ENERGY ALTERNATIVES:
RENEWABLE ENERGY AND ENERGY CONSERVATION TECHNOLOGIES

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Energy systems should be consistent with environmental, economic and social sustainability in order to ensure regional sustainable development. This enhances both current and future potential to meet the human needs and aspirations. Sustainable development, a process of change, in which, the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are in harmony. National energy programme should prioritize the development of renewable energy sources, which offer the potentially huge sources of primary energy.

The path for sustainability in the next millennium is the low energy path through wise use of energy. Energy conservation and energy efficiency measures would certainly result in meeting the energy demand with as little as half the primary supply at current levels. This requires profound structural changes in socio-economic and institutional arrangements. Environmentally sound, technically and economically viable energy pathways will sustain human progress in the long term future giving a fair and equitable share of the underprivileged and poor of the developing countries.

Renewable energy is considered by some as the only hope for the survival of planet yet by others it is viewed as a marginal resource with limited resource. All too often, however, the facts behind the role that renewable energy can, and will, play in the regional energy scene are disguised or ignored as rival camps distort the evidence to suit their own objectives. It was in the light of this confusion that the Energy Research Group at Centre for Ecological Sciences, Indian Institute of Science undertook investigation in Kolar and Uttara Kannada Districts in Karnataka State, India to identify the potential contribution of several types of renewable energy sources: Solar, Wind, Hydro, Bioenergy, etc.

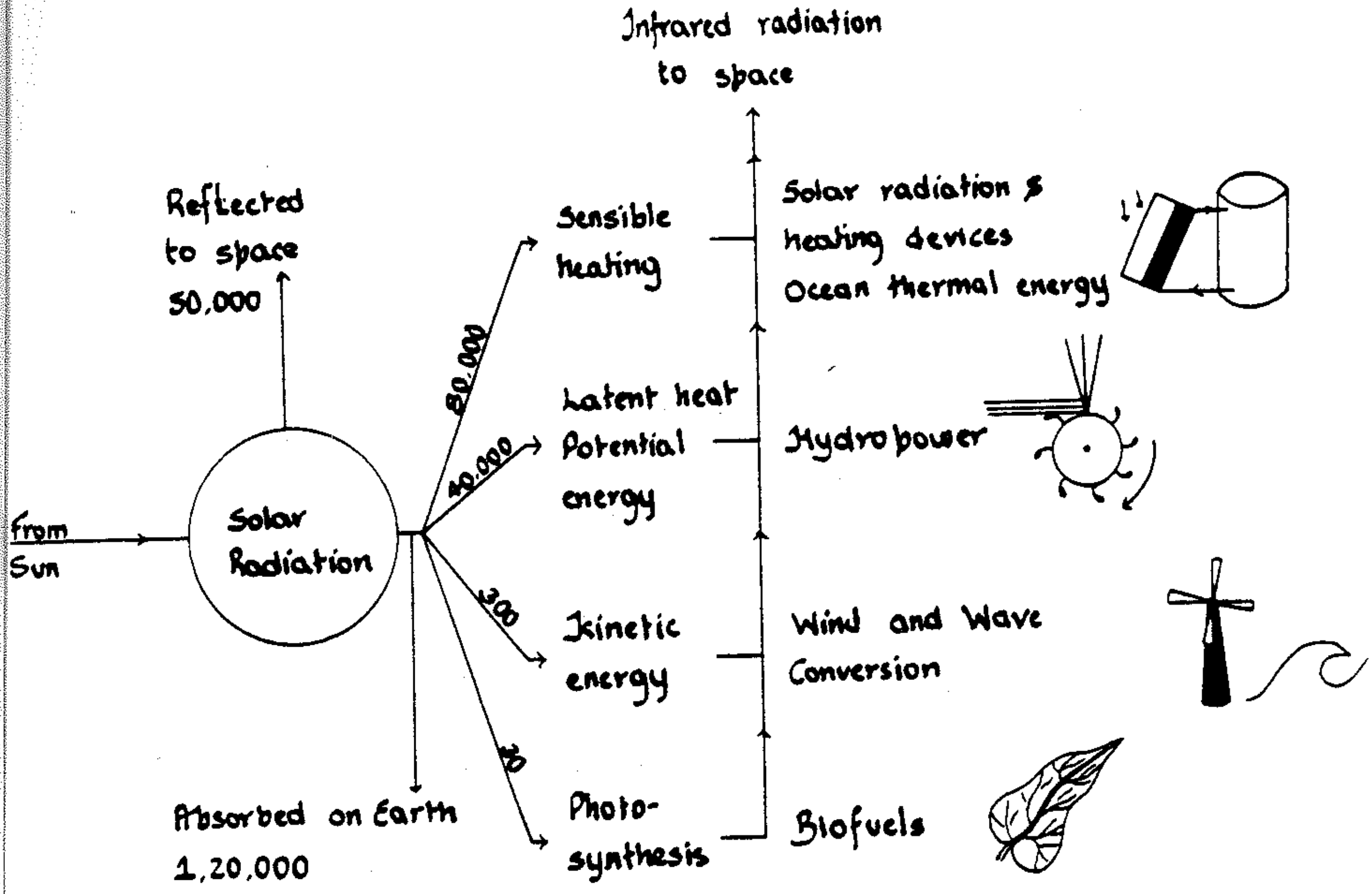
In this regard it is necessary to:
Include regional energy where relevant as one of the key elements in the overall strategy for sustainable development. Integrate programmes for food, water, energy and social development.

Establish regional centres of excellence for renewable energy, to provide training, technology support, and resource databases appropriate to the regional needs. Develop and implement regional demonstration programmes as showcases of the best elements of renewable technologies.

Gather, review and publicise success stories involving renewable energy, to give realistic examples of what has been done and is possible.

This publication provides a comprrehensive review of Renewable Resources from a technical point of view, and details and synthesises the results of the detailed research undertaken at Kolar as a part of UNDP-NRDMS programme of the Ministry of Science and Technology, Department of Science and Technology, Government of India.

Introduction



Energy Alternatives: Renewable Energy and Energy Conservation Technologies

Introduction

Energy plays a vital role, affecting all the activities that take place in the society. Its role in economic development of a region needs no emphasis; because of its qualitative effects, it exercises greater influence. It is the key element in the production process, and the lack or shortage of it has a serious impact on the economy. It is a central concept in most branches of natural science, social science and engineering, since it is essential to make things happen. It plays a crucial role in diverse processes like chemical reactions, cloud formation, functioning of cells, production of goods, transportation, etc. Fossil fuels, such as, coal, oil and natural gas lay the foundation for an industrial society, but they are disappearing at an alarming rate. Present fossil fuel potential is unable to meet the growing demands of the society. There is a need to look for viable alternatives to meet this scarcity. In this regard, rational decision making is necessary to eliminate wasteful use of resources.

Energy Use versus Time

The history of man's emergence from the ecological niche, appropriate to medium size omnivorous mammals, to his present position as the earth's dominant species is attributed to his increasing skill in harnessing and manipulating energy. Each stage of his evolution has been marked by an extension of his ability to control the natural flows and accumulated energy resources. Initially, he used only food energy, as did all other species of animals. Primitive man's use of energy was of the order of 2000 kcal/day, mainly as food energy. Hunting man used some fuel wood for heating and cooking, his use of energy being about 3000 kcal/day. Early agricultural man used animate sources of energy for agriculture and transportation, with his consumption roughly being about three times that of hunting man. Gradually, man discovered new ways of using energy supplies to his own advantage by controlling fire, growing crops and domesticating animals. Cultural development led to the use of other energy sources and increase in human population. Thus, the influence of energy availability is seen in the form and structure of the human society itself.

In a subsistence agricultural economy, majority of the people spend most of their time working to obtain the food necessary for their own survival. Agriculture is essentially a process by which the stored energy of photosynthesis is directed towards man. It begins with the selection and cultivation of plants. Irrigation, manure and fertiliser have enabled him to maximise food production. With these, he has opened wider the gates of photosynthesis, through which solar energy becomes his food. The domestication of animals widen the control of natural energy flows. With this domestication, grasslands have become energy gatherers. Grass otherwise cannot be used by man as fuel or food. With domestication, the cattle is allowed to graze, and the subsequent milk and meat produced is used by man. Muscle energy is used for ploughing, to lift water and for transportation. The use of human beings as slaves was a feature of the early civilisation. They were given energy only in the form of food for the work carried out. Both the slave and domestication of animals were precursors of the mechanical engine: they were means of converting the energy of food or fuel into work.

Village and urban settlements were common by 2000 BC and the pace of change gradually increased. The growing ability to harness energy and therefore reliable food supplies gave impetus to civilisation. Gradually, around 100 BC, waterwheel (in the West, China and India) and windmills (in the Arab countries) acquired the place to provide energy in the medieval economy. This hastened the pace of social and technical development. Tapping of fossil fuels like coal, oil, etc., led to an endless catalogue of achievements and conquests of the physical world. This led to the industrial revolution. In the nineteenth century, a host of new inventions took place in response to the growing availability of energy, for harnessing more energy sources. This resulted in advancement of science and technology and emergence of many disciplines like civil, structural, mechanical and electrical engineering. But, a declining trend in available stock of fossil fuels like coal, oil and natural gas in the later half of the nineteenth century has necessitated the search for viable alternatives. In looking at the earth's energy resources, it is necessary to go beyond the mere question of their absolute magnitude or their theoretical potential, if the technology to harness them could be devised. The practical availability of energy resources is limited by social, geographical, political, economic and technical constraints. Abundant coal resources in Russia or oil resources in middle east and constraints associated in using these resources by other countries have clearly shown that proving the existence of resources does not always promise accessibility to everyone.

Technical Aspects of Energy

Energy is the capacity to do work - to exert a force 'F' through a distance 'd'; to accelerate a mass 'm' from rest to some velocity 'v'; to move an electric charge 'q' across a voltage difference 'V'; to lift a mass 'm' to height 'h'. In each case, a specific amount of energy - Fd, $(1/2)mv^2$, qV or mgh - is required. Energy comes in many different forms:

Potential energy -	objects, because of their position, capable of doing work on other objects are said to possess potential energy;
Kinetic energy -	the energy of moving body, proportional to its mass and the square of its speed;
Heat energy -	the kinetic energy of random thermal motion of matter on an atomic scale;
Mechanical energy -	the kinetic energy of organised motion of bulk matter;

Electrical energy -	the energy due to the forces that charged bodies exert on one another;
Chemical energy -	the energy of chemical bonds, due to electrical forces acting at the atomic level in accord with quantum mechanics;
Nuclear energy -	the energy of nuclear binding due to nuclear forces;
Gravitational energy -	the energy due to the force of gravitational attraction - such as the potential energy that a body of water has because of its height above sea level;
Light energy -	the energy of visible, ultraviolet, infrared, electromagnetic radiation, etc.

Energy undergoes transformations from one form to another. These transformations are governed by the laws of thermodynamics, which state:

(i) Energy is a conserved quantity - while it can move from one place to another, it is neither created nor destroyed. That is, the total amount of energy does not change.

