Energy Options For Sustainable Development

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Integrated renewable energy approach which utilises different resources such as solar heat, wind, biomass and falling water to satisfy various needs in a region is 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.

Introduction

The history of man's emergence from the ecological niche appropriate to a medium sized 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, 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. The modern society has grown without realising the extent 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 of supports received from the environment. Market economies based on value addition treated many energy resources like wood, coal etc. as free resources assuming their infinite availability, and generated more energy intensive technologies. Exponential growth in population coupled with associated increased use of energy resulted in an indiscriminate pursuit of development with problems like depletion of natural resources, environmental degradation, wide economic disparities etc. This has necessitated a switch over to "sustainable development". The key features of sustainable energy for development are:

* Satisfying basic human needs
* Meeting the needs of all the sections of the society
* Promoting energy efficiency improvements (conservation), and
* 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, and 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. Efficient use

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of bioenergy by converting biomass feedstocks into solid, liquid and gaseous fuels and to electric energy would improve the quality of life 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 places. The three components of energy system are:

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,

Transport/Transmission system: Energy system transported from place of availability / generation to places of use

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 Resources

Energy resources are broadly categorised as (a) renewables and (b) depletables. The depletable resources are those whose availability keeps on decreasing depending on their use; renewables are available always and hence defined as a flow of energy that is not exhausted by usage. Energy resources are also classified as primary or secondary ones—coal, firewood etc being primary while electricity is secondary. 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 the state of Karnataka in south India have been studied over a period of time. These studies reveal that a vast potential exists for conservation measures and introduction of renewable sources to sustain and speed up the overall development of the state.

Karnataka state extends over an area of 1.92 lakh sq. km. The state is located in the west-central part of the Deccan Peninsula of the Indian union and is between 13°3' and 18° 45' North latitudes and 74° 12' and 78° 40' East longitudes. The major portion of Karnataka lies in the elevation range between 450 and 900 metres above the mean sea level. With a population of 448 lakhs (1991 census) it accounts for about 5.31 per cent of the country's population and 5.84 per cent of the area. 71.1 per cent of the total population lives in the rural area. There are in all 27,028 villages. The economy of the state is predominantly agriculture based with around 45 per cent of the state domestic product being accounted by this primary sector.

Energy Consumption Pattern

Source-wise consumption study in Karnataka reveals that commercial sources of energy like coal (3.51%), oil (20.33%), electricity (17.90%), kerosene (6.4%), LPG (0.4%) constitute 48.54 per cent of the total energy consumption, while non-commercial sources of energy like firewood (41.29%), cowdung cake (0.83%), agrowastes (9.34%) constitute the balance of 51.46 per cent. Firewood and other biomass residues are used in large quantities in almost every part of the state. They are mainly used by the rural people for cooking, bathing and rural industries like brick making, silk, tobacco, tea industries etc. The sectoral consumption pattern of commercial energy reveals that industry consumes 44 per cent of the total, followed by transport 24.4 per cent, household 18.1 per cent and agriculture 5.6 per cent.

Electricity Consumption

Karnataka was a pioneer in the development of hydro-power. Karnataka is endowed with a vast hydropower potential to the tune of 7700MW of which only 2645 MW has been harnessed by the end of the year 1990 with a per capita annual consumption of 209 kWh. Against an unrestricted demand of 19,756 MU (million unit), the generation is only 11,108 MU leaving a gap of 8648 MU. To meet the growing demand for power, 630 MW of coal based thermal power has been added to the existing grid from late eighties.

A shortfall of 30 per cent in power availability against demand exists even today. While the daily unrestricted requirement is 55.3 MU with a peak demand of 3,410 MW, the availability is only 46 MU with installed capacity of 2340 MW. About 30,000 new installations with a peak demand of 45 MW, are being added to the system every month. At present there are 55,83,207 installations with a connected load of 8713.9 MW which is almost thrice the present installed capacity. These include 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. Transmission and distribution losses are of the order of 20-22 per cent. A five per cent reduction in T & D losses would mean extra availability of 700 million units, with an additional revenue of Rs. 70 crores, to the State Electricity Board.

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 the construction of big dams of large hydel projects (e.g. Linganamakki, Kali, Kodasalli). Polluted air with fly ash has led to diseases of the respiratory system in the thermal power station at Raichur district in Karnataka. Such environmental disasters have necessitated eco-friendly alternative energy technologies and conservation measures.

Energy Conservation

Energy conservation aims at using energy efficiently without reduction in economic activity. Energy conservation is not only cheap but can also be relatively quick and easy to carry out. There are three ways to conserve energy, some involve change in attitude while others change in life style.

