecting surfaces etc.) (Viswanathan, 1982).

Solar collectors for medium (over 100°C) temperature applications have a lot of potential but need a lot of investment. For example, solar refrigeration and airconditioning, and solar assisted heat pumps are expensive now but may have lower costs in ten years. Prime movers (turbines etc.) for low and medium temperature applications, operation of small pumps, etc. are being developed. Solar concentrators through parabolidal dishes, energy storage devices and solar power plants are also being developed.

During the last three years, several solar thermal demonstration systems have been installed in the country. They include solar air and water heaters, dryers, wood seasoning kilns, demonstration plants, space heating systems, cold storages, thermal pumps etc. Air and water heating systems are becoming more popular and adopted by a number of industries and establishments. These may no longer need Government support. Photovoltaic R & D is in the preliminary stage and is mainly focussed on material development. Solar cells cost now Rs.120/peak watt and the effort is on to reduce this figure. The 1985 target is 1 MW solar electricity production. Applications in remote areas (lighting, TV, water pumping etc.) seem worth pursuing.

Industrial thermal applications (process steam, heat for driving) particularly in low (60°- $90^{\circ}C$) temperature seems now have the highest potential for commercial applications. With the threat of power cuts in most states, industries would like to have some degrees of self reliance in energy supply by installing such systems. (Samuel and Ramaswamy, 1982).

We have briefly surveyed the renewable energy technologies and the focus of the present R & D effort. Let us presently review at the macro-level issues for renewable energy development.

4. Economic and Environmental Issues:

In the Sixth Plan, the total outlay on energy is around Rs.265 billion (30 per cent of the total outlay in the plan). Its distribution is: Rs.192 billion for Power, Rs.29 billion for Coal, Rs.43 billion for Oil, and Rs.1 billion for Research and Development. Towards the end of seventies, there emerged a greater appreciation of the rural non-commercial and renewable energy needs. The Department of Science and Technology since 1975 and the Commission on Additional Sources of Energy of Government of India since 1981 have been supporting renewable energy, research, development and demonstration (RDD). In 1975-76, this amount was Rs.10 million and by 82-83, it has grown to Rs.60 million. The R & D programmes support basic research, applied research and design in R & D laboratories, public sector enterprises, academic institutions like IITs and universities and voluntary organizations as well as demonstration of processes, devices and systems. Over 80 per cent of this amount is spent by CASE and the remaining by CSIR etc. A small amount is directly spent by industry on renewable energy RDD.

The economics of the renewable energy sources, as we have mentioned earlier, is context dependent. While there is general agreement in the market place about the more economical use, precise universal figures or cost benefit ratios are hard to come by (World Bank 1981). Table 6 gives the relative economic position, given the present technology of renewable sources for various applications.

TABLE 6

Economics of Renewable Energy Sources

Legend: 1. Definitely cost effective
2. May become cost effective but not established under field conditions.
3. Definitely not cost effective.

Use/Type	Proto-voltaic	Wind Energy Elec.	Wind Energy Mech.	Solar Thermal Low Temp.	Solar Thermal Medium Temp.	Biogas
Water Pumping	3	-	2	-	-	-
Cooking	-	-	-	1	1	1
Electric Power (small)	3	3	-	-	-	-
Electric Power (large)	2	2	-	-	-	-
Hot water	-	-	-	1	-	-
Crop drying	-	-	-	2	-	-
Refrigeration	3	2	-	3	-	-
Grain grinding	3	3	2	-	-	-
Desalination	3	3	-	3	-	-
Lighting	3	2	-	-	-	2
Food processing	-	-	-	1	-	-
Industrial processing	-	-	-	1	2	1
Transport	2	-	-	-	-	2

Source: Proceedings of National Seminar on Adoption of Renewable Sources of Energy 1982, Hyderabad: Administrative Staff College.

The Sixth Plan programmes, considering the relative economics indicated in Table 6, have three major objectives:

(i) To implement on a large scale, programmes like energy forestry and biogas where the technology is fully developed for commercial application.

(ii) To carry out field testing and demonstration on a country-wide basis of technolgies which have potential commercial viability in the next 5-7 years and

(iii) To encourage R & D in areas where the potential can be realised only in the long term (10 years and above).

Several field studies indicate that there are some specific economic problems in the renewable energy sector. These can be summarised as (Subramanian and Srivastava, 1981):

(a) Investments in biogas may yield no cash flows to the individual farmer but only biogas and fertilizer for use. The alternatives may be better in the short run, where cash flow needs are high.

