Ecologically Sound Energy Planning Strategies for Sustainable Development (IISc)

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Abstract :

Energy planning plays a dominant role in the development of a region. Western ghats provide a variety of ecological niches and of resources, but are under threat of deterioration due to short term perspectives and narrow sectoral approaches in planning process through indiscriminate pursuit of developmental activities. Deterioration of the fragile eco system through deforestation, soil erosion has impact both at local and at global level. This necessitates promotion of conservation activities and the application of environmentally sound technologies. The procurement of energy is also responsible in varying degrees for much of the ongoing deforestation, loss of vegetation and top soil. While energy availability is a determining factor for agricultural productivity, the traditional use of agricultural residues for energy production leads to soil impoverishment. The current inefficient energy use in various sectors is certainly responsible for detrimental impacts throughout the environment. Hence sound policy and management decisions must involve three elements: economics, environment and energy. These elements must be considered in the search for ways to improve current energy supplies. Primary energy demand can be reduced substantially, while maintaining a given level of energy services through higher end-use efficiency, higher transport and conversion efficiencies. The best hope for environmentally benign energy supplies is to tap the renewable sources like small or modest scale hydro power, distributed wind systems, solar energy etc. Finally the approach should involve improved energy planning and decision making. The need is for an integrated energy planning framework that encompasses economic, environmental and energy factors taking into consideration energy supplies (through various means), demand considerations and a detailed look at how energy is being used. Pricing, taxation, subsidies and investments are major tools that can be used judiciously to channel energy production and utilization toward cheaper and more environmentally sound options. Improvements in conventional energy systems provide only a temporary measure that will buy time to perfect the renewable energy systems needed for reliable large-scale power generation and fuel production. Need for incorporating principles of ecologically sustainable development through integrated renewable energy approach which utilises different resources such as solar heat, wind, biomass and falling water to satisfy various needs in a region are discussed in this paper.

The State of Karnataka depends mainly on hydroelectricity. Exponential growth in population coupled with mechanisation of agriculture, industrial growth and acute rainfall shortage resulted in a serious power crisis in the state in recent years. This necessitated the promotion of alternative sources of energy like solar, wind, micro hydel plants etc. About 100 to 200 MW of electricity can be generated from wind, 225 MW from potential micro hydel sites, 1000 MW from biomass process and solar energy has unlimited possibilities.

Key Words: Sustainable Development, Renewable energy, Ecologically sound energy planning, Integrated renewable energy approach, energy conservation, kilo watt hour (kwh), million units (million kwh), thermal efficiency, specific fuel consumption.

Introduction :

Energy is as important to life as food, clothing and shelter. It provides power for industry, lighting, heating (domestic purpose) and fuel for transport. Our primary needs to sustain life on earth are obtained from the sun. Since the day man invented fire, he invented also an acquired form of energy with its uses. Initially the energy requirement were met mostly from animate sources of energy and to some extent from wood. Therefore all these necessities of daily life were located within walkable distance of everyone. Gradually man learned to harness new sources of energy and use them for cooking food, making implements and for other uses like in transportation. Minor leap started after the evolution of agriculture and with the industrial revolution man's dependence on energy has increased enormously.

The history of man's emergence from the ecological niche appropriate to a medium size omnivorous mammal to his present position as the earth's dominant species is one of increasing skill in harnessing and manipulating energy at each stage of his evolution, has been marked by an extension of his ability to control the natural flows and accumulated energy resources about him.

As technology innovations proceeded at a faster pace to conquer various problems of mechanisation, energy consumption rates also started to gallop. It appears that the modern society has grown without understanding the future nature of its dependence on energy. The complex edifice of industrial civilisation, with its endless catalogue of achievement and conquest of the physical world, has so impressed people that they have failed to see the fragility some of supports received from the environment. Market economies based on value addition treated many energy resources as free resources assuming infinite availability such resources like wood, coal etc. and thus has led to generation of more energy intensive technologies. Exponential growth in population coupled with associated increased use of energy has actually led to crisis situations in resources which we are now facing.

Development has always been an increasing quest of mankind, and this has made the modern man to achieve quality of life he enjoys today. The indiscriminate pursuit of development has led to problems like depletion of natural resources, environmental degradation, wide economic disparities etc (**Ramachandra** 1993 and **Ramachandra** et al 1993). This has necessitated the thinking of "Sustainable development". The key features of sustainable energy for development are

(a) satisfying basic human needs, (b) meeting the needs of all sections of society, (c) promoting energy efficiency improvements (conservation), (d) beginning transition to renewable energy sources.

Energy strategies for sustainable development should not only be compatible with but also contribute towards development. Distribution of energy sources is to be decentralised to energy end-uses for cooking, supply of drinking water, agriculture, electrification, rural and urban industries creating employment. At present biomass or fuelwood is the most widely used alternate energy source and its use is restricted to domestic and non-commercial purposes (Ravindranath and **Ramachandra** 1991). Efficient use of bioenergy by converting biomass feed stocks into solid, liquid, gaseous and electric energy carriers, would contribute in improving the quality of life. Use of renewable would go long way in achieving the goal of sustainable development.

Energy is a complex process because it is possible to convert it into different forms, transport it, store it in some form and use it for various end-uses at innumerable number of places (**Ramachandra** et al 1992, Wilbur 1985, Mortimer 1991 and Kishore et al 1988). The three components of energy system are

(1) Generation system : Energy resources are converted into a transportable form like electric energy in centralised systems or as gas or steam in a decentralised form,

(2) Transport/Transmission system : Energy system transported from place of availability / generation to places of use.

(3) Distribution system : Distribution and use in end use activities.

In the case of decentralised systems, all these three activities may not be present. Energy resource is transported directly to place of use and used in suitable end use device.