(ii) In energy transformations, energy tends to pass from concentrated forms to dilute forms. It changes in such a way that the amount of work that can be obtained from it decreases.

The first law of thermodynamics is based on laws of motion of Isaac Newton, whose work was instrumental in providing theoretical view of the universe, in which energy is the central concept linking the whole range of observed phenomena. Einstein later, through his theory of relativity was able to transcend Newtonian concept of the physical universe, widening the perception of the nature of physical reality. Einstein's special theory of relativity equated mass and energy and expressed it as $E = mc^2$, that is, energy is equal to the square of velocity of light. Joule, electronvolt, kilocalories, kilowatt-hour and kilogram mass are the units commonly used in the different disciplines of electricity, atomic physics, dietetics and engineering to express energy. All these units that can be expressed in terms of each other, can also be reduced to units of mass. For example, 1 kilowatt-hour is 3.6 Giga joules, 859.8 kilo calories, 2.247×10^{25} electronvolt or 4.007×10^{-11} kilogram mass. This highlights the unifying power of the concept of energy.

Accounting of energy, using the first law, allows one to translate energy from various sources into thermal equivalent units such as kcal, while energy measured using units (such as MTOE: million tonnes of oil equivalent, MTCE: million tonnes of coal equivalent) based on the second law of thermodynamics takes into account efficiency of conversion, as well as, differing efficiencies of combustion.

Usefulness and transformability of energy are explained in terms of "entropy" by Clausis. Energy at a high temperature is obviously more useful, or transformable, than energy at low temperature. This leads to the definition of 'energy efficiency'. Efficiency is defined as the amount of useful energy produced by a system as a proportion of the total energy input. In assessing the resources as alternatives, limitations imposed by the second law need to be clearly appreciated.

Classification of Energy Sources

All the sources of energy, currently available for harnessing, can be linked to two fundamental forces in nature - gravitational and nuclear. Nuclear fusion is the source of solar energy - the driving force for much of the energy consumed on earth today.

Renewability or non-renewability of a solar driven process is distinguished based on the energy storage or cycling time involved. Renewable resources have a cycling time less than 100 years, while for non-renewable resources, it is greater than a million years. The depletable resources are fossil fuels, which are non-renewable since the rate of their utilisation far exceeds the rate at which they are formed. Examples of renewable resources are hydro energy, solar energy, wind, biomass, and energy from wastes (such as biogas, agrowastes, etc.).

The renewable solar energy is subdivided into direct and indirect types. Sunlight used directly can produce electricity, heat or derive a chemical reaction. It is used indirectly when it drives other processes, biological-chemical or climatic-mechanical, which in turn are used as sources of energy.

The energy sources can be classified in a number of ways based on the nature of their transaction, as commercial and noncommercial sources of energy. All energy resources, particularly the commercial ones, are natural. Coal, oil and nuclear sources constitute commercial sources, while firewood, biomass and animal dung constitute non-commercial sources. Also, the energy sources are classified based on animate and inanimate characteristics.

Energy sources could also be classified as exhaustible/depletable or non-depletable/renewable resources. The distinguishing feature of an exhaustible resource is that, it gets exhausted when used as an input of a production process, and at the same time, its undisturbed role of growth is nil. That is, the temporal services provided by a given stock of an exhaustible resource are finite.

Further, based on conventionality in deriving energy, energy sources could be classified as conventional (coal, oil, hydro, nuclear, etc.) and non-conventional (solar, wind, tidal, geothermal, biogas, etc.) sources.

They are also classified as primary or secondary types - coal, firewood, etc., being primary sources and electricity, a secondary source. Energy in its primary form can be of different kinds. The main types are Chemical (fossil fuels - coal, oil, natural gas, peat; biomass - wood, agricultural residues, etc.), Potential (water at a certain height), Kinetic (wind, waves), Radiation (sun), Heat (geothermal reservoirs, ocean thermal reservoirs) and Nuclear (uranium). The primary form of energy must generally be converted into secondary or final forms of energy before it can be used. For instance, the potential energy of a waterfall (primary energy) is converted into electricity (secondary energy), which is transmitted and transformed to supply (final) energy to a factory, where it is converted into mechanical energy (useful energy) for productive operations.

Important types of secondary energy are electricity and mechanical energy. But chemical energy is also important as a secondary energy, for instance, in the form of refined oil products. Final energy is the energy that reaches the consumer. This can be electricity at a suitable voltage, or chemical energy in kerosene or batteries. The consumer, finally, uses certain equipment to convert the final energy he buys, into useful energy for one of his end use activities, e.g., irrigation, transport, cooking, etc.

Most of the energy sources are substitutable to each other due to the fact that some form of energy can be converted to other - such as coal to electricity, use of photo electricity to drive a chemical reaction, wind energy to pump and store water that could be used to produce electricity when required, or solid biomass to produce liquid or gaseous fuels of higher calorific value. All forms are ultimately converted into heat. This gives rise to the inter-fuel substitution process with which an economy can substitute its abundantly available resources to the scarcely endowed one.

Components of Energy System

Energy is a complex process as it is possible to convert it into different forms, transport it, store it in some forms and use it in various end use modes in innumerable kinds of places. Thus, an energy system essentially consists of four components. They are generation, transmission/transport, distribution and consumption/utilisation.

Generation involves conversion of energy sources into acceptable forms that can be easily transported. Energy can be drawn from water falls, sun, wind and from chemical energy stored in coal, oil and biomass resources. The major factors which influence the generation components of an energy system are the technologies of generation and their scales, efficiency and costs. Examples of these are electricity generated from thermal, hydro or nuclear stations, coal extraction and oil refinement. The size and site of generating facilities depend on a number of factors like availability of raw materials, land, water and other infrastructural facilities.

Transmission/transport and distribution are needed to supply the useful forms of energy to various places of consumption. Electricity from centralised power stations is more conveniently transmitted over long distances by transmission and distribution networks. Sources like coal, oil, LPG (liquified petroleum gas) and wood can be transported to different places either for direct use or for further conversion into other useful forms, e.g., transportation of coal or oil to run a thermal power station located near a major load centre. Consumption/utilisation relates to that component of an energy system where energy is utilised in several end use devices required to carry out specific tasks. For example, wood or LPG is used for cooking stoves, while electricity is used for lighting.

Many energy sources can be used either in direct or indirect mode to perform a task. Electricity, kerosene and firewood can be used in the direct mode for cooking. In indirect mode, energy from resources need to be converted in many stages to the form required by an end use device. An example is conversion of coal to heat (in a boiler to raise steam), heat to mechanical energy (in a turbine), mechanical to electrical energy (in a generator), electricity to mechanical energy (in a motor), and mechanical to potential form (in a pump) to lift water from a well. There may be multiple paths from a source to an end use device, such as, biogas can be used for lighting either directly through a mantle lamp or converted to electricity and used to light a bulb.

In the case of a decentralised system, energy resources are transported directly to places of use, and used in a suitable end use device. Some examples of decentralised systems are - use of firewood for cooking and water heating in the domestic sector, small industries like brick kilns, tobacco curing, sericulture, etc. However, before the advent of technologies for large-scale exploitation in a centralised system, decentralised systems were the only mode of energy used. Because of convenience, easy maintenance, diversity of usage and reduced costs of operation, energy production became centralised. Efficiencies, costs, and conversion possibilities of end use devices are some of the factors that influence the final stage of energy system.

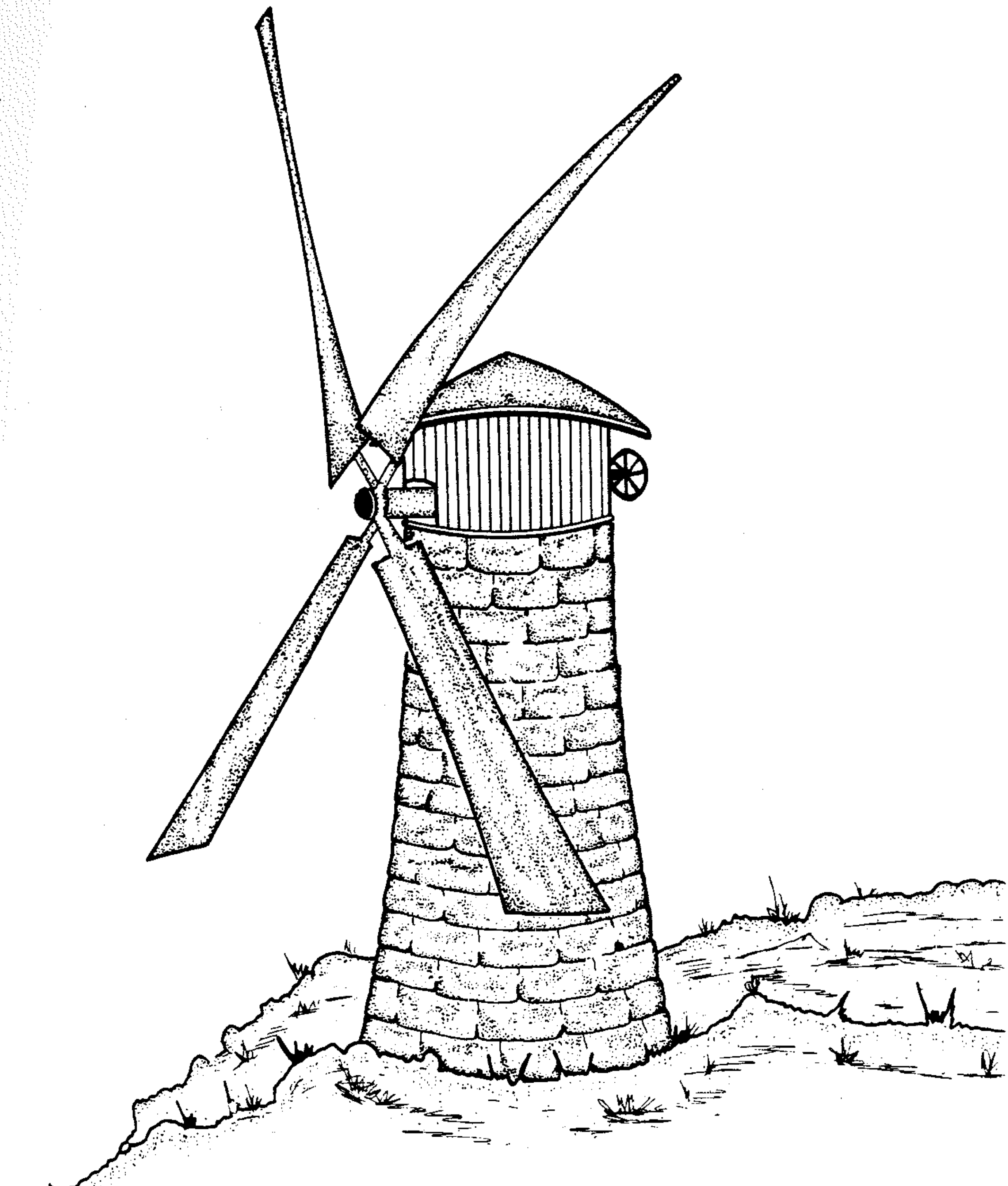
REVIEW OF RENEWABLE SOURCES OF ENERGY

The main types of useful energy are heat and mechanical energy. Heat though predominant in household activities like cooking and water heating, is also needed for productive activities like drying and industrial applications. Mechanical power is predominant in the productive sectors, e.g., industry, agriculture and transport.