(b) The private costs and social costs in renewable energy diverge. (e.g. denudation of forests and ecological impacts). Subsidy from public funds may be necessary to bridge this gap so that the individual makes the socially optimal decision. Given the market distortions of energy prices, this is necessary.

(c) While small biogas plants are less economical than community based large biogas plants, the implementation problems of the latter (collection of dung, people's participation and distribution of products)are more severe.

(d, Regional, seasonal and diurnal variations in output and productivity of renewable energy have a lot of variability, making reliable satisfaction difficult.

(e) Lack of standardisation in materials, components and performance and absence of fabrication, repair and maintenance facilities makes diffusion of renewable energy difficult.

(f) In many renewable programmes, there is very poor participation by the users. This has lead to poor adoption and use as market processes do not effectively substitute for participation.

A major advantage of renewable energy is that it is environmentally sustainable. An understanding of their environmental impacts is thus critical to preserve this advantage. Table 7 lists them and the environmental impacts should be linked to the planning processes.

5. Opportunities and Constraints in the use of Renewable Energy:

We have noted that development of renewable energy cannot be based only on conventional models of diffusion innovation or market development. Physical and social context, participation and life styles pose special problems in the adoption of renewable energy. It is important to understand some of the opportunities and constraints in the use of renewable energy. Table 8, illustratively outlines these in the present situation.

TABLE 7

Environmental Impacts of Renewable Energy Development

Source/Impacts	Land	Water	Air
Solar			
1) Solar Passive			
Construction	Terrain, Water tables, physical features should be considered.	-	
Operation	-	-	Where insulation and weather proofing are used, care should be taken not to reduce air exchange in the building, to avoid indoor air quality degradation.,
2) Solar Flat Plate			
Construction	Small size minimises land use	-	-
Operation	(see Air)	While problems are minimal, care should be taken to avoid leacking through soil from optical coating debris. This may result in surface and ground water contamination.	Small releases detergent solutions and organic solvents used in cleaning collectors into air.
3) Solar Thermal			
Construction	For Central Generation large land use	Disturbance of water streams due to run-offs.	Minimal release of coatings - metal oxides pollution. If large areas are closed in arid zones - dust problems

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Operation		For power production large quantity of water needed ; may pose problem in arid zones. Disposal system needs to be planned.	Localised solar radiation may pose hazard to personnel and fauna. Thermal release from collector fields may modify weather.
4) Photovoltaic			
Construction	For arrays significant amount land required	Treatment of effluents from Cell manufacture needed.	Workplace hazards due to exposure to chemicals (cadmium, selenium Arsenic)
Operation			minor releases of weathered or damaged solar cells airborne particulates.
5) Wind			
Construction	Land use problems significant	-	-
Operation	- do -	-	Electromagnetic interference due to reflections in wind energy conversion blades or other structures; Noise pollution; obstruction to birds.
6) Biogas			
Construction	Local site characteristics water table to be considered.		
Operation	Effluent can be used to fertilize land; possible negative impact caused by diversion of dung from poor; forcing increased use of fuelwood and soil erosion.	Can eliminate diseases but if many units are used, local water supply may get affected.	Some omission of CO_2, SO_2, NO_x H_2S and Ammonia odour from digestion process

7) Woodfuel

Construction	Land use for production and nurseries vis-a-vis competing uses.	Protection of endangered watersheds	
Operation	Protection against soil erosion from fuelwood, harvesting needed. Forest management necessary to avoid deforestation.	Over harvesting will lead to degradation of surface water quality due to runoff, flooding and siltation, loss of habitat.	
Consumption	Boiler ash and stack wastes require disposal		local particulates of SO_x, NO_x will be emitted in wood-fired combustion.

8) Charcoal

Operation	localised runoff requires mitigation	(see land)	local air pollution
Consumption	creation of increased demand for wood may lead to deforestation. Need to ensure soci-economic and ecological regime to sustain wood supply, exists.		