Energy resource:

Energy resources are broadly categorised as (a) renewable and (b) depletables. The depletable resources are stored one whose availability keep on decreasing depending on their use. While, renewable sources are available every year and hence defined as a flow of energy that is not exhausted by being used. Examples of renewable are hydro-energy, solar, wind, geo-thermal, wave, tidal, biomass, energy from wastes (biogas, agrowastes, industrial wastes etc). Example of non renewable are petroleum products, coal, uranium etc. If the annual consumption of fuelwood is less than its annual production then fuelwood can also be treated renewable source of energy. Energy resources are also classified as primary or secondary ones - coal, firewood etc are being primary while electricity a secondary one. Whenever there is transformation of energy from one form to another only a part of energy input gets converted to usable output. To highlight the increased use of depletable resources of energy with increased population without much conservation efforts energy consumption patterns for Karnataka in south India are studied over a period of time (**Ramachandra** 1994, Government of Karnataka 1990). These studies reveals that how vast scope exists for introduction of conservation measures and as well as introduction of renewable sources to sustain if not speed up the overall development of the state.

Karnataka State: Location and Demography Details:

Karnataka state extends over an area of 1.92 lakh sq.kms. of the total geographical area of the country. It occupies about 5.84%. The state is situated in the West-Central part of the deccan peninsula of the Indian union and is stretched between 13^0 3' and 18^0 45' north latitudes & 74^0 12' and 78^0 40' east longitudes. Major portion of Karnataka lies in the elevation range between 450 and 900 metres above the mean sea level. With a population of 4,49,77,201 accounts for 5.4% of the country's population. For administrative purpose, the state has been divided into divisions, districts and taluks. There are 27,024 villages spread over 175 taluks. 69.07% of population resides in rural area (3,10,69,413 persons). Economy of the state is predominantly agriculture based with around 45% state domestic product being accounted by this primary sector (Government of Karnataka 1990).

1.2.1 Karnataka's Energy Scene: As Karnataka does not have any coal deposits, It gets its coal from outside. The electrical energy for Karnataka was purely hydro for a long time and only now with the commissioning of Raichur thermal power station, it gets electrical energy from coal also. The other major source of commercial energy - oil - is also not available in Karnataka. Hence the main source of commercial energy for the state is from hydroelectric plants. Karnataka state depends both on commercial and non commercial forms of energy (Government of Karnataka 1990 and Government of Karnataka 1994). Non commercial energy has a major share of 53.16%, met mainly by sources like firewood, agricultural residues, charcoal, cowdung. While commercial energy's share is only 46.84% met mainly by electricity and oil. Electricity is the major commercial energy source with a share of 55.64% of commercial energy consumed for 1990-91. Firewood consumption is around 7.44 million tons of oil equivalent, i.e. 42.99% of the overall energy consumed. Agro wastes have a 8.73% share. This demonstrates that we depend mainly on biomass to meet our rural energy needs. Sectorwise energy consumption shows that industries sector has a major share of 51.4% similar to the national scene. This is followed by transport sector (23.0%), household (11.2%), and agriculture (3.5%).

1.2.2 Electrical Energy Use in Karnataka: Since electrical energy plays a dominant role in the energy scene of Karnataka, it is being looked at in detail in this section (Government of Karnataka 1990 and Government of Karnataka 1994). Installed electrical energy capacity as on March 1993 is 3005 MW, out of which 79% is by Hydel source (2375 MW) and balance 21% is by thermal power station (630 MW). The gross energy generation from these sources for four years shows that it ranges from 12,430 - 14408 million units (million kwh). And electrical energy met from central source during these years ranges from 3061 - 3502 million units. The plant load factor for only thermal power plant at Raichur varies from 33.5% (in 1985-86) to 76.9% (in 1990-91). Transmission and Distribution losses varies from 24.6% (in 1980-81) to 19.3% in 1991-92. The losses have increased to 20.9% in 1992-93. Study of number of consumers and percentage of households electrified at five years interval for the period 1970-71 to 1990-91 shows that at the end of 1970-71 about 24.66 % households were electrified in Karnataka, and at the end of 1990-91 60.43% households are electrified. Percentage growth of consumers over a period of five year shows maximum growth of 61.69% during 1980-81 to 1985-86 period. This is followed by 40.86% growth during 1975-76 to 1980-81 period. The high percentage during 1980-81 to 1985-86 period may be attributed to the introduction of popular schemes such as Bhagya Jyothi (at least one bulb for social and economic backward categories of society).

Per capita consumption of electrical energy varies from 101.5 kwh (1971-72) to 295.4 kwh (in 1990-91). Based on districtwise Percentage of households electrified, districts can be grouped into four categories based on a range of percentage households electrified in each district. These categories are a) Category 1 - more than 90% of households are electrified, b) Category 2 - wherein more than 60% - 90% households are electrified c) Category 3 - wherein 40 - 60% households are electrified d) Category 4 - wherein households electrified is less than 40%. In Category 1, Bangalore stands alone with 92.13% of households are electrified. Category 2 consists of Belgaum (70.65%) followed by Tumkur (70.01%), Mandya (69.88%), Mysore (68.81%) and Shimoga (68.55%). Uttara Kannada (49.42%) and Dakshina Kannada Districts (49.02%) with moderate performance are in category 3. While Category 4 consists of districts such as Bellary (34.79%), Raichur (31.83%), Gulbarga (30.16%), Bidar (29.59%) and Bijapur (29.51%). Coincidentally the category 4 districts are also economically backward districts in Karnataka.

Sector wise electric energy consumption data indicates that during 1989-90, Industries sector consumes 4780 million units constitutes share of 44.86%,followed by irrigation pumpsets with a share of 28.63%. It is seen share of irrigation pumpsets is gradually increasing. 8.82% of pumpsets energised till 1991-92, is already consuming 36.26% of total electrical energy. This is followed by industries with a share of 34.34%.