Efficient use of energy is achieved when unnecessary energy conversions are avoided, as each conversion has limited efficiency and, therefore, implies a certain loss of energy as wasted heat. For instance, if secondary energy can immediately serve as final energy, or even as useful energy, substantial losses can be avoided. Examples are wind machines in irrigation or hydro turbines powering a shaft. This principle favors decentralised energy generation and is particularly relevant with new and renewable energy sources. Very high efficiencies can be achieved with cogeneration, where heat as a by-product of power is not wasted, but put to good use on the spot. This can be applicable to biomass gasification. The counterbalance originates from economics of scale which generally favor large-scale energy conversion.

The foregoing sections make clear that renewable energy technologies cannot be limited to the technologies per se. It is therefore important as to what form of energy is provided, and how the technology can serve a particular end use activity. Sometimes, a combination of technologies would give an optimum energy mix, to secure a continuous and reliable energy supply. In the following section, some renewable energy technologies, such as, wind energy, hydro energy, solar energy, geothermal energy and draught animal power are reviewed.

Wind Energy



WIND ENERGY

Windmills have been used for centuries to grind grain and pump water in rural areas. Winds are caused by rotation of the earth and heating of the atmosphere by the sun, and has global patterns of a semi-continuous nature. It is affected significantly by topography, and weather, with seasonal, daily and hourly variations.. The total annual kinetic energy of air movement in the atmosphere is estimated to be about 3 x 10^{15} kWh or about 0.2% of the solar energy reaching the earth. The maximum technically usable potential is theoretically estimated to be 30 trillion kWh per year, or about 35% of current world total energy consumption. The power in the wind blowing at 25.6 km/h is about 200 W/m^2 of the area swept by the windmill. Approximately 35% of this power can be captured by the windmill and converted to electricity. However, it is important to note that the power output from the windmill varies with the cube of the wind speed. Consequently, only windy locations on mountains and coasts are suitable for the economic generation of electricity by wind power. Harnessing of wind energy could play a significant role in the energy mix of a region. Wind energy is renewable and environmentally benign. It has the advantage of being harnessed locally for applications in rural and remote areas. Pumping of water for agriculture and plantations is probably the most important application that contributes to rural development through multiple cropping. Wind driven electric generators could be utilised as an independent power source, and for purposes of augmenting the electricity supply from grids.

The extent to which wind can be exploited as a source of energy depends on the probability density of occurrence of different speeds. To optimise the design of a wind energy device, data on speed range over which the device must operate to maximise energy extractions are required, which requires the knowledge of frequency distribution of the wind speed.

Mean Wind Speed and Energy Resource

The annual wind speed at a location is useful as an initial indicator of the value of the wind resource. The relationships between annual mean wind speed and potential value of the wind energy resource are listed below.

Annual mean wind speed @ 10 m Height	Indicated value of wind resource
< 4.5 m/s	Poor
4.5 - 5.4 m/s	Marginal
5.4 - 6.7 m/s	Good to Very Good
> 6.7 m/s	Exceptional

In locations where data are not available, a qualitative indication of a high annual mean wind speed can be inferred from geographical location, topographical features, wind-induced soil erosion, and deformation of vegetation. However, accurate determination of the mean annual wind speed requires anemometer data for at least 12 months.

Earlier studies have revealed that the mean wind speed for a given year varies from year to year but within ±10% of the long-term mean. A ±10% variation in mean wind speed would show a variation in energy content of ±30% or more.

Part of the kinetic energy of wind can be captured by a rotor and converted into mechanical or potential energy. The major drawback of a wind power system stems from the nature of the source - wind has a low power density, and wind speed and direction are highly variable. Therefore, wind power systems are best for applications which can tolerate varying power input, such as, pumping of water from wells, the traditional windmill application in many parts of the world. The power that can be achieved by a wind system is proportional to the cube of the wind speed and the square of the windmill diameter. That is,

$$P = n\, C\, d^2\, v^3$$

where,
- P = theoretical wind power (kW)
- d = windmill diameter (m)
- v = wind speed (m/sec)
- C = constant (5.10^4 kg/m^3)
- n = windmill efficiency (20-40 per cent)

There are three principle dimensions to wind energy technology, namely:

(a) Type of machine - horizontal axis, from sail and multibladed to fast-running rotor types, and vertical axis from Savonius to fast-running Darrieus and variations,
(b) Applications - water pumping, desalination, heating, cooling, autonomous power generation and power generation with grid connection, and
(c) Size of machine - small (less than 10 kW), medium (10-100 kW), medium-large (100-1000 kW) and large (more than 1 MW).

(i) *Wind Energy Driven Waterpumping Systems (Windpumps)*

A small windmill with direct mechanical drive to a water pump is an old technology, and commercial machines are still in extensive use in many parts of the world. In most cases, water is pumped whenever the wind blows and is stored in a tank for use as needed. Careful matching of the windmill to pump characteristics is important, and the windmill, pump and storage must be treated as a system.

The conventional multibladed windmill is a type that has been widely used for this purpose in the past, but has not found widespread application in developing countries because of economic and financial reasons. Compared to the traditional multibladed windmills, they are considerably lighter in weight, more simple to construct and have slightly higher over-all efficiency. These windmills, after adapting the design to locally available materials, can be manufactured in sparsely equipped workshops and are cheaper than commercially available windmills by a factor of 2 to 4. Many such windmills are operating in pilot projects in India, Kenya, Pakistan, Peru, Tunisia and Sri

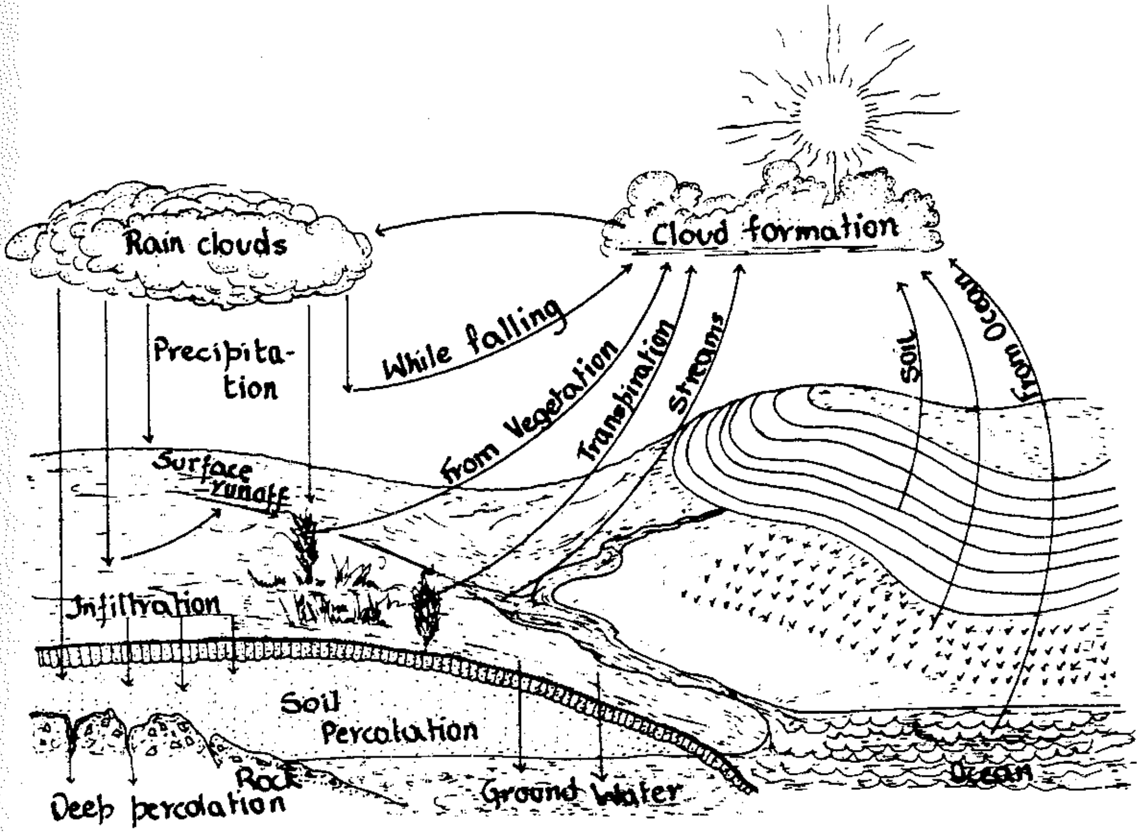
Lanka. Experience in these projects are showing that extensive field testing is essential, and is resulting in several design modifications to ensure the reliability of the machines.

Besides the design of all-metal windmills, improved types of sail and/or wooden windmills have been developed in Colombia, India and The Netherlands, to try and meet the demands of the subsistence farmer. These mills, which can be fabricated in village workshops, are cheaper than commercial mills, even allowing for replacement of sails every two years. Drawbacks of this type of windpumps are relatively low efficiency and higher time requirement for operation and maintenance.