Source : SIERRA CLUB REPORT to United Nations, 1981 (New York)

TABLE 8

Opportunities and Constraints in Renewable Energy

Opportunities	Constraints
Biogas	
1. Saving nitrogen in dung.	1. No organization for community biogas plants.
2. India has 12 million cattle population.	2. Cost reduction elusive.
3. Good source for cooking as well as lighting.	3. Dung collection difficult and related livestock devt.
	4. Farmers do not know about biogas very well.
Social Forestry	
1. Existing Forest Area	1. Seeds of fast growing trees not widely available.
2. Vacant and marginal land available.	2. Lack of proper managerial and pricing policies.
3. Technology well proven	3. Maintenance responsibility not clear.
4. Farmers know about tree planting	4. Firewood distribution network poor.
5. Competitive with agriculture.	
6. Low investment for using fuelwood.	
Wind Energy	
1. Pumping does not require storage.	1. Variability/site specificity.
2. Can be used for generation of power.	2. Availability uncertain.
3. Can be linked to grid	3. R & D knowhow not proven.
	4. Manufacturers yet to be developed.
Solar Energy	
1. Available everywhere	1. Variability
2. Low temperature use -- simple technology	2. Storage difficult.
3. No adverse environment impact	3. Concentration devices costly.
4. Free of pollution	4. Only large scale production can bring down costs.
	5. R & D in materials needed.

Source: Seminar on Adoption of Renewable Energy, (1982) Hyderabad : ASCI.

A major problem in the use of renewable devices is that there are no commonly accepted national standards. For ex-ample, there are fifty manufacturers of solar water heaters in India. They all produce different kinds of heaters. Sometimes, the standards developed by the American Society for Heating, Refrigeration and Airconditioning or the U.S. National Bureau of standards are used. The absence of standards is a major constraint to widespread consumer adoption based on local needs. (The Hindu, 1983). The structure of renewable energy equipment industry is such that uneconomical and inadequate systems get produced. Considering the contextual nature of renewable energy applications, it is quite logical to argue that only components should be standardised and made in large scale. Assembly and supply of systems and devices should be done locally. But in India we find that large companies making solar water heating systems in a central place and transporting them across the country. Manufacturing policy by companies and licensing policy of Government should be changed to discourage such practice. Of course, local testing, and assembly, maintenance and repair facilities are needed in small scale sector before such a policy can be implemented.

Another example is the story of the development of the flat plate collector. This product has been developed in many places but not tested, standardized or reliable. Using more or less similar technology, Central Arid Zone Research Institute, National Physical Laboratory, Indian Institute of Science and IIT, Madras have developed flat plate collector systems. While redundancy in development is sometimes desirable to minimise risk and encourage innovation, such unplanned, wasteful and often sub-critical effort is clearly unproductive. Even within the same Institute, there is duplication of effort. In IIT, Madras, the Heat Engine Laboratory is developing a flat plate collector for a solar refrigeration system right from the beginning when the know-how is already available in its own Mechanical Engineering Department. Research Coordination is poor and this is a major constraint in our developmental efforts.

Sometimes, Government policy can be an inhibiting factor. For example, if a manufacturer wants to import materials that enhance the efficiency of devices such as copper tubes or electro-deposited selective coatings on nickel foil or tough plastic film that can be used instead of fragile glass glazing, he has to pay an import duty of 300 per cent, whereas a whole system can be imported at a concessional duty of 60 per cent. Such inconsistency in policy can be a constraint, to the development of endogenous capability.

6. Public Policy Options

In the eighties, the Government of India has initiated a number of specific policies in the promotion and development of renewable energy. These policies provide a macro-setting that needs to be reviewed.

(i) Fiscal Policies are a major instrument now for the development of renewable energy. Two years back, Central Excise Duty on solar water heaters was abolished. Many states have removed or lowered the sales tax on solar devices. In the 1983-84 budget, the Government has allowed 100 per cent depreciation as a write off in the first year of purchase as well as an investment allowance of 35 per cent for renewable energy equipment which can be deducted from profits before tax. The Gujarat government gives 50 per cent of the cost as subsidy to the purchasers of solar coolers. The Tamilnadu government gives 10 per cent investment subsidy for the manufacturers of solar devices. Cheaper (under differential rate, backward area, small scale industry schemes) credit is also available. Raw material supply is also made to solar manufacturers on a priority basis.

(ii) The Government has not used many regulatory instruments (standard setting for products, prohibition of non-renewable energy for certain users, locational or technological choice etc.) in the promotion of renewable energy. Positive instruments as well as negative instruments may be needed. For example, assembly testing and systems manufacture can be reserved for small scale sector (local entrepreneurs). Similarly, production of components can be reserved only for large scale manufacture.

(iii) Public expenditure is the most important policy instrument Government has in the promotion of renewable energy. The Government practically finances all the Research, Development and Demonstration efforts. A large public sector presence is therefore necessary. Even a few public sector enterprises manufacturing components on a large scale may be needed.