A look at overall energy consumption does reveal how energy is used. The profile of connected load from 1969-70 to 1985-86 in various sectors shows that the annual increase for the year 1985-86, is greatest for Agricultural pumpsets (11.9%) followed by AEH consumers (11.86%) and LT installations (10.5%). When we look at the increase for the three years from 1980-81 to 1985-86, the connected load AEH category grows faster (57.2%) than that of LT industries (46.5%) HT industries show a small growth rate. The overall annual growth rate is only 8.9%. AEH, LT and Agricultural installation have growth rate greater than the overall growth rate. In the case of 1980-81 to 1985-86 growth rate AEH and LT industries, agricultural sector have greater increase than the overall values. The sector wise annual consumption of electrical energy in various sectors reveals that in last 20 years the total electrical energy consumption varies from 2338.5 - 12568 million units. It is seen that increase in energy consumption for agricultural pumpsets is about 30.52 times (from 149.3 to 4557 million units), domestic sector 9.7 times (150.3 to 1929 million units) and in HT industries 2.84 times (1519 to 4316 million units) in last 20 years.

A shortfall of 30 per cent in power availability versus demand exists even today. Accentuating the shortages, every month about 30,000 new installations with a peak demand of 45 MW, are being added to the system. At present there are 55,83,207 installations with a connected load of 8713.9 MW or which is almost thrice the present installed capacity. These includes 2,151 high tension installations and 7,67,991 irrigation pumpsets, with connected loads of 1,460 MW and 2,763 MW respectively. In the last two decades Karnataka faced power cuts due to vagaries of monsoon (as Karnataka mainly depends on hydel-power) ranging from 25 per cent to 80 per cent on different categories of consumers. This resulted in the lay off of industries and loss of revenue to the tune of Rs. 9000 crore. Heavy transmission and distribution losses of the order of 20-22%. A five per cent reduction in T & D losses would mean extra availability of 700 million units, which means additional revenue of Rs. 70 crores, to State Electricity Board.

Environmental impacts associated with large scale energy projects has necessitated to look at eco-friendly energy projects (Ashenayi and Ramakumar 1990). Submersion of land, rehabilitation of local people, destruction of natural gene pool, flora and fauna and desiltation problem, earth quake, spread of diseases like malaria are associated with construction of big dams of large hydel projects (e.g. Linganamakki, Kali, Kodasalli), air quality, visibility, polluted air with fly ash has led to the diseases of respiratory system in the case of thermal power station (at Raichur district in Karnataka). These has necessitated to look for alternative energy technologies and conservation measures.

Energy conservation :

Energy conservation means using energy efficiently without sacrifice, discomfort, reduction in economic activity. Energy conservation is not only cheap and clean but can also be relatively quick and easy to carry out (**Ramachandra** 1992). There are three ways to conserve energy, some involves change in attitude, others change in life style.

(a) Conservation through improved efficiency of use like,

* Use of fuel efficient cook stoves instead of traditional stoves.

Improved fuel utilization and reduced smoke emission, together are the goals of improved stoves. ASTRA Ole (improved cook stove) designed and disseminated at rural households in Karnataka by our Institute, has efficiency of 32 - 33% compared to the traditional stove efficiency of 5 - 10% (**Ramachandra** 1994).

* Improving automobile performance by good maintenance and driving at a lower or more economical speed.

* Using fluorescent rather than incandescent lights which provides better illumination in addition to saving electric power.

* Use of compact fluorescent lamps saves 75% of the energy from incandescent bulbs plus lasts 10 times longer, saving labour hours from changing bulbs as well as saving on electric bills.

* Replacing inefficient industrial equipments : In Karnataka industrial consumption of commercial energy constitutes 44% of the total (Teddy 1990-91 Subramanian et al 1985). A survey conducted on 60 industries reveals that 46.55% of total load is used for heating, machineries 47.25%, welding 1.10%, lighting 1.33% and others like street lighting etc. 3.77%. Since electrical energy is high quality energy and as it is derived form of energy, it is desirable to use it mainly for high quality of work - movements and electrolysis etc. Electrical energy need not be used for heating activities substitution of lower quality energy is desirable in all the industries for heating purposes. Such a substitution will not only match source with end-uses, but also increase efficiency of use.

Study conducted on the energy efficiency of some end-use devices in an Electro metallurgical industry at Bangalore city reveals great scope for conservation by improving the maintenance, educating workers about the energy losses and replacement of inefficient end use equipments.

(b) Conservation by alternatives : For e.g. use of unburnt compacted dense soil blocks in place of burnt bricks. At present brick is manufactured in kilns or traditional clamps using firewood and the efficiency is very poor. Study conducted on utilisation of firewood for brick manufacture shows wide disparities ranging from consumption of 167 kg firewood per 1000 bricks to 700 kg firewood. Improved kiln/clamp with improved drying process saves fuelwood (Kishore and Bansal 1988). Compaction of soil to make blocks saves fuel wood completely and generate employment for rural areas.

* Walking or cycling instead of driving.

* Modernising inefficient industrial process.

* Incorporation of frictionless foot-valves and HDPE piping for irrigation pumpsets.

(c) Conservation by change

* Using public transport instead of private vehicles.

* Use of LPG instead of electricity or kerosene for cooking in urban households

* Using the sun and wind to dry washing instead of tumble dryer.

* Replacement of electric water heater by solar water heater at home.

There are many barriers which prevent the achievement of more efficient pattern of energy consumption :

(a) lack of capital for financing energy efficient projects.

(b) lack of information and technical expertise about energy conservation opportunities.

(c) cooperation of large number of consumers and decision makers.

Renewable Energy Sources :

Renewable energy is a flow of energy, that is not exhausted by being used. The primary renewable energy source on earth is solar radiation. The total flow of solar energy through earth's natural system is some 10,000 times greater than the present flow of energy through man's machines. Even the one per cent of the solar influx that generates the great atmospheric pressure systems which drive the winds, and which in turn generates the waves, in some 180 times as large as man's rate of energy use. And though, on the average, the photosynthetic process is less than 0.2 per cent efficient, even photosynthetic production creates 10 times as much energy as man uses.