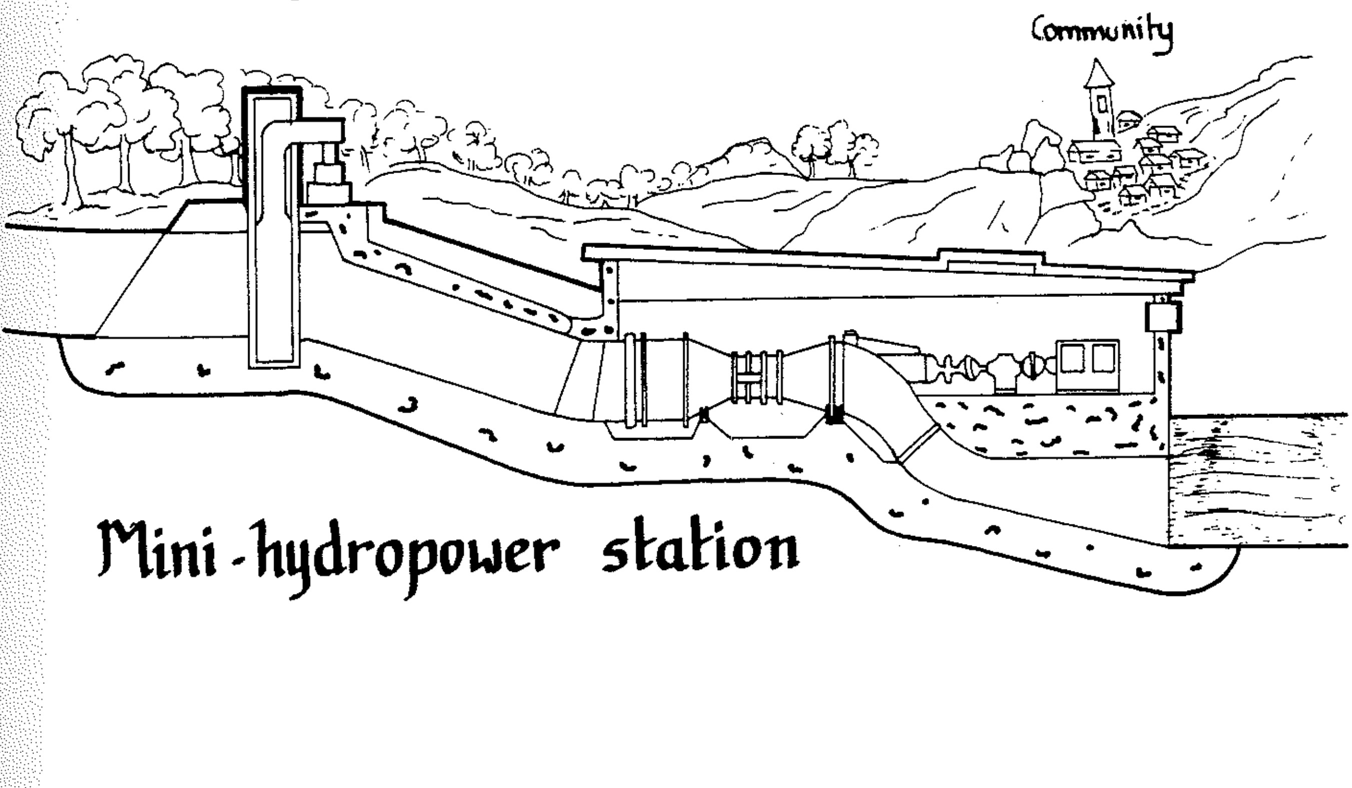
(ii) *Wind Energy Driven Electricity Generation (Wind Generators)*

Autonomous wind power systems in 10-1000 kW range, with diesel back-up and possibly hydroelectric storage, are already an economic alternative to conventional diesel generation for isolated communities in good wind regimes. With existing technology, the wind turbine can be used to give significant fuel savings, although it cannot replace the diesel. Systems are of low solidity (high speed) type and comprise horizontal, as well as, vertical axis windmills.

Hydro Energy



Hydrologic Cycle



Mini-hydropower station

HYDRO ENERGY

Hydraulic potential is the combination of the possible flows and distribution of gradients, and hydraulic resource is that fraction of hydraulic potential that is still accessible after economic considerations. Hydropower owes its position as a renewable resource to the varying, but more or less continuous flow of a certain amount of water in the stream. This water, supplied by rain and always moving, constantly flows from the mainland to the sea, where it evaporates into the atmosphere in an unending cycle controlled by two opposing forces, heat of the sun and the earth's gravity. Hydropower is a precipitation dependent resource, subject to the uncertainties which it entails. Water run off can vary within wide limits.

The harnessing of energy of the falling water to provide mechanical power has been one of man's greatest achievements. Water wheels providing mechanical power for grinding and water pumping are still in common use. The industrial revolution created new requirements, which demanded larger power generating capacities, which led to rapid improvement in the design of water wheels, turbines and generators. The capacities of hydropower plants became very large as electricity generation became common place by the end of 19th century. The position has ultimately reached a stage where large-scale hydroelectric plants contribute significantly to the State's and the National energy demand. Unfortunately, every development has its cost and the cost of exploiting hydropower is vigilance in ensuring the environment is not irreparably damaged and the life of the river continues to flourish. This demands considerable care and attention in planning.

A micro, mini or small hydropower station can divert only potential energy of the water which would have dissipated to no benefit in the natural flow along the water course. The domain where these can have potential impact on development is domestic lighting and stationary motive power demand for such diverse productive uses as water pumping, wood and metal work, grain mills, agro processing industries, etc.
Mini, micro and small hydro plants combine the advantages of large hydro plants on one hand and decentralised power supply on the other. The disadvantages associated with large hydropower plants, like high transmission costs, environmental issues like submergence of forests and crop lands, and displacement of families, are not present in small plants. Moreover, the harnessing of local resources like small hydro resources, being of a decentralised nature, lends itself to decentralised utilisation, local implementation and management, making rural development possible based on self-reliance and use of local natural resources.

Hydropower plants classified based on:

Power and head: mini, micro and small hydropower plants.

		Head (metres)		
Type of plants	Power (kW)	Low	Medium	High Head
Micro	up to 50	< 15	15 - 50	> 50
Mini	50 - 500	< 20	20 - 100	> 100
Small	500 - 5000	< 25	25 - 130	> 130

Potential energy of water at a certain height can be converted into mechanical energy by using a turbine. The falling water hits or exerts a pressure on the blades of the turbine. The power available is proportional to the head and the rate of discharge of the water. That is,

$$P = \eta \, C \, H \, Q$$

where P = power available (kW)

η = hydropower system efficiency (70 per cent)

C = constant ($\approx 9.81 \times 10^3$ kg/m^{2}s^2)

H = head of the water (m)

Q = flow of the water (m^3/s)

The flow through the turbine is not independent of the water head. For a given turbine size, the flow will actually be faster if the head is larger. As a result, high heads are favored for hydropower generation. In practice, water heads are used from less than one meter to several hundred meters. With low heads, obviously, a large flow must be available to get a substantial amount of power.

The capacity of hydropower plants can vary between a few kW to about 1,000 MW. The appropriate scale of a hydropower unit depends on local geographic and climatological conditions, and the characteristics of the demand for power. The scale and local conditions also, to a large extent, determine the type of construction and machinery required, and accordingly the investments. Hydropower generation is highly site-specific. This implies that proper attention must be given to site selection and local surveys. For big hydro schemes, it would require elaborate feasibility studies that have to be done by specialised consultants. For small hydro units simple survey methods can be adequate. Another classification of hydro plants is based on different systems of water usage. That is,

i. River power plants, where the head is created by weirs or dams,
ii. Diversion schemes that basically utilize naturally available heads,
iii. Run-of-river plants with little or no control of discharge, and
iv. Storage power plants with high dam and large reservoir for flow regulation.

The construction of a hydropower unit essentially consists of a water intake, a penstock that leads the water to the turbine, a control system, the turbine itself, and except micro units, a generator to convert the mechanical energy into electrical energy. The hydropower system also includes civil works like dams, weirs, canals, etc.

Various types of turbines are available. They can be of the reaction type, like the Francis turbine and the Kaplan turbines, where the turbine is completely submersed in the water, or of the impulse type, like the Pelton turbine, where a jet of water hits the turbine blades. The traditional water wheel can also be considered as an impulse type system. The cross flow turbine that is used for mini and micro units have the characteristics of both the types. Special types are the Segner turbines that can be used in micro units, and the hydraulic ram. The latter does not produce mechanical power, but can be used to pump relatively small quantities of water to relatively higher heights.

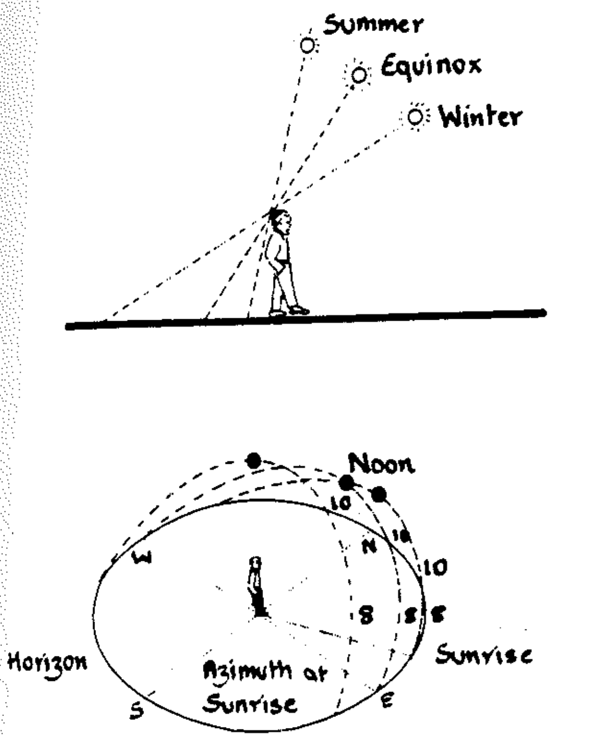
Turbines for big hydro units are tailor made, i.e., specifically adapted to the prevailing head, flow and local conditions. To a lesser extent, the same is true for smaller hydro units. Such adaptations determine the efficiency that can be achieved. Hydro technology is a mature technology and local manufacturing is possible in many countries. Turbines have a long life time (30 years or more) with little maintenance required and their operation is relatively simple.

(i) *Hydroelectricity:*

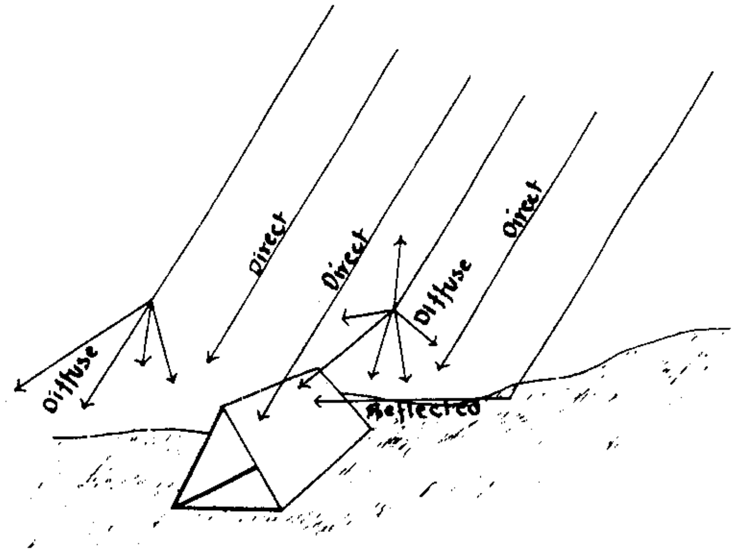
The utilisation of hydropower is mainly for electricity generation. The generator is linked to a system for the transmission and distribution of electricity. Big hydropower units are generally linked to the national or central electric grid. The electricity generation costs per kWh can be low, e.g., for units bigger than 10,000 kW, some one third the costs of fossil fuel powered systems. Small hydro units often serve a local electric grid. The problem here is to achieve an acceptable capacity utilisation. Specific demands (e.g., for lighting) together with low off-peak demands, result in low average load factors for the unit. Load factors as low as 15 to 20 per cent are not uncommon, which result in a very unattractive price per kWh. This is sometimes aggravated by high maintenance costs and breakdowns. The position of mini and micro units that produce electricity is different, as will be discussed in the next section. Furthermore, hydropower schemes often serve irrigation, fisheries and flood control systems as well.