(a) *Conservation through improved efficiency of use*

* Use of fuel efficient cook stoves instead of traditional stoves: Improved fuel utilization and reduced smoke emission, are the goals of improved stoves. For example, ASTRA Ole (improved cook stove) designed and disseminated in rural households in Karnataka by the Indian Institute of Science has an efficiency of 32 - 33 per cent compared to the traditional stove efficiency of 5 - 10 per cent.
* Improving automobile performance by good maintenance and driving at optimum speed.
* Using fluorescent lights in place of incandescent lights which provide better illumination in addition to saving electricity. Compact fluorescent lamps use only 25 per cent of the energy consumed by incandescent bulbs plus last 10 times longer.
* Replacing inefficient industrial equipments: A survey conducted on 60 industries reveals that 46.55 per cent of total load is used for heating, machineries 47.25 per cent, welding 1.10 per cent lighting 1.33 per cent and others like street lighting etc 3.77 per cent. Since electricity is high quality energy, it is desirable to use it mainly for high quality of work - movements and electrolysis etc. Use of electrical energy for heating purpose should be avoided and substituted with lower quality energy. Such a substitution will not only match source with end-uses, but also increase efficiency of use. For example, study conducted on the energy efficiency of some end use devices in an electrometallurgical industry reveals great scope for conservation by improving the maintenance, educating workers about the energy losses and replacement of inefficient end use equipments. Efficiencies calculated for some end-use devices are listed in table 1.

Table 1: Energy Efficiencies of End Use Devices in an Electro metallurgical Industry

End use	Energy Efficiency (%)
Welding sets	14
Furnace	10.4
Shearing machine	33.3
Bending machine	30
Electroplating process	38
Diesel Generating sets	36.5
Press brake	14.06

(b) *Conservation by alternatives:*

* For example 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 to 700 kg firewood per 1000 bricks. Improved kiln/clamp with improved frying process saves fuelwood. Compaction of soil to make blocks saves fuel wood completely and generates employment for rural areas.
* 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 patterr of energy consumption:

* Lack of capital for financing energy efficient projects.
* Lack of information and technical expertise about energy conservation opportunities.

Renewable Energy Sources

The primary renewable energy source on earth is soiar radiation. The total flow of solar energy through earth's natural system is 10,000 times greater than the present flow of energy through man's machines. Even one per cent of the solar influx that generates the great atmospheric pressure systems which drive the winds, and which in turn generate the waves, is 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, by urbanisation, agricultural practices, deforestation etc. Man's activity also changes wind patterns and modifies cloud coverage. Injection of pollution into the atmosphere, removal of forest cover and man made structural changes influence both radiation and heat and water flows.

Technologies for tapping renewable energy flows are listed in table 2.

Solar Energy Conversion Modes

Solar energy is captured and converted to other forms of energy by chemical reaction, thermal excitation and 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 cells use energetic photons of the incident solar radiation, converting solar energy into electricity.

Some advantages of photovoltaic devices are:

* No inherent life time limit
* Efficiencies are independent of size
* Modular
* Compatible to all environments
* Fairly constant voltage independent of sunlight intensity
* Relatively low maintenance
* Low operation and maintenance costs
* Simplicity
* No cooling water required.

Potential areas of commercialisation of solar photovoltaics are domestic lighting, community lighting (street lighting), health care, telecommunication, water pumping and 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 should 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:

* Theoretical efficiency of about 25 per cent combined with low energy intensity of sunlight requires a relatively large collector.
* Economically not competitive with other sources
* 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 dispensing with geysers. Solar water heating system is a simple device working 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:

Thermosyphon or natural circulation

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.

Table 2: Renewable energy technologies

Resource Technology	Energy Product	Status
Hydro		
Micro-hydro	Electricity	Developed. economic, 225 feasible mini (100 to 1000 kW) and micro (<100 KW) hydel sites at Karnataka. The KAEMALA hydel scheme with an installed generating capacity of 400 kW generating 2.5 million units commissioned in Jan. 1990. 1000 MW plant at Sirwar and 350 KW plant at Ganekal are near completion. - Total potential from all sites is estimated to be 250 MW (approx.)
Solar		
Passive heating	Heat	Developed, economic
Active heating	Heat	Developed, economic
Photovoltaics	Electricity	(a) used for street lighting (b) water pumping for domestic and micro irrigation
Solar ponds	Electricity and Heat	Demonstrated and found uneconomical
Wind		
Pumping	Mechanical	Developed. deployed in rural areas, working satisfactorily
Turbines	Electricity	Six sites with mean annual wind speed greater than 18 kmph have been identified. At Talacauvery 0.55 MW wind farm is in function. It is proposed to install a 100 MW plant at Kappadagodda near Gadag where mean annual wind speed over a belt of 30 Km is in the order of 28 to 30 Km
Biomass		
Agriculture and forest residue surpluses		
Domestic and industrial wastes		
Biomass crops		
Direct combustion	Heat	— Widely used but inefficient with traditional stoves. — 46,724 improved cooking stoves have been installed by the end of eighties. (i) Conserves and optimises (ii) alleviates the drudgery of women in rural areas (iii) provides employment to trained youth (iv) provides good health due to low emission.
Decomposition/Fermentation	Fuel	(a) Sample size (i) 1495 plants have been installed in Karnataka. (ii) Biogas is used for cooking and lighting (mantles). (iii) 94.1 per cent of total plants still functioning. (b) community biogas plant at Pura village (i) Community biogas plant with 5 Kw electric generation unit using biogas (ii) System is self sustaining with revenue to village (iii) Employment to village youths (iv) Maintained by village community (v) Used for street lights and domestic lighting (vi) Slurry has good fertiliser value used in fields (vii) cost of electricity is Rs. 2.75 per kWh.
Gasification/Pyrolysis	Fuel and Electricity	(a) Community wood gasifier is functional at Hosahalli village. (b) Used to illuminate 43 houses with fluroscent lamp and 1 x 15 W incandascent lamp. (c) Energy plantation with annual yield of 6 + 1 hectare on wastelands provides wood to gasifier in sustainable way. (d) self employment to village youth. (e) Cost of electricity generated is Rs. 3.5 / kWh. (f) Used for pumping drinking water.
Energy plantation on wastelands/ Villagecommon lands	Fuel	(a) Renewable and sustainable (b) Management by village community
Tidal		
Streams	Electricity	Speculative
Estuary dams	Electricity	Economics depend on financing assumption
Geothermal		
Aquifers	Electricity	yet to be tried
Hot dry rock	Electricity	yet to be tried