The flow of solar and solar derived energy forms is not independent from the activities of man. The radiation fluxes are modified by changing the reflectivity of earth surface, examples by urbanisation, agricultural practices, deforestation. Man's activity also change wind patterns and modify cloud coverage. Injection of pollution in to the environment, removal of forest cover as well as man made structural changes, influences both radiation, heat and water flows (Carlsmith et al 1990 and Fulkerson et al 1989).

Solar Energy Conversion Modes

Solar energy is captured by being converted to other forms of energy by (a) chemical reaction (b) thermal excitation (c) photovoltaic effect. Solar energy is chemically converted into energy through photosynthesis. This directly produces food and wood. Simple thermal conversion devices, such as flat plate collectors, are suitable mainly for providing low energy, high entropy heat to systems of the same nature. The flat plate collector can deliver temperature up to approximately 100 C. The direct conversion of sunlight to electricity by means of solar cells is the photovoltaic effect. The solar cell use energetic photons of the incident solar radiation, converting solar energy into electricity.

Some advantages of photovoltaic devices are,

(a) no inherent life time limit, (b) efficiencies are independent of size, (c) modular (d) compatible to all environments, (e) fairly constant voltage independent of sunlight intensity, (f) relatively low maintenance, (g) low operating and maintenance costs, (h) simplicity, (i) no cooling water required.

Potential areas of commercialisation of solar photovoltaics are (a) domestic lighting (b) community lighting (street lighting) (c) health care (d) telecommunication (e) water pumping (f) entertainment gadgets like television, radio etc. Solar photovoltaics alone cannot successfully cater to the energy requirements without a very high efficiency balance of system design. The choice of balance of equipments may be carefully made. Another major requirement is the storage of energy wherein batteries of low maintenance and high recycling capacities are to be used. However, some disadvantages are: (a) Theoretical efficiency of about 25% combined with low energy intensity of sunlight requires a relatively large collector. (b) economically not competitive with other sources and (c) requirement of DC to AC inversion equipment to supply AC loads

Solar Water Heating

Solar energy for daily use in households is already a popular concept. For the present they are virtually confined to heating water, more than 600 homes in Bangalore city are already using this system, thereby doing with geysers (Fulkerson et al 1989). Solar water heating system is a simple device, works on the principle of black body radiation and green house effect. It generally involves use of flat plate collectors, storage tank, circulation system and appropriate controls and accessories. Solar water heaters can be broadly classified as (a) Thermosyphon or natural circulation, (b) forced circulation system. Usually thermosyphon units are used for domestic application (for capacity of 300 litres) and forced circulation is used in the case of industrial and commercial applications.

Industrial and Commercial Systems

Normally forced circulation system is used for this purpose. A pump is used for circulating water through the collector system and a thermostat is used to control temperature. The fixed temperature controller and differential temperature controller are the two types of controlling the flow of water in the system. In the case of fixed controller system the system will deliver hot water at constant temperature, but the quantity of hot water delivered depends upon the level of solar insolation and ambient conditions in the differential temperature controller fixed quantity of hot water is delivered at varying temperature depending upon the solar installations.

Domestic Water Heating

Thermosiphon systems are generally used from the ease of operation and maintenance point of view. For proper functioning it is necessary to have least amount of resistance in the Thermosiphon path and proper cold water supply. An automatic electric back up system is incorporated in some cases to ensure hot water availability throughout the year. Storage tanks are largely double walled, insulated systems with a variety of materials of construction in use ranging from metals like MS/GI, aluminum and copper to certain plastic materials like HDPE, Polypropylene, etc.

It is the flat plate collector - the heart of the system where a wide range of material and design choices are available now. The basic absorber could be galvanized steel, aluminum or copper and both flat black paint or selective coatings are available options. The glazing could be plain window glass, toughened glass or acrylic. Saw dust, cork etc are occasionally used for insulation. Majority of the commercially available collectors use mineral wool, glass wool or even polyurethane foam for bottom insulation. While wooden boxes are once again employed in some instances to contain insulation absorber etc. Metals like steel and aluminum as well as reinforced plastic are more frequently employed.

Present Status in Karnataka

The total number of industrial and commercial systems installed in the state is around 150 in the range 1000 litres per day (35 systems), 1000 to 5000 LPD (72 systems), 10000 LPD (10 systems). Assuming that the system is used effectively for 225 days in a year the amount of equivalent electrical energy saved annually is 6 million units. In

Bangalore city alone 4.2 lakh All Electric Houses (AEH) consume electricity for water heating. The amount of electrical energy that can be saved by installing solar water heaters is approximately 1.8 million units. The generation capacity required to meet their demand is 250 MW which will cost the state Rs. 380 crores. But for installing the solar heating to All Electric Homes (AEH) in Bangalore city would cost Rs. 250 crores.

The cost of domestic water heater is between Rs. 8000 and Rs. 10000. Government of India provides a subsidy of Rs. 3000 to each person who goes for it. Solar heaters save about 50 to 75 kwh of energy per month per household. By educating people about solar energy through mass media substantial saving in electric energy and fuelwood could be achieved. The reason for low level market penetration are (a) high capital cost of the system (b) inadequate fund for disbursement of subsidy (c) absence of attractive financial package for buyers and (d) lack of awareness of the technology.

Technical Issue

Technical snags encountered in solar heater are ;

(a) corrosion of various forms has been a nagging problem as efforts have been made to use MS and aluminum with raw water. Use of galvanizing has been resorted to in case of steel absorbers and performance has been reasonably satisfactory, problems in certain localized areas still persist. Use of copper overcomes this problem but shoots up the cost.