(ii) *Shaft Power and Multipurpose Hydro Units:*
It is increasingly being accepted that mini and micro hydro units do not have to be built on the same standards as big hydro systems. For instance, relatively quick survey methods for site selection can be used, protection measures be less strict, control mechanisms simplified, and lower efficiency accepted. This greatly reduces the investment costs and still leaves a useful option for small-scale power supply. The power of micro hydro plants is best used when the larger part is consumed on the spot as mechanical shaft power. Applications can be small-scale agro-processing industries like grinding, rice hulling and oil pressing, or sawing and water lifting. In addition, cheap dynamos can be connected for supplying electricity in the evenings. Civil works and operation of the system can be provided by semi-skilled local labour. Cross flow turbines are particularly promising for these units, because of their versatility and simple construction.

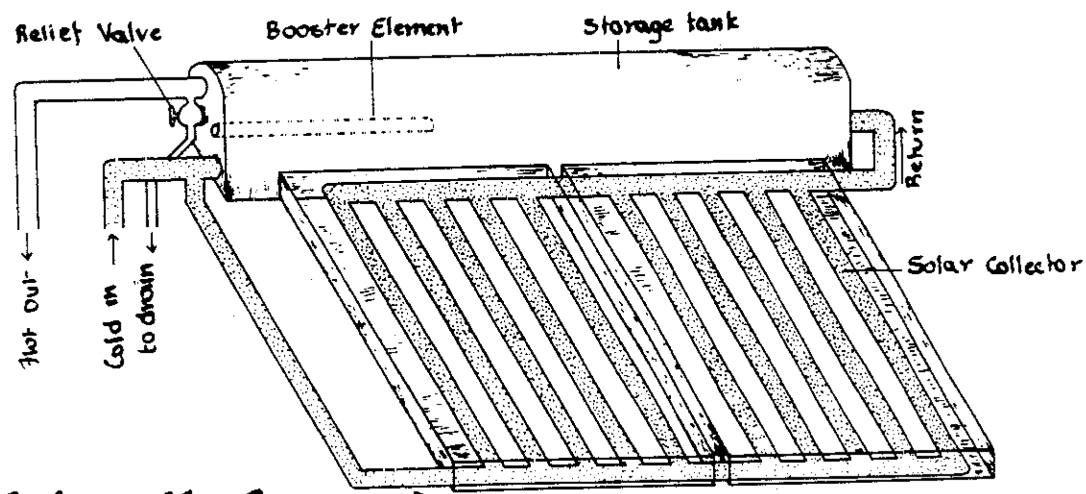
Solar Energy



Variation of Solar Position with time



The Three different Components of solar radiation



Solar Water Heater

SOLAR ENERGY

The sun is the only significant source of energy to the earth. Received entirely as radiation, this energy is subsequently converted, so that at any given time and place, an original quantum may appear in any one of the several diverse forms. Thus, with respect to the energy encompassed in the day to day climate at a given place and time, solar energy may appear as the latent heat of vapor, the advected heat of air masses, radiant energy from sky and terrestrial objects, and unconverted solar radiation arriving as direct beam. The unconverted solar radiation in the form of direct beams is a very important form that is dominant in the hydrologic processes of evaporation, transpiration and snow ablation, as well as, in the growth and succession of vegetation. The total flux of energy to a site at any given time is difficult to measure, and the flux of radiant energy alone can be measured readily at a point. However, this flux varies so widely over most land surfaces that point measurements are of limited value. The spatial heterogeneity in the radiant flux is due to the variation in solar beam irradiation caused by variation in the inclination of the earth's surface with respect to beam direction. Within a geographic region subject to uniform atmospheric conditions, irradiation from the sky is fairly uniform, regardless of surface inclination. However, the total sun and sky irradiation varies widely with surface orientation and slope. The variation of direct beam radiation varies in time with atmospheric condition and path length, the combined effect of which can be estimated.

Systematic long-term measurements of solar and terrestrial radiation in India using calibrated and maintained instruments as per international standards was started in the year 1957-58. The radiation laboratory of the India Meteorological Department, Pune, serves as the radiation centre for India and monitors 25 specifically selected sites, which form the National Radiation Network. Of these 25 stations, 13 (principal stations) are equipped to monitor continuous records of global and diffuse solar radiation, and measure direct solar radiation at regular intervals in addition to recording sunshine. In the remaining 12 stations (ordinary stations), a minimum program is carried out of continuous recording of only global solar radiation in addition to recording sunshine. Apart from these parameters, all stations maintain continuous records of other meteorological parameters such as temperature, relative humidity, rainfall, wind speed and wind direction.

The radiation energy of the sun can be captured and converted into heat and/or electricity. A distinction must be made between beam and diffuse radiation. The former reaches the receiving surface in a straight line from the sun, while the latter is reflected in the atmosphere by clouds, dust, etc. This leads to different systems of solar energy conversion.

(i) *Solar Energy Technologies*:

(a) Passive Thermal Systems:

The simplest method for the collection of solar energy is to design windows of buildings for systematic collection of available solar energy in the cold season. Solar collectors that make no use of ancillary equipment like fans and pumps are known as passive systems. Passive collection is the simplest and usually the most cost-effective way of gathering solar energy (beam and diffuse), and many of these techniques have been used for centuries. They became neglected by architects and builders during the period of low-energy costs. Technically speaking, passive heating techniques are well understood. They have the advantage of using traditional materials and building techniques, and can be used in a wide range of climates. Since people live in the "collector", the approach is chiefly of interest for heating buildings in temperate climates and upland and mountainous areas in lower latitudes.

(b) Flat Plate Collectors:

By far most of the stationary solar collectors are flat-plate type. Simple flat-plate collectors have been able to achieve temperatures of 40^0 - 80^0 C with conversion efficiencies of between 40 and 80 per cent. To achieve higher temperatures, the absorber is often covered with a special selective coating. For temperatures in excess of about 100^0 C, special designs of stationary collectors, such as the evacuated tube collectors, have been designed and tested. Advantages of the flat-plate collector are its simplicity and the absorption of beam, as well as, diffuse radiation. Disadvantages are the low maximum temperatures that can be reached (40-120^0 C) and the rather low efficiencies at "elevated" temperatures.

Constructed in a modular form (units 1-4 m^2), the flat-plate collectors can be coupled to make collector arrays of various sizes, depending on the application. However, there is a maximum size for collector arrays, owing to their thermal losses. It is therefore possible to design a heating facility for a block of houses, but it would be necessary to install several units for a whole agglomeration.

(c) Tracking Collectors:

It is very difficult to obtain fluid temperatures in excess of 150° C using even the most sophisticated flat-plate collectors, because their surface thermal losses become appreciable. A possible and practical means of achieving higher temperatures is by using concentrating type of solar collectors. This necessarily implies that practically all of the diffuse component of solar radiation is lost to the system. Therefore, attempts must be made to utilize as much of the direct solar beams as possible. Hence, the concentrator is normally equipped with a tracking device which, in effect, ensures that it "follows the sun" continuously. The absorber in this case is located close to the geometric focus of the concentrator, to ensure that it intercepts most of the incident direct radiation. There are, in general, two types of concentrators: the linear-focusing concentrators and the point-focusing ones. The former is generally equipped with a single-axis tracking system, and the latter with a two-axis system. In the former case, the absorber is a tube on which the solar image shifts as a function of the sun's position, while in the latter, the absorber covers the area around the focal point. In practice, linear concentrations are generally limited to a factor of 30 to 40, while point concentrators range from 500 to 2,000. For the two classes of concentrators, the efficiencies of direct solar beam conversion is usually in the order of 60-70 per cent. Point-focusing systems are far more sophisticated and complex than linear-focusing systems, and can only be justified when high temperatures (300^0C to $1{,}000^0C$) are to be reached.

(d) Photovoltaic Generators (Solar Cells):
Solar cells, usually in the form of thin films or wafers, are semiconductor devices that convert 3-25 per cent of the incident solar energy into DC electricity, with efficiencies depending on illumination-spectrum intensity, solar-cell design, materials and temperature. A solar cell behaves much like a low-voltage (about 0.5 volts) battery, whose charge is continuously replenished at a rate proportional to incident illumination. Connection of such cells into series-parallel configurations allows the design of solar panels with high currents and voltages as high as several kilovolts. The extraordinary simplicity of a solar-voltaic system would make it a highly desirable energy system, both in developing areas and in industrialized nations. The attractions of photovoltaic arrays include the absence of moving parts, very slow degradation of properly sealed cells, possibility for modular systems at sizes from a few watts to megawatts, and extreme simplicity of use.

Until now, however, high costs of development and fabrication of solar arrays have discouraged widespread application. There is evidence that, with appropriate technological development and mass production techniques, the cost of solar arrays can be lowered to the point where a complete system - solar conversion, power conditioning and transmission/distribution - can compete on a lifecycle cost basis with other large-scale energy-system alternatives, and perhaps be even useful in small-scale applications in remote rural areas.

(ii) *Applications of Solar Energy*

(a) Solar Cookers

Three types of solar cookers have been developed: solar heat boxes, which must be oriented manually and are composed of an insulated box with double glazing; parabolic disk-type reflectors that concentrate the direct beams on a focal zone where the pot is placed; and a system in which solar collection is separated from the cooking stove and heat is transported by a working fluid. The latter makes it possible to cook inside the house and to install a heat storage system for cooking when the sun is not shifting. It is well known that a number of promotional demonstrations of solar cookers failed. Such factors as high unit costs, lack of storage facilities for supplying heat to cook the food during evening hours, unreliable units which could not withstand rural conditions and inadequate social acceptability was responsible for the failure. In the last two years, however, it seems that the insulated box cooker in certain parts of India (especially Gujarat state) has been introduced with a reasonable amount of success. The collector surface and, therefore, costs of solar cookers not only depend on average overall solar radiation, types of fuel and cooking habits, but also on the thermal efficiency of the cooker. These thermal efficiencies are again related to design, materials and state of maintenance of the equipment. Devices and corresponding efficiencies are as follows.

Flat plate solar cooker:	10-20 per cent (of the total with heat transport solar radiation)
Parabolic disk reflector:	60-70 per cent (of direct cooker beam radiation)
Insulated box cooker:	35-45 per cent (of direct beam radiation)

(b) Solar Dryers

Of all the direct uses of solar energy, sun drying of crops is perhaps the most ancient and widespread. Traditionally, drying is done by spreading the products on the ground in the open and exposing them to the sun. However, at the same time, they are exposed to bad weather and insects. In order to reduce the risk resulting from such hazards, solar dryers have been designed, built and used extensively. The earlier units were based on the "greenhouse effect". They reduced the drying time, enhanced the quality of the products, and were found particularly useful for products harvested in the wet seasons. Solar dryers have also been used for timber and wood drying. Generally, the principle of the solar dryer is to heat air in a suitable solar collector and circulate it by natural or forced means through the product to be dried. The solar collector or air heater, as it is normally called, may be external to or form an integral part of the dryer. Solar dryers are particularly suited to small homesteads and villages in developing countries, where they can play an important role in crop preservation. As an added incentive, the technology involved in the construction and operation of a typical dryer is simple enough to be universally applied. One attraction of solar dryers is that several designs can be built by using mostly locally available materials. Further research is required, however, with regard to materials particularly, to ensure that the units last for more than ten years. Perhaps, the main inhibitions to the use of solar dryers have to do with lack of information and the acceptability of dried products. The latter factor is of great importance when the products are cash crops.