There are several institutes and research laboratories working in renewable energy. Coordination among them is vital. CASE, as the lead agency funding these efforts, must have a clearly laid down technology development policy and encourage complementary and cumulative efforts. The present practice of supporting a large number of subcritical R & D efforts is wasteful. A few, large "centres fo excellence" are needed. State level agencies like Gujarat Energy Development Agency, Karnataka State Council on Science and Technology, Andhra Department of Energy and Environment are very critical. Inter-organizational collaboration can be managed effectively through funding policies. Voluntary organizations' efforts can also be coordinated through funding. New institutions like Energy Cooperatives and Development Associations, trusts working for the common good in renewable energy, with local roots should be encouraged. The present funding or public expenditure policy seems skewed as it encourages primarily RDD. The other institutional links in the innovation chain have been ignored. This situation must be corrected. Institutional Development, thus, is an important policy instrument. Orchestrated development of R & D, design and consultancy, equipment manufacturing, energy generation, and users and professionals' organizations is vital.

(iv) Import of technology and foreign collaboration are important policy instruments. It is useful to import technology for large scale component manufacture and thus leap-frog several stages. In photo-voltaic cells, for example, this seems necessary. We do not need to start from the beginning. Similarly, joint ventures may also be allowed in selected areas.

(v) Public expenditure can promote systematically information service, extension programmes, R & D projects, education, training, and awareness through the media.

(vi) One key requirement for renewable energy development is the setting up of an energy planning system that links energy planning with development planning efforts. Presently, renewable policy is focussed only on RDD in the hope that more RDD will lead to its widespread use. This will not necessarily happen unless the other linkages are also planned and resources allocated. Hopefully, the Energy Advisory Board of the Government of India and the Department of Non Conventional Energy Sources will address this important problem.

(vii) Another important task is the development of manpower at all levels (R & D, education, managerial, maintenance, use etc.). Tables 9 and 10 indicate the education and skills needed at various levels.

7. The Political Economy of Renewable Energy Development

We began with the analysis that renewable energy is both physical (technological, spatial) as well as social. Thus both physical reality and social structure (the organization of production and distribution in our society) are renewable energy forming and renewable energy contingent. Understanding of this mutuality of relationships is very crucial for renewable energy development.

The strategies that one would advocate for renewable energy development depend on the perspective one has. Renewable energy strategy making is not an objective exercise, based on empirical evidence. If one formulates the energy problem as a supply problem, then one would advocate supply enhancement solutions (e.g. more social forestry). If one sees the problem as a demand management problem, then pricing policy, tax policy, energy audit, conservation etc. may be advocated. If one has a technological perspective, then more RDD, design of fuel efficient

TABLE 9

Components and skills for Renewable Energy Development

Type	Components	Skills needed
1. Direct Solar Energy		
a) Hot air drying	Collector, drier reservoir	Sheet metal work Mech. Engg. Chemistry Glass work
b) Distillation	Tray with polluted water condensing glass, reservoir	" "
c) Water heating	Collector, water circuit hot & cold water tanks	" "
d) Solar coolers	Collector, concentration screens, energy storehouse food reservoir	" "
e) Solar Refrigeration	Collector, Heat Exchanger, Refrigeration Chamber	" and boiler making
f) Solar Electricity	Photocells or gas expanders Turbine, Generator, Pump.	High purity chemistry Precision mechanism.
2. Wind mills (Pumping)	Rotor, transmission, Pump	Mech. Engg., casting, machining, Ball bearing,
3. Firewood and Charcoal		Mech. Engg.
4. Biogas Digesters	Intake, Digestion chambers, Gas outlets, measurement & analysis Equipment.	Boiler making, Electrical and mech. Engg.

Source: UN Conference on New & Renewable Energy 1981.