(b) Formation of scales in absorbers due to direct use of raw water inhibits flow and increases resistance to heat transfer. The problems is more severe where thin and narrow passages are employed. A scale thickness of 1.22 mm in a 15 mm G.I.Pipe would decrease the collector efficiency by about 1 to 2%, (c) Failure and very poor reliability of the control hardware in the case of forced flow system like (i) A simple thermostat changes calibration over time. Capillary thermostat would provide better performance and reliable operation but are quite expensive (ii) problem with solenoid valve and at times level controllers.

Inadequate attention to controls and their maintenance, compromise made with selection of materials and processing of materials (to bring down initial costs) would severely hamper the commercialisation of solar water heaters.

Wind Energy

Wind energy is an indirect form of solar energy. About 1% of the total solar radiation that reaches earth is converted into wind energy. Wind results from the differential heating of the earth and its atmosphere by the sun. Although wind occurs universally, it is intermittent and its strength and reliability varies from one location to another. At ground level where winds are easiest to use, coastal and hill country often have stronger winds than flat inland areas. Wind energy is renewable and poses no environmental threat, particularly in windy locations. The characteristics are (a) variability in locations (b) location and site specificity (c) lower T and D losses in case of wind farms (d) relatively high initial capital costs, compared to thermal power stations (e) zero fuel costs (f) low gestation period provides quicker benefits.

The most important uses for wind energy are :

- pumping water, compressed air generation

- generation of electricity

- as a prime mover for mechanical machines

Wind Energy Systems

Based on applications, are broadly classified as (a) direct shaft power system (b) hybrid or autonomous system (c) wind farms.

Wind turbines converts kinetic energy of the wind to mechanical power. This may be used to pump water or drive electric generators or be converted to chemical energy for storage in batteries. Vertical axis wind turbines and the horizontal axis types are two basic technologies employed for converting wind to useful energy. In Karnataka 0.55 wind farm is installed at Talacauvery. Wind pumps of horizontal axis type are working in Karnataka (42 numbers disseminated by KSCST for pumping water etc.).

Economic Aspects

From the economical point of view and the functional efficiency the water pumping wind mill has proven to be more advantageous compared to the diesel pumps considering the free running cost of wind mill where as in the case of diesel pumps recurring expenditure is incurred in terms of fuel and regular maintenance. It is found that the usage of wind energy for pumping water (each machine) saves about 150 litres of diesel and annual saving of 1800 litres. Therefore the large scale use of wind mills for irrigation and drinking purpose could save large quantity of depletable sources of energy like diesel. Because of economic viability and trouble free performance wind energy exploitation for pumping is gaining momentum in the regions where the wind velocity is favourable.

Waste/Residue Based Energy

We generate a lot of waste like cattle dung, human wastes, plant, fruit, vegetable wastes, factory wastes, agricultural residues; Biogas plants convert many organic wastes into methane gas which can be used as a energy source. The gas can be used to run duel fuel engines, to provide lighting, to cook food and to heat small furnaces. Agricultural residues can be improved in quality by bricketting and pyrolysis and used as an energy source (Subramanian 1984).

Hydro Electric Power and Energy

Flowing water has been one of the earliest sources of energy. Water mills grind grains and can run a generator. Many water mills were in operation centuries ago. Later, the potential energy was tapped to run turbines and generate power. Initially, small hydroelectric projects were set up. Since many of these projects were in mountainous terrains, the operation of these plants depended on the availability of water. Normally, the availability of water depend on rainfall. During rainy seasons. there is more water available and during the other seasons the quantity was less. In order to even out power generation throughout the year, dams were constructed and reservoirs impounded the water. This led to major hydroelectric projects like Sharavathy. These reservoirs submerged prime forest lands thereby adding to the deforestation effect.

Hydro electric plants can be categorized as follows:

(i) run of the river plants

(ii) weekly pondage schemes

(iii) monthly reservoir based schemes

(iv) seasonal plants

(v) carry over reservoir schemes

(vi) micro and mini plants

(vii) major plants

These are explained below :

(i) Run of the river plants: Rivers have a flow of water. Initially hydroelectric projects have been set up to tap the energy from the flow and convert it into electricity. Run of the river plants need minimal construction, and submerge least area. Normally a small barrage is built and if there is a local head, it is exploited. Such plants can be put up in canals also. Many plants can be put up in a river. These plants normally are of small capacities and they do not need any storage area for reservoirs. They are ecologically sound. China has tapped its river water's energy potential through a series of such plants. We have a large potential for such run of the river/streams/canal schemes. Even though these plants are seasonal, a well developed grid can absorb the seasonality through a proper load generation balance with appropriate thermal generation scheduling.

(ii) Weekly and monthly pondage schemes: Whenever a large or medium head of water is available, and water can be stored in a pond or small reservoir, we can go for these schemes. Depending on the capacity of a pond, we can store water equal to a week's energy or a month's energy and the scheme is appropriately called. Such schemes handle minor variation in the flow in a river and can supply stable power reducing the fluctuations that may occur in a strict run of the river plant. There is a requirement for some area to be submerged. But this is much smaller.

(iii) Seasonal plants: We have many irrigation projects in which water flow is regulated to meet the needs of irrigation. There may not be any water in the reservoir during the lean season. In this case we can have a seasonal plant which works only when there is water flow and is shut down during the other periods. For example the Mettur tunnel scheme works for 4 months in a year and is closed down for the remaining 8 months.