(c) Solar Power

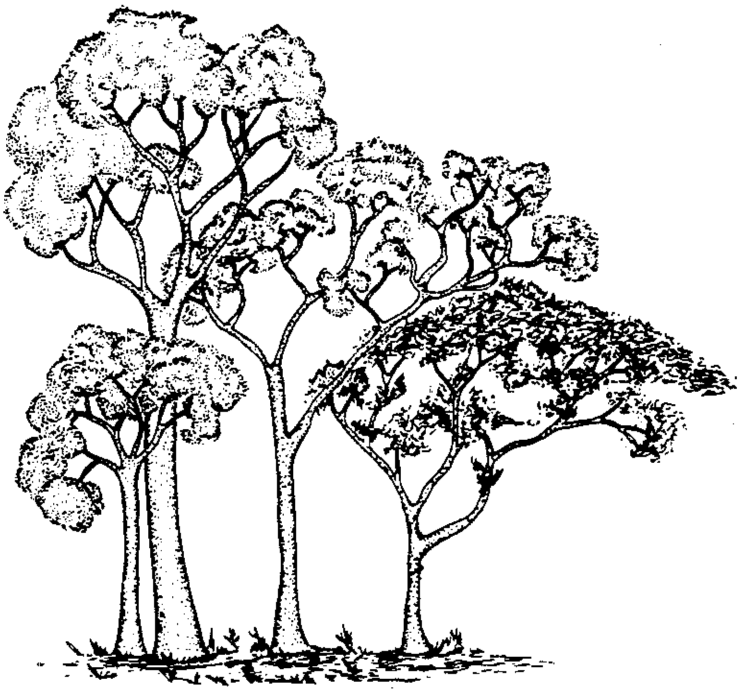
Electricity can be produced in two different ways: photovoltaic or thermodynamic. Today, only decentralized production of solar electricity can be envisaged as an economic possibility. For very small amounts of power (to 5 kW), photocells are definitely most appropriate. Beyond that level, photovoltaic and thermodynamic conversion may be competitive. While it is possible for the situation to change, it must be noted that at present, solar-generated electricity is often too costly. However, photocells are an ideal power source for remote areas and for equipments that require only little power: school televisions (20-30 W), Hertzian relays (1-100 W), air radio-navigation systems (6-400 W), railroad signals (to 500 W), and telephones in rural areas (0.5-60 W).

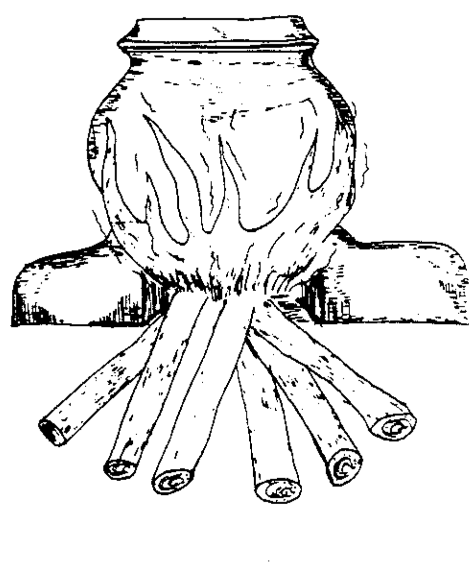
The production of high levels of electricity (1 MW and more) may be justified only when the electricity produced is integrated into one utility grid. The difficulty of storing energy for night use may impede the isolated use of solar plants. Fortunately, solar electricity works very well as a supplement to the traditional electricity sources: hydropower, fuel fired and nuclear plants. The thermodynamic conversion systems are classic: alternative engines (Rankine); steam turbines (water and organic); gas turbines. All these generation systems have been field tested, and the only problem that arises is economic in nature. However, the economics of solar power production may be improved by using cogeneration techniques, providing both thermal energy and mechanical or electrical power, and using the normally wasted heat properly. A good deal of research has been carried out to establish the capability of solar electricity (photovoltaic or thermal) to compete in the future with conventional electricity sources. In the short and medium term, solar electricity will be widespread in isolated applications only.

(d) Solar Pumps

Recent technological progress makes solar energy for water lifting, in the 100-800 W range, a realistic option under certain conditions. The solar pump system consists of a photovoltaic array, a motor and a pump. Particularly, the pump efficiencies have been improved up to 65 to 70 per cent, and the overall costs have been reduced. Typical applications are irrigation of landholdings up to two hectares with 60 m^3 of water per day through static heads of 2 to 10 m, or the supply of some 20 m^3 of drinking water per day through static heads of 10 to 30 m for a village of up to 1,500 people. However, solar pumps are still expensive, which implies that this technology is attractive only when alternatives (diesel, wind, etc.) are lacking. Investment costs are still such that pay back periods may exceed 5 years. It is expected that in a few years time the costs will fall further so as to make solar pumps more competitive among prevailing alternatives.

Bio Energy





BIOENERGY

Biomass refers to solid carbonaceous material derived from plants and animals. These include the residues of agriculture and forestry, animal wastes and wastes from food processing operations. A small amount of solar energy is used by plants in the process of photosynthesis and this trapped energy can be used in various ways. Wood and grass can be dried and then burnt to release heat. Plant material, particularly those rich in starches and sugars such as sugar-cane, wheat, etc., can be fermented to produce ethanol. Alternately, methanol can be produced by the distillation of biomass which contains considerable amount of cellulose such as wood and bagasse (residue from sugar-cane). Both these alcohols can be used to fuel vehicles and machinery, and can be mixed with petrol to make a petrol/alcohol blend. Although biomass energy is predominantly used in rural areas, it provides an important fuel source for the urban poor and many rural small and medium scale industries. In order to meet the growing demand for energy, it is imperative to focus on efficient production and use of biomass energy to meet both traditional (as a heat supplier) and modern fuel requirements (like electricity and liquid fuels). This production of biomass, in all its forms for fuel, food and fodder, demands environmentally sustainable land use and integrated planning approaches.

Detailed planning would be required from National to State, District, Taluk and Village levels. The inappropriate selection and site matching of species or management strategies can have adverse effects and lead to degradation and abandonment of land. However, the correct selection of plant species can allow the economic production of energy crops in areas previously capable of only low plant productivities. Simultaneously multiple benefits may accrue to the environment. Such selection strategies allows synergistic increases in food crop yield and decreases fertiliser applications, while providing local source of energy and employment.

Present Role of Bioenergy

Bioenergy is one of the primary sources of fuel in India. A recent study on energy utilisation in Karnataka considering all types of energy sources and sectorwise consumption reveals that, traditional fuels such as firewood (7.440 million tonnes of oil equivalent (mtoe) - 43.62%), agro residues (1.510 mtoe - 8.85%), and biogas and cowdung (0.250 mtoe - 1.47%) account for 53.20% of total energy consumption. In rural areas, the dependence on bioenergy to meet domestic requirements like cooking and water heating is as high as 80-85%. Fuel wood and agricultural residues are also widely used as fuel in rural industries like cashew and other agro processing industries, brick kilns, and in commercial sectors like hotels, etc. Detailed investigation of energy consumption in ninety villages of Kumta taluk reveals that annual per capita fuel wood consumption for domestic purposes (cooking, water heating, etc.) is 0.7-1.1 tonnes, and in rural industries, such as cashew processing (fuel wood consumption is 4.5-8.5 kgs per kg of cashew kernels), jaggery making (one tonne of fuel wood (logs) for processing 5 tonnes of sugar-cane), brick manufacture (400-800 kgs of fuel wood for making 1000 bricks), etc.

Techno-Economic Analyses of Bioenergy Systems

The fundamental forms of bioenergy use are,

(i) Traditional domestic use for household cooking, lighting and water heating (for bath). The efficiency of conversion of the biomass to useful energy is between 5 to 15%.

(ii) Rural industrial use in agro processing, bricks and tile manufacture, and pig iron where the biomass is considered as free energy source. There is generally little incentive to use the biomass efficiently, so conversion of feedstock to useful energy commonly occurs at an efficiency of 15% or less.

(iii) Biological conversion, including anaerobic digestion for biogas production and fermentation for alcohol.

The overall efficiency of biomass utilisation depends on the moisture content of the fuel and type of stoves used. Freshly cut wood contains about 25-60% moisture. The removal of a kilogram of water from wood involves an expenditure of about 620-670 kcals of heat energy. It is noticed that a reduction of 25% moisture in fuel wood causes a saving of nearly 15% of fuel wood. It is observed that dried wood with moisture content of 8% releases heat too fast and the whole log tends to burn, bringing the flame out of the stove.

Fuel Efficient Stoves

The most commonly used stoves in most households for cooking are either mud stoves or three stone stoves, also referred as traditional cookstoves (TCs). The efficiency of these stoves are less than 10%. Applying the principles of combustion and heat transfer, wood and other biomass burning fuel efficient stoves have been designed by ASTRA (ASTRA, Indian Institute of Science), also called as Astra stoves or Improved cookstoves (ICs). In Astra stoves complete combustion of fuel wood takes place with as little excess air as practicable to generate the highest temperature of flue gases. In ICs, combustion of fuel wood is carried out over a grate in an enclosed fuel box with ports of suitable size for entry of air. The grate helps in entry of air below the fuel bed to burn the char as well as for separation of ash from fuel. Air required for burning the volatile matter released as a consequence of heating the fuel (also referred as secondary air), enters through a port at a level slightly above the grate. Heat gets transferred to the pans by the mechanism of conduction, convection and radiation. Fuel efficiency studies have shown that the fuel need for cooking is about 1.92(avg)±1.02(Sd) kgs/person/day in TCs, while in ICs it is about 1.1(avg)±0.78(Sd) kgs/person/day. This means that there is a saving of about 42% of fuel by switching over to ICs from TCs. The average fuel consumption for water heating in traditional stoves (efficiency 10-16%) is about 1.68(avg)±0.80 (Sd) kgs/person/day, while in improved stoves (efficiency 35-60%), it is about 1.36(avg)±0.63(Sd) kgs/person/day. This result based on sample households shows a potential of 19 to 24% saving in improved design. Traditional stoves in most villages are without chimney. With the chimney, the efficiency of the stove increases and is about 22%. In improved stoves the fuel is allowed to burn over a cast iron grate. Air required for burning is allowed through the grate so that combustion is controlled. Rate of burning (to a temperature of 45-50°C) in improved stoves is about 30 minutes for 50 litres.