Industrial & 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. Fixed controller system delivers 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

Thermosyphon systems are generally used for ease of operation and maintenance. For proper functioning it is necessary to have least amount of resistance in the thermosyphon 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, aluminium and copper to certain plastic materials like HDPE, Polypropylene, etc.

For the flat plate collector which is the heart of the system a wide range of material and design choices are available now. The basic absorber could be galvanized steel, aluminium 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 or even polyurethane foam for bottom insulation. Wooden boxes are employed in some instances to contain insulation, absorber etc. Metals like steel and aluminium as well as reinforced plastic are more frequently employed.

Technical Issues

Technical snags encountered in solar heaters are as follows:

(a) Corrosion of various forms has been a nagging problem as efforts have been made to use MS and aluminium with raw water. 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 problem 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 per cent.

(c) Failure and very poor reliability of the control hardware in the case of forced flow system. (i) A simple thermostat changes calibration over time. Capillary thermostat provides better performance and reliable operation but is quite expensive

(ii) Problems with solenoid valve and at times level controllers.

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

Present Status in Karnataka

The total number of industrial and commercial solar water heating systems installed in Karnataka is around 150 in the range of 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 installing 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. 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 reasons for low level market penetration are high capital cost of the system, inadequate fund for disbursement of subsidy, absence of attractive financial package for buyers and lack of awareness of the technology.

Wind Energy

Wind energy is an indirect form of solar energy. About 1 per cent the total solar radiation that reaches earth is converted into wind energy. Although wind occurs universally, it is intermittent and its strength and reliability varies from one location to another. At ground level winds are easiest to use, coastal and hill country often have stronger winds than flat inland areas. Two sites in the coastal belts of Karnataka were identified—one on National Highway Sillae Gudda and other at Ramtirta (Kumta, North Kanara district) where wind is in the order of 14 - 20 kmph. Integration of solar and wind energy would assure the continuous generation of electricity.

Wind energy is renewable and poses no environmental threat, The characteristics of wind energy 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 wind energy systems are broadly classified as direct shaft power systems, hybrid or autonomous systems and wind farms.

Wind turbines convert 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 horizontal axis types are two basic technologies employed for converting wind to useful energy. In Karnataka, 0.55 MW wind farm is installed at Talacauvery. Wind pumps of horizontal axis type are working in Karnataka (42 numbers disseminated by Karnataka State Council for Science and Technology (KSCST) for pumping water etc.)

Economic aspects

From the economy point of view and functional efficiency, the water pumping wind mill has proven to be more advantageous compared to diesel pumps considering the free running cost of wind mill whereas in the case of diesel pumps, recurring expenditure is incurred in terms of fuel and regular maintenance. Usage of wind energy for pumping water (each machine) saves about 150 litres of diesel and annual saving of 1800 litres. Therefore large scale use of wind mills for irrigation and drinking purposes 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.

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 tandem. Such a system:

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

(b) Is renewable, sustainable and available in the immediate environment

(c) Requires minimum handling, transport and transmission

(d) Protects and improves the environment.

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

(f) Establishes 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 situation 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 economy 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 the linear programming approach 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:

* The biogas route is optimal for lighting and cooking

* The cost minimisation model allocates grid electricity lag behind the biogas - engine - generator electricity route.

* Firewood stoves become part of the cooking solution only when the cost of firewood is reduced and stove efficiency is increased.

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

Conclusions

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 fuel wood), irrigation pumpsets etc.

Renewable energy systems like community biogas plant, wood gasifier would provide employment, good drinking water, 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 and economic viability of the decentralised system make the system self sustaining.

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