Seasonal plants submerge less areas. Thereby, they are also ecologically sound. These are the best type of plants in many of our river valley schemes in forest areas. For example, let us consider the Bedthi hydro electric project in Uttara Kannada District, Karnataka state. If we put up a seasonal plant, then the plant will generate a large quantum of power and energy during monsoon and minimum during the lean period. Hence the reservoir area required will be less. We can find the ratio of reservoir area as:

reservoir area for annual scheme k + 2

------------------------ = -------

reservoir area for seasonal scheme 3

(k is the ratio of power generated in monsoon to power generated in lean period), For large k, the seasonal scheme needs very much less area for submergence. If we also consider the fact that the area also produces biomass and consider it as another energy form, and we try to get maximum energy; we will reduce the submerged area still further. It may even be possible to construct a mixed hydro-thermal plant Our analyses of Bedthi hydroelectric project shows that with hydro thermal combination, and having seasonal plant the energy generated is almost twice that of year round storage plants. Earlier proposal of Bedthi hydro project is supposed to submerge 95.03 sq.km of land and generate 850 million units of electricity. Our calculation shows that by going in for run of river scheme- seasonal plants land submerged is about 5.7 sq.km. (to have two days storage) and generate same amount of electricity. And balance of 89 sq.km. hence saved can cater the fuelwood need of the region. At 6.5t/ha/yr biomass productivity, thermal energy available is about 319 million units, while the fuelwood requirement in this region is about 312 million units. Thus by this integrated approach one can meet the fuelwood requirement for domestic cooking and water heating and as well as generate electricity through hydel source.

(v) Carry over reservoir schemes: We get more rain in some years and less in some other years. If we want to store and carry over the surplus water to the next year so that the energy is not wasted, we will be designing a carry over scheme. Since this scheme needs a larger sumbergence area and since most of the area will be dry during low rainfall years, leading to higher siltation rates, thus scheme is not desirable.

So far we looked at the classification based on the type of storage of water and use of energy. Let us now look at the classification based on size.

(vi) Micro and mini hydel plants: There are a large number of streams, canals and rivulets with drops at many places. Today new technologies are available for the construction of water turbines for a small head of 2 - 3 metres. Hence it is possible to set up a large number of small plants. These are known as micro and mini plants because of their capacity. Plants with capacities upto 500 kw are called micro hydel plants and with capacities upto 50 MW as mini hydel plants. Micro hydel plants do not need any submergence, can be installed any where; (we can install a micro hydel plant in a multi storied building to use the head of water flowing from an overhead tank to flats at lower levels); costs are coming down. Hence it is desirable to allow people to put up these plants wherever possible. We should encourage setting up of many thousands of such plants in our state. China has installed lakhs of such plants. This also helps in starting rural services and industries due to the availability of electric power and energy. Power supply reliability also will improve dramatically. Cost of an installed KVA today is around 40000-50000 rupees for major projects (including transmission system) and the corresponding costs for micro and mini hydel plants will be lower around 20000 to 30000 rupees. One of the main reasons for going in for large plants was economy of scale. But with increased costs of construction of reservoirs, the economics of scale is not working. A second reason was grid operation. Operating a grid with a large number of small plants was difficult leading to frequent unstable conditions. But electronic controllers available today can solve this problem. Technically, it is now feasible to use computer control techniques to operate a grid containing a large / very large number of microhydel/mini hydel plants.

(vii) Major plants: Hydro electric projects generating power in the range of 100 MW and above are classified as major plants. They submerge large areas, store a lot of water leading to evaporation losses, deforest a large area leading to higher siltation rates. They also uproot a large number of people. In the present context, it is difficult to implement such projects. It is desirable to convert them into seasonal ones so as to tap the energy with minimal losses all around.

Energy Planning :

Currently, energy planning in our country is not an integrated activity. Since there are many energy sources and end uses, there are many organisations and agencies that deal with different aspects of energy. The plans for electricity, coal, oil and fuelwood are done by respective organisations mainly based on the projection of energy demand. The primary goal of this approach is to go in for energy supply expansions on the assumption that there is a correlation between energy use and gross domestic product. With this approach energy becomes an end in itself, and the focus shifts on meeting increased energy consumption through energy supply expansion alone. This supply and demand based planning approach for each individual energy form has resulted in problems like more losses, more conversions and low efficiencies. This is evident from the disappearance of forests, village wood lots, roadside trees, construction of giant hydro electric dams, fossil fuel based power plants and controversial nuclear plants. This conflict between the energy demand and environmental quality goals can be solved by having an integrated approach to the problem of energy planning with a view to minimise consumption of non renewable resources of energy and maximise efficiency of energy usage and harnessing of renewable sources of energy in an ecologically sound way. Another aspect that has to be considered in the planning process is that of matching energy resources and end uses. Because of convenience, current usage of high quality energy such as electricity used for low quality activities like bath water heating is to be discouraged. Hence, strategies for integrated energy planning should include a) Improvements in efficiencies of end use devices and/or conversion equipments, b) optimising energy source - enduse matching, c) organised approach towards optimal use of renewable resources, d) proper exploitation of biomass energy resources and e) discourage use of depletable resources (by penalising).

Our earlier studies shows that there is vast scope for energy conservation in energy sectors. Highlights of some of our earlier studies are

1) Domestic sector in rural areas shows that there is scope for saving of 42% in the quantity of fuelwood used by switching over from traditional stoves to improved stoves (**Ramachandra** 1994, **Ramachandra** 1992, Subramanian et al 1983, and Subramanian 1984).

2) Study of energy efficiencies of end use devices in an Electro metallurgical industries (**Ramachandra** and Subramanian 1992) have shown that the efficiency of welding sets is about 14%, Furnace 10.4%, Diesel generators 36.5%, Electro plating process 36.5%. This shows possible saving in industries sector by switching over to transformer-rectifier welding sets with micro processor based numeric controller from conventional motor generator welding sets. Motors and drives consume a large percentage of the electrical energy used in the industrial sector. High efficiency motors (85.5 - 95% efficiency) currently available in the market are now competitive with the conventional type of motors, considering the cost of motor losses.

3) Energy analyses carried out for food processing sector revealed that most of industries are utilising less than 50% of installed production capacity (**Ramachandra** and Subramanian 1993). Low power factor when motor is under loaded, leads to inefficiency. It is estimated that 23 to 38% energy could be saved at improved efficiency due to full utilisation of installed production capacity.