Biogas Technology

Biogas is a product of anaerobic fermentation of organic matters, and consists of about 60-70% methane, 30-40% carbon-di-oxide, etc. The inputs for biogas digesters are the wastes that are found locally; animal dung, agricultural residues, leaf litter from forests, etc. The residues are introduced into a closed digester, where, without the presence of free oxygen the responsible micro organisms work successively to convert complex organic matter into CH_4, CO_2, H_2, H_2S, etc. The optimum conditions for biogas production are: temperature 30-35°C, pH 6.8-7.5, Carbon/Nitrogen ratio 20-30, solid contents 7-9% and retention time 20-40 days. Among these parameters, temperature is the most difficult or costly to control. The gas formation virtually stops when the temperature drops below 10°C. Retention time decides the rate at which the waste is digested. The longer the time, the larger is the volume of gas produced from a given amount of waste and vice versa. Thus, if the available amount of input materials is limited, a bigger digester can be adopted to exploit the gas potential more fully; and where the waste is abundant, it can be fed at a higher loading rate into a small digester to maximise the gas production per unit volume of the digester. The optimum retention time depends on the temperature. In practice, a longer retention time is usually adopted to cope with cool seasons. There are various designs of biogas digesters such as:

(1) Floating gas holder type designed by Kadhi and Village Industries Commission (Directorate of Gobar Gas Scheme, 1979).
(2) Optimised design developed by Application of Science and Technology to Rural Areas (ASTRA) at Indian Institute of Science (Subramanian, 1984).
(3) Fixed dome type designed by University of Agricultural Sciences - Bhagyalaxmi design.
(4) Raitabandu Biogas Plant - designed by a farmer from Sagar taluk, Shimoga district to suit the needs of Malnad region.

(i) *Biogas Usage*: Biogas can be used for many purposes, mainly cooking and lighting in rural areas. It can be burned with a gas mantle or be converted to electricity using dual mode engine. The per capita requirement of gas for cooking is in the range 0.34-0.43 m^3/day (efficiency of standard burner is about 60%). The gas requirement to generate one unit of electricity (kWh) is about 0.54 m^3. The calorific value of m^3 of gas is about 4713 kcals.

(ii) *Biogas as Substitute for Fuel wood*: Socio-economic survey conducted in villages of Kolar has shown that per capita requirement of fuel wood is around 0.7-1.1 t/yr. If 30% population opts for biogas, then fuel wood saved in the district would be in the range 2.6-4.10 lakh tonnes/year.

By switching over to biogas, the drudgery involved in collection and transport of fuel wood (which takes about 5-6 hours per day) gets reduced, and also reduces cooking time from 4-6 hours (fuel wood stoves) to 1.5-3 hours (biogas stoves) a day.

(iii) *Electricity Generation*: The decentralised electricity generation system by a community biogas plant was tried out in 1987 in Pura village, Kunigal taluk, Tumkur district for illumination and drinking water facility. The biogas system is accepted and maintained by villagers due to multiple advantages like better illumination facility than kerosene lamps, convenient method of drinking water supply and better fertilizer in the form of sludge without pathogens and weeds (due to anaerobic condition and long retention time in closed digesters). A 5 kW electricity generation unit using biogas-diesel engine-genset system caters the needs of pumping domestic water and illumination in the evening (for 4 hours). Two youths have been trained to maintain and manage the system. This community system provides revenue for the village to the extent that the total revenue received through outputs exceeds the expenses for diesel and dung charges (paid to villagers). Detailed economic analyses carried out based on life cycle costing method show that at 4.3 hours/day capacity utilisation, the cost of electricity is Rs. 2.75/kWh. It is noticed that as capacity utilisation increases to 15 hours/day the cost per kWh reduces to Rs. 1.40. Comparison of decentralised biogas system with nuclear power station show that in a capital starved situation where the real discount rates are high, the cost/kW of installed capacity is lower for biogas systems compared to nuclear power plants.

This review of bioenergy production from animal residues has shown that potential solutions do exist, but there are very few in practical operation. The economics of such solutions would ultimately depend on local conditions, requirements, subsidies, etc. If farmers are forced/convinced to treat the residues for biogas prior to disposal to compost pits, it would be a valuable way to conserve fuel wood and improve the cooking environment in the kitchen.

Energy Plantations

Technically speaking, energy plantation means growing select species of trees and shrubs which are harvestable in a comparably shorter time and are specifically meant for fuel. The fuel wood may be used either directly in wood burning stoves and boilers or processed into methanol, ethanol and producer gas. These plantations help provide wood either for cooking in homes or for industrial use, so as to satisfy local energy needs in a decentralised manner The energy plantations provide almost inexhaustible renewable sources (with total time constant of 3-8 years only for each cycle) of energy which are essentially local and independent of unreliable and finite sources of fuel. The attractive features of energy plantations are: (a) heat content of wood is similar to that of Indian coal, (b) wood is low in sulphur and not likely to pollute the atmosphere, (c) ash from burnt wood is a valuable fertiliser, (d) utilisation of erosion prone land for raising these plantations helps to reduce wind and water erosion, thereby minimising hazards from floods, siltation, and loss of nitrogen and minerals from soil and (e) help in rural employment generation - it is estimated that an hectare of energy plantation is estimated to provide employment for at least seven persons regularly. Selection of multipurpose species provides a number of by-products like oils, organic compounds, fruits, edible leaves, forage for livestock, etc. Data collected from Forest Department reveals that annual woody biomass available is in the range 11.9 to 21 t/ha/yr. An energy forest raised at Hosalli village in Tumkur district to support a wood gasifier plant has annual yield of 6 t/ha/yr.

Biomass Fired Steam Power Generation System

Biomass fuelled steam power system, providing electricity as well as the process heat, has been utilised for many decades in most countries of the world. Such systems have found widespread applications in paper and pulp, plywood and metallurgical industries. In such a system, the energy in the biomass fuel is utilised through the process of direct combustion to generate steam for driving steam engine or turbine. The efficiency of these devices is around 35%. In a study on biomass fire steam power system, results show that for systems utilising biomass fuels 0 and 60% (wet basis), excess air rates between 0 and 200%, boiler efficiency 84 to 49%, steam engine efficiency 18 to 13%, overall plant efficiency 11 to 8.4% and electricity fuel ratio between 0.7 and 0.2 kWh/kg, the cost per unit of electricity ranging from 24 to 39 paise.

Wood Gasification

Biomass gasification is basically conversion of solid biomass (wood, wood waste, agricultural residues, etc.) into combustible gas mixture normally called producer or low Btu gas. The process is typically used for woody biomass and involves partial combustion of such biomass. Partial combustion occurs when air supply is less than adequate for complete combustion of biomass. It produces carbon monoxide (CO) as well as hydrogen (H_2), both are combustible gases. Conversion to gas results in loss of up to 25% energy. Use of gas can be highly efficient and hence overall efficiency could be very high. Gas can be fed directly into internal combustion engines (I.C. engines) thereby saving commercial fuels. Also, it can be employed at any scale (above few kilo watts), and hence is ideally suited for decentralised applications - shaft power, electricity or thermal energy. In case of shaft power / electricity, the gas is basically burnt inside an engine (diesel based - compression ignition engine) with pilot diesel injection to start combustion.

Biomass gasification provides a valuable fuel for both mobile and non mobile uses. Producer gas can replace natural gas, gasoline or fuel oils used to make steam for generating electricity and fire boilers, and produce heat for industries and homes. It can also be used as fuel for internal combustion engines for a wide array of purposes. Gasification is an efficient way to extract heat from biomass. It is estimated that for each 100 kcal of potential energy in solid fuels, gasification can extract about 80 kcal in hot raw gas. This is more efficient than many devices that burn biomass directly in a hearth or fire box. Producer gas can be piped short distances and used for industrial purposes like fuel kilns: brick kilns, ceramics, glass pottery, etc., for boilers in rice mills, saw mills, cashew industry or for power generation. In any case, while using producer gas for heating, the burner must be designed for operation on low energy gas.

The function of a gasifier is to convert solid carbonaceous fuel, such as wood into combustible gas by a combination of oxidation, pyrolysis and reduction process (Talib, et al., 1987). The major chemical reaction taking place are both exothermic ($C+O_2$ -> CO_2, $C+0.5O_2$ -> CO) and endothermic ($C+H_2O$->$CO+H_2$, CO_2+C->$2CO$). In order to effectively carry out these reactions, the solid fuel passes through the following zones: drying, pyrolysis, combustion and reduction. In drying zone the temperature is around 150°C and moisture in the biomass is driven off. In pyrolysis zone, at 400°C thermal break down of wood / bio residues takes place in the absence of air, resulting in the formation of methanol, acetic acid and heavy hydro carbon including tar. The solid material left after pyrolysis is primarily fixed carbon in the form of charcoal. The pyrolysis material along with the gases and the organic vapors produced passes through the combustion zone. In combustion zone, exothermic reaction takes place and the heat released is used for sustaining both the pyrolysis and the reduction reactions. The temperature in this zone ranges from 1000-1500°C. Combustion zone has controlled introduction of air.

By forcing the vapors through a narrow area directly underneath the combustion zone, organic liquids and tar formed in the pyrolysis zone are cracked. In the cracking process, heat intensity increases. The gases thus formed are drawn to reduction zone where endothermic reaction takes place. The mixture of final product gases (producer gas) consisting of 18-25% CO, 13-15% H_2, 3-5% methane (CH_4), 0.2-0.4% heavy hydro carbon, 5-10% CO_2, 45-54% N_2, 10-15% H_2O and particulate matter is drawn into the clean up system at about 250°C. In clean up system, the gas is cooled and cleaned to remove particulates and later introduced into the engine. Commercially available biomass gasification system for power generation covers the range of 3-500 kW. The major areas where this system is relevant for power generation in a decentralised manner are:

(a) Village electrification in remote areas which have adequate biomass resources,
(b) Energisation of a number of pumpsets located in a cluster,
(c) Captive power for industrial units located in rural areas having extensive land area which can be devoted for energy plantations, and
(d) Captive power for industries that have biomass waste processes such as paper mills, saw mills, rice mills, etc.

Wood Gasifier Based Electricity System

Community wood gasifier installed at Hosalli, a non electrified village in Tumkur district, by I.I.Sc demonstrates that, these units can be self sustaining and technically and economically feasible decentralised systems if managed properly. Main features of this system are:

(1) The 5 kW wood gasifier-diesel system in operation since 1988, meets the lighting (for 4-5 hours/day) and drinking water requirement of all 43 households.

(2) An energy plantation in 2 ha village land has been raised (in 1987) consisting of *Leucaena leucocephalla, Dalbergia sisso, Eucalyptus* hybrid, *Cassia siamea, Acacia auriculiformis* and *Casuarina equisetifolia* with density of 6600 plants/hect and approximate annual productivity of 6 t/ha/yr.
(3) The annual wood requirement of the gasifier is 5.1 tonnes at the rate of 1.2 kgs/kWh. Households are provided with two electrical lighting points of 40 W and 25 W bulbs. Water is pumped using a 2 kW submersible pump from a borewell, at a depth of 87 m, for drinking and domestic use. Apart from this, the energy is used for 9 street lamps and a flour mill. This system is being managed (technical and financial management) by three trained village youths.
(4) Diesel replacement up to 85% is achieved under favorable operating conditions.