TABLE 10

Education and Training in Renewable Energy

Category	Typical background	Information and training Requirements	Proposed mechanism	Institution
1. Government Policy makers	Social Sciences	Role of Energy in the Development Process : Potential direct and indirect contributions of Renewable Energy to Development	Short courses Workshops	Educational Institutes R & D Centres
2. Energy Planners	Social Sciences Technology	Contribution of Renewable Energy in overall energy needs : assessment of energy supply and use, including decentralised and non-commercial sources.	Short and medium courses	- do -
3. Professionals and Scientists	Scientific or other speciali-sation	Detailed state of the art reviews, technologies, tools, products R & D needs and results.	Medium and long courses	- do -
4. Teachers and Trainers	Scientific and educational	Variable according to type and role of participants (e.g. extension service workers, elementary teachers)	- do -	- do -
5. Technicians and skilled workers	Technical School and experience on the job	Training related to a specific renewable energy technology	Short courses with practical experience	Local centres or mobile units
6. Central Public	Basic Education	Opportunities, Constraints, linkages and simple techniques for using Renewable Energy	Mass approaches through media and use of voluntary organisations to reach special groups	Media, local groups, basic educations system.

Source: United Nations Conference on New and Renewable Energy, 1981.

equipments etc. would be championed. Presently, the Government policy is largely technological, as policy making is dominated by scientists, engineers and academics. As other aspects of policy are neglected, we have a lot of R & D which may not benefit the poor. Public participation in R & D choice or resource allocation is, presently minimal. Therefore, context and commitment are far less important than they should be. If only the technology is sought to be changed (technological determinism) without corresponding changes in the social organization or production and distribution, (as seems to be happening now) renewable energy development cannot meet the objectives of development.

Energy is a basic human need. It cannot become a source of profit. While the efficiency of the market is desirable in some aspects of renewable energy development, it cannot be the sole basis for developing a structure. Market, the state and the community - all three of them should play important and balanced roles in the development of renewable energy. This balance is not articulated now and it is the most important strategic question for India. Renewable energy development, thus, must be focussed on meeting the basic need of urban and rural households, particularly, those of the poor.

Finally, in analysing the political economy of energy, we must recall that more renewable energy does not necessarily mean a higher quality of life. There are enough examples to show that with the same amount of energy consumption, one can have different levels of GNP or quality of life. How renewable energy is owned, controlled, developed, produced, distributed and used will determine its impact on quality of life.

8. Strategies for Renewable Energy Development

(i) A mix of comprehensive policy instruments that address a whole range of national objectives is called for as outlined in section 7 of this paper. This package is yet to emerge in India. Such a package in consonance with development goals at different levels can lead to meaningful energy planning and implementation at local level.

(ii) Development objectives are usually in conflict. Decentralization is opposed to scale economies (and hence centralization). Reliance on pricing mechanism alone will externalise social costs. (e.g. environmental degradation). Public participation may be in conflict with efficient decision making by bureaucrats or managers. These conflicts are important to recognise and ought to be faced.

(iii) Building endogenous capacity is an important strategy. Creation of awareness and education at all levels are thus critical. Public expenditure in providing education is likely to be critical.

9. Conclusion

The development of renewable energy in India is not simply a technological question. The macro-analysis attempted here reviews the complexity, interdependence and the structural-systemic features of the renewable energy system and its embeddedness in larger contexts. The need for a comprehensive policy package that addresses need and supply, technology and institutions, environment and education, pricing and substitution and local conditions and standards is thus necessary but is yet to evolve. The political economy of renewable energy indicates that technological and social actions are simulataneously called for. The market, the state and the community must play balanced roles and articulation of this balance in renewable energy is a strategic question for India. The macro-analysis shows the need for structural adjustments (in terms of changes in mix of economic activities) and hence changes in energy intensity and growth rate. Technological responses like development of energy efficient and renewable energy using equipment or interfuel substitution are not sufficient to promote renewable energy use. Hence a micro or project approach is not enough in renewable energy planning. A macro-analysis may help us to understand and possibly transcend the structural barriers. This paper explores some dimensions of this complex issue of renewable energy development and proposes some strategies.

References

1) Maheswar Dayal (1982) Inagural speech delivered in the Seminar on Industrial Applications in Solar Energy. Anna University, Madras.

2) The Hindu (1983) Why poor use of Solar Energy? Madras, June 9.

3) A.A. Samuel and M.K. Ramaswamy (1982) Solar Energy in Industries: A Case Study. Madras : College of Engineering, Guindy, (Mech. Engg. deptt.)

4) Ashok Subramanian and U.K. Srivastava (1981) New and Renewable Energy Projects : From Policy to Action. Ahmedabad : Indian Institute of Management, Working paper 393.

5) A. Viswanathan (1982) Solar Water heating systems. Unpublished paper, Hyderabad : BHEL Corporate R & D Division (Unpublished)

6) World Bank (1981). Mobilising Renewable Energy Technology in Developing Countries : Strengthening local capabilities and Research. Washington D.C.