4) usage of solar water heater, for bathing water heating could bring down electricity consumption in urban area and fuelwood consumption in rural areas.

5) harnessing hydel potential in ecologically sound way by means of mini/micro/small and hydro+thermal (as against major dams) potential in hilly districts. It is estimated that about 2250 million units per year could be generated in Bedthi and Aghnashini river catchment alone in Uttara Kannada district

6) harnessing solar energy in coastal regions. Our estimate shows that in coastal taluks like Kumta, Karwar, Honnavar, Bhatkal in Uttara Kannada District of Karnataka state that there is potential of 5.5 kwh/m^2 (based on mean daily insolation).

7) Our study of energy utilisation in Industries sector shows that, about 27.72% energy could be saved in Industries sector. Which means about 1541 million units of electricity could be saved (as per electricity statistics Industries sector in Karnataka has consumed about 5560 million units during 1991-92). This saved electricity is equivalent to electricity output of 300 MW installed capacity of generating stations. Environmental problems associated with mega projects, the increasing demand of states/ country and resource depletion make it increasingly imperative that our planners divert their attention towards improving efficiency in all sectors. This illustrates that, there is ample scope to conserve energy in industries sector.

The advanced technologies discussed below promise significant reductions in energy use, implementing these may be less costlier compared to generating electricity through supply expansions taking into consideration environmental costs associated with new installations.

(i) Proper maintenance of electric motors in textile industries brings down energy consumption considerably; about 3% of power consumption can be saved by improved maintenance. This also reduced repairs as shown by the fact that burnout of motors varies in frequency from one in three months / 10,000 spindles to 8 - 20 in three months / 10,000 spindles. The increase is 8 - 20 fold in the second case. Similarly burnout frequency varies from 1 - 7 to 60 for six months for 25,000 spindles.

(ii) Waste heat recovery in boilers can reduce energy use by about 10%. It is shown that the payback period is a few months.

(iii) Use of polyester cotton tapes etc. in textile mills will reduce consumption by about 10%.

(iv) Replacement of old boilers with high efficiency boilers and introduction of turbines and generators can reduce total energy requirements by more than 20 - 30%.

(v) Spindle speed is an important factor in energy consumption in textile industries. Proper speed can reduce energy use. In the survey the energy consumption varies from 60% to 165% (with the base of 100 chosen for one mill). This shows that proper speeds can reduce consumption.

(vi) Advanced processes in the steel industry are mostly major process changes that could revolutionalise the Iron and Steel sector (Carlsmith et al 1990). The plassmelt method involves smelting partially reduced iron powder with pulverised coal by using heat supplied by a plasma system. ore to powder steel making could reduce the energy consumed by 40 percent. Direct steel making could double or triple production rates compared to the blast furnace and offer a 30% reduction in energy savings. The energy required to produce steel from scrap is less than one-half that required to produce steel from raw materials. However scrap contain residual elements that have adverse effects on the properties of the steel. The electric arc furnace is well established technology and because of its increasing market share, improvements such as scrap pre heating, DC arc furnace, induction melting, heat and dust recovery and ladle refining are to be researched.

(vii) Conventional chemical pulping in the paper industry is dominated by the very energy intensive kraft process. The energy required to recycle paper is about one-half that required by the kraft process. Desired improvements in the recycle process concentrate on improving the process to remove color and filler. Improvements in the paper making process focus on improved process control, process physics, and improved materials. These improvements would have a substantial effect on decreasing energy consumption. Bio pulping, chemical pulping with fermentation, and ethanol organosol pulping are the most recent promising advanced processes involve integration of at least one fermentation process with a conventional pulping process.

(viii) Carbothermic reduction of Aluminum ore or alumina has the potential for substantial energy savings. Aluminum trichloride electrolysis allows for more production per unit cell volume. The permanent anode design would decrease the frequency of anode replacements and the wetted cathode might enable a reduction in the distance between the electrodes associated with a high voltage loss without a loss in current efficiency.

(ix) Catalysts are used in many industries to produce chemical reactions at a lower pressure and temperature, thereby using less efficiency. Better understanding of the basic mechanisms of catalysts may lead to new classes of catalysts. These could be beneficial in the areas of one-step conversion of methane to methanol, photocatalytic reduction of water, combustion enhancement, and pollution control (Fulkerson et al 1989).

(x) Recovery and reuse of waste heat offers significant opportunities for energy conservation. The development of cost effective heat exchanger and thermal storage units is needed for the recovery of high temperature reject heat. The development of high lift heat pumps could greatly enhance the utility of low grade waste heat.

(xi) Cogeneration is the simultaneous production of process heat and electric power. Providing moderate or low temperature heat as a by product of the work from a heat engine is much more efficient than providing heat directly by burning fuel. Most typical Cogeneration industry converts only 10 to 15% of the energy into electricity (Williams 1978). Intercooled Steam injected gas turbine - a new technology is being developed which incorporates a modern aircraft engine and can accommodate variable amounts of steam returned to the turbine combustor and therefore has a flexible electricity-heat ratio (Ross 1989). Steam not returned to the turbine is used for process heat. With a full steam injection, 40% of the energy can be converted into electricity.

(xii) Variable speed controls for motors are currently available for application on existing and new equipment to adjust the speed control so that the motor and driven equipment can match the requirement of the process. Motors account for about 55% of the electric energy consumed in Karnataka State. The potential for conserving energy by applying high temperature superconductors in place of conventional conductors in industrial motors is very large. The advantages include reduce volume and mass, higher power density, enhanced performance and improved operating efficiency.

(xiii) Industrial separation processes involving separation of the components in a mixture are highly energy intensive. Advancement of alternative processes such as membrane separation, solvent extraction, critical fluid extraction and advanced drying concepts are less energy intensive. This could be beneficial to applications like black liquor concentration in the paper and pulp industry, hot food processing waste water concentration, dilute soluble food process stream concentration and drying of products such as textiles and paper (Dale 1991).

Integrated Renewable Energy Concepts :

Integrated renewable energy systems utilise several manifestations of solar energy such as solar heat, solar radiation, wind, biomass and falling water to satisfy various needs in tandeum. Such a system will

(a) Satisfy basic needs : provide continuous energy supply of the type which will be most inappropriate and cost effective in relation to specific application.

(b) Renewable, sustainable and available in the immediate environment

(c) require minimum handling, transport and transmission

(d) protect and improve the environment and shift the emphasis from the much abused standard of living to the quality of life.

(e) transfer benefits including employment in the immediate environment rather than in the faraway places as in the case of centralised systems.

(f) establish a symbiotic relationship among man, environment, resources and technologies.

The organisation of such independent, self contained, integrated energy systems will depend upon accessibility to potential technological intervention possible in a given socio-economic situations at the micro level. The extent to which energy transformation and quality upgradation should be attempted to satisfy energy needs within the framework of socio-economic, ecological parameters must be established. Depending upon the economic method of performing various tasks, the needs of the community for thermal, mechanical and electrical energy are assessed. For most applications there are two or more possibilities of energy supply - solar, fuelwood and biogas for cooking;

biogas and electricity for lighting; mechanical power for irrigation and wind mills or biogas engine for other needs. Subramanian and Chetty, (1983) have adopted linear programming approach by restricting themselves to the cooking and lighting needs of a village in the arid zone of Karnataka. The implementation of the cost minimization linear programming model shows that the cost of some of the alternative options for meeting the cooking and lighting needs can be as low as one-sixth of the present expenditures. Some of the important findings are :

(1) the biogas route is an optimal route for lighting and cooking,

(2) the cost minimisation model allocates grid electricity lag behind the biogas- engine - generator electricity route.

(3) firewood stoves become part of the cooking solution only when the cost of firewood is reduced and stove efficiency is increases at low stove efficiencies firewood cook stoves do not find the solution.

Obviously the design result depend on the technologies and their effectiveness and on the cost of devices, all of which are in the state of dynamic change.

The important goals of an energy planning activity for a region is summarised as follows:

(i) Instead of generating more energy, we should start with conserving energy. Today the cost of conservation of energy equivalent to one KVA is less than the cost of generation of similar quanta. Some examples are : (a) industries can easily save up to 10% of their consumption with good house keeping practices. (b) use of energy efficient bulbs for lighting instead of incandescent bulbs will reduce power requirement in Karnataka by 200 MW or more. (c) use of efficient irrigation pumpsets will reduce power and energy requirements by 20%.

(ii) We should match the quality of resource with the quality of end use. Electricity need not be used for low quality activities like water heating. Industries consume about 40% of their electrical energy for heating requirement. This can be met by coal, firewood or oil over all coal, oil consumption.

(iii)It is desirable to use renewable energy sources. Solar energy should be used both in direct and indirect forms. Solar water heaters, dryers etc should be encouraged. Photosynthesis route should be used to improve biomass yields. Biomass and agrowastes can become a major source of energy for many years.

(iv) Seasonal hydroelectric projects should be preferred to annual and carryover schemes. Local people will also support such approaches. We can get the potential energy through a proper generation mix and local generation balance.

(v) People should be encouraged to set up microhydel plants on canals, rivers, streams and waste water flows. In a city like Bangalore, waste water to the tune of 300 million litres / day is flowing into valleys like Vrishabhavadhy valley, K and C valley and Hebbal valley. We should be able to use the head and generate power.

(vi) Industrial wastes are normally organic wastes. Industrial waste water especially from distilleries contain a large amount of organic matter reflected by their B.O.D. Gas generation units can be set up on them. They will reduce pollution and generate energy as a by-product. Health of the city will improve.

(vii) Biogas plants should be set up by trained people, operated properly with a maintenance team and organized in a scientific manner. Biogas plants can meet a substantial part of the states requirement. In addition they produce more nitrogen.

(viii) Industrial wastes especially lignin should be separated and briquetted as a fuel.

(ix) Recycling of wastes should be encouraged. This also reduces energy requirements in many cases.

While following the above, it is necessary to remember that there is no unlimited supply of energy (other than the solar energy) available for all time to come for our exponentially increasing usage.

Conclusions :

From the discussion above it is clear that for sustainable development, it is necessary to increase the magnitude of energy inputs through increased supplies from renewable sources like solar water heaters, biogas, gasifier, mini-micro hydro electric plants, energy plantations (on wastelands) etc and conservation through improved efficiencies of the end use devices like cook stoves (thus saving of fuel wood), irrigation pumpsets etc.

About 27.72% energy could be saved in Industries sector. Which means about 1541 million units of electricity could be saved (as per electricity statistics Industries sector in Karnataka has consumed about 5560 million units during 1991-92). This saved electricity is equivalent to electricity output of 300 MW installed capacity of generating stations. Environmental problems associated with mega projects, the increasing demand of states/ country and resource depletion make it increasingly imperative that our planners divert their attention towards improving efficiency in all sectors. This research illustrates that, there is ample scope to conserve energy in industries sector.

Cooking is the dominant end use activity. Use of highly efficient improved cook stoves and biogas would save fuelwood of the order of 20-30% . Water heating for bathing could be done through solar heaters. This reduces pressure on electrical energy in urban areas (all electric homes) and fuel wood in rural areas.

Decentralised renewable energy generation systems like community biogas plant, wood gasifier would provide employment, assured electricity supply, good drinking water (water pumping), good illumination at home and streets, revenue to the village and lead to the self reliance of the rural communities. Involvement of village community in the implementation and management, technical feasibility, economic viability of the decentralised system makes the system self sustaining. Renewable resources utilization would help in preserving the environment, reduces import of non-renewable resources like coal, oil etc., improves balance of payment and provides better protection of consumers.

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