Capital cost of gasifier, engine, generator, accessories, wood chipping machinery, energy forest and building is about Rs.63,600. Life of gasifier and engine is considered to be 50,000 and 20,000 hours respectively. At an operational level, annual maintenance cost is taken as 5% and 10% of cost for gasifier and engine respectively. Economic analysis carried out using the discounted cash flow techniques (NPV) method (considering total life cost and benefits) shows that at the current level of operation of 4 hours per day, the cost per unit of electricity is about Rs. 3.50/kWh. However, analyses show that cost per kWh can be reduced to Rs. 2.50 by increasing the hours of operation to 20 hours per day.

Draught Animal Power (DAP)

The draught power of an animal depends on the species, breed, size, body weight and the intensity of feeding. The energy output is also influenced by climate and terrain, training and management factors, nature of work and finally, but decisively, the implement (agriculture tools) efficiency itself. Majority of draught animals (DAs) produce between 0.3 to 0.6 kW on a sustained basis. Assuming a conservative average of 0.4 kW per DA, the power output for an estimated 300 million DAs in the world may be in the order of 120 million kW. Replacement of a majority of these animals by tractors appears unfeasible in the foreseeable future in most low-income countries.

The DAP system can fulfill its potential role only if conscious attempts are made to upgrade it. The following procedures would certainly enhance DAP's contribution to the rising demand for energy in farming:
(a) increase the number of days of utilization of DAs,
(b) better food and health care for animals should mean increased output,
(c) better implements and carts enable better utilization of DA energy potentials,
(d) better recovery and use of by-products during the animal working life and after death, will improve the economics of the DAP and
(e) breeding schemes can improve on motive power and efficiency of the DAP system.

(i) *Draught Animal Pumping*

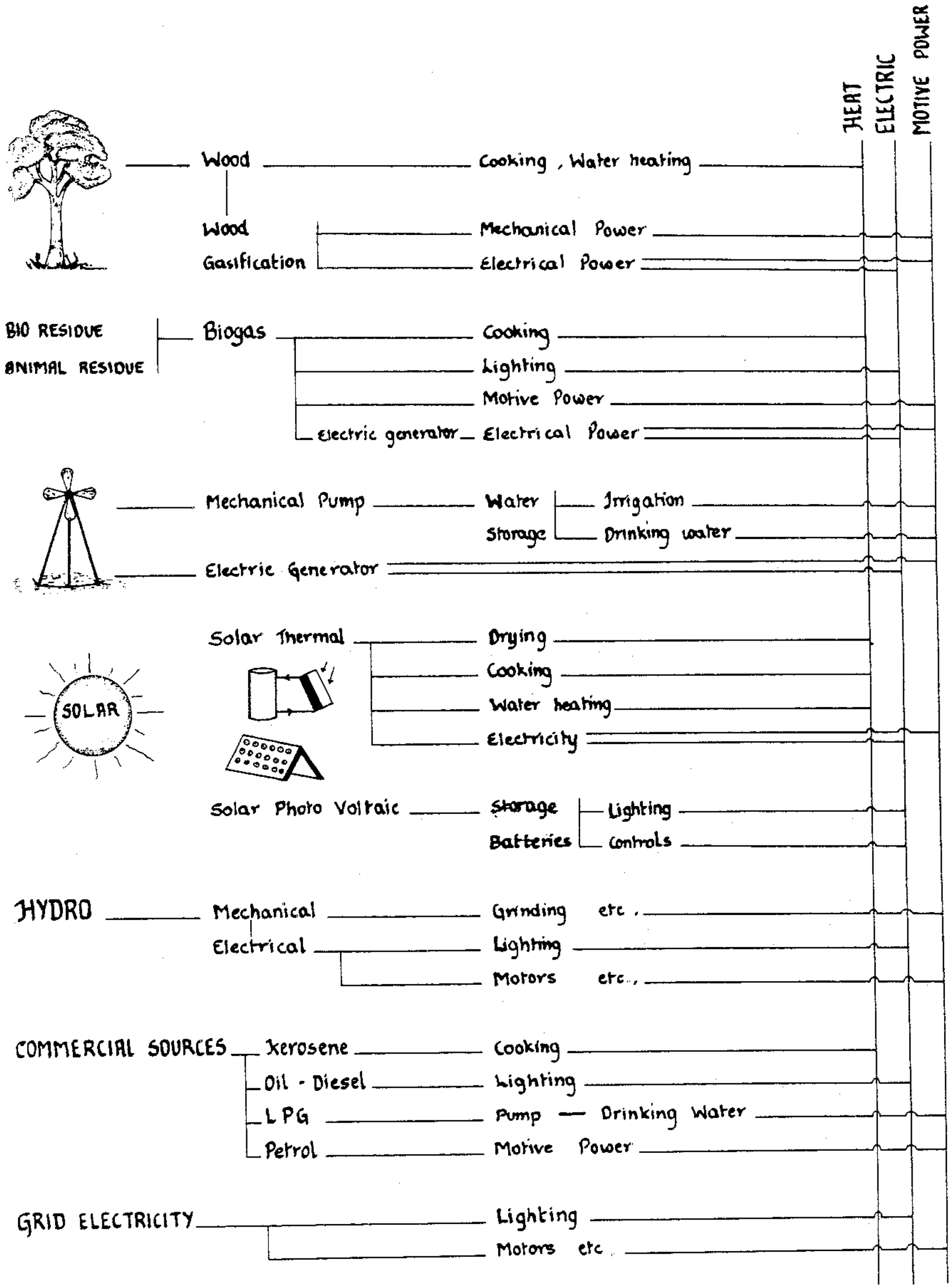
The gross energy expenditure of a working bullock can be calculated as the energy consumed daily as food by the animal, minus the energy in its dung. This method gives a daily gross energy input for a bullock as about 97,200 kJ. If this energy is supplied to the animal as cereal, it will need approximately 6.7 kg/day. Useful work production of a bullock is estimated at 7,920 kJ/day, which puts the efficiency of an animal at around 8 per cent.

(ii) *Draught Animal Transport*

Freight in most regions of the developing countries is often small in weight, if not in volume, and the produce in the rural areas rarely exceed 750 kg (an average discerned from a survey of Indian cart operations). Animal drawn vehicles are economical for loads ranging from half to two tonnes over distances up to 40 km in the course of a single day. Trucks require at least five tonne loads over distances of 100 km or more for 250 to 300 days of the year, if operations are to break even. In contrast, animals work only for 50 to 100 days in conjunction with carts. In the carrying of sugar-cane, cotton, tobacco, wood for fuel, hay, bran for dry feed, fertiliser, and manure in the rural areas, animal drawn vehicles enjoy a distinct advantage over trucks. They are thus extensively used for intra-village and inter-village transport. The animals are used for ploughing, tillage, carting and a variety of farm operations so that the farmer is able to spread the cost of maintenance over a number of operations. Cart designs are highly commodity-specific. Large-volume and low-density loads call for a different kind of platform structure than concentrated commodities like firewood, coal, brick, etc. In order to improve on the efficiency of animal drawn vehicles for rural transportation, following measures should be taken:

- improvement of vehicle design (pneumatic tyres, bearings, axles, etc.),
- improvement of harnessing of animals (in present designs the animal not only hauls the combined weight of cart and freight, but also carries an appreciable weight of its own body),
- improvement of animal breeding (this measure eventually will lead to increased and more efficient motive power).

The proper audit of existing energy sources and the pattern of energy end use by different activity sectors of regional economy is essential for framing the future plan for energy strategy for alternative resources.



An Integrated Regional Energy System

ENERGY PLANNING

Currently, energy planning in India is not an integrated activity. Since there are many energy sources and end uses, many organisations and agencies deal with different aspects of energy. The plans for electricity, coal, oil and fuel wood 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, road side trees, construction of giant hydroelectric 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 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 - end use 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).

Ecologically sound development of the region is possible when energy needs are integrated with environmental concerns at the local and global levels, for which an integrated planning framework would be necessary. The central theme of the integrated energy plan would be to prepare and implement the area based decentralised energy plans for meeting energy needs for subsistence, development of alternate energy sources (renewable, non-renewable) at the least cost to the economy and environment, and linking the micro level plans with national economic planning and development programs, including those for energy, agriculture and rural development sectors.

Towards the goal of implementing analytical methods for integrated energy planning, computerised Decision Support System (DSS) is used. This provides useful assistance in the analyses of available information, optimal allocation of resources for various end uses, the projection of future scenarios and the evaluation of alternative scenarios.

The energy plan development exercise consists of the following components:

(i) Database Development: Energy planning depends on the availability and quality of data, and gaps and deficiencies in the database can be identified as a result from planning. The database serve as input to demand and supply analyses. The objective of the database is to identify, generate and assemble information required for energy analyses. It is part of the iterative and continuous process of energy planning.

(ii) Sectorwise energy demand: This involves the survey of the present energy consumption in different sectors for various end uses covering the type, magnitude and composition of fuel, trends, seasonal constraints and preferences in consumption; and estimation of energy demand based on the sample survey data.

(iii) Assessment of the supply situation: This involves analysis of present energy supply system; assessment of woody and other bioresources; assessment of renewable sources potential, such as, solar, wind and hydro; and study of supply system of commercial energy.

(iv) Development of an energy plan for the district: Based on the estimated supply and demand, an energy plan to meet the energy demand would be worked out in accordance with the development priorities. Techno-economic analyses of various energy technologies would be carried out to find out the technical and economic viability of the system. An energy plan at district level would be proposed based on the Decision Support System approach. Analyses of the importance of community participation in energy conservation, planning and identification of measures that will enhance the level of participation.

(v) Implementation and management: With the knowledge of administrative structure at district level and agencies implementing the energy development program, a suitable institutional structure would be suggested for implementing and managing the energy plan.

District is taken as the unit of energy planning since (i) district is the basic administrative unit for implementing all developmental programs and (ii) district level planning will facilitate integration between national planning exercises and planning at lower levels.

Energy Plan Implementation

The framework of energy planning for a region or implementation of the ecologically sound technologies, discussed so far, can become operational only after overcoming a large number of barriers and constraints, which usually come in the way of integration of energy supply programmes with the energy needs at the local level. These constraints include, among others, lack of mechanism at the local level to carry out assessment with the involvement of the potential beneficiaries, energy planning mechanism, project formulation and implementation. Proper coordination between the energy sector and the overall planning and development machinery is needed in a region for successful implementation of the energy plan. These and related issues are discussed in the following section.

Management Aspects of Energy Planning

The current approach to planning in the energy sector does not offer any significant role to the district or local level institutions. Moreover, the coordination needed between the energy sector and the overall planning and development at district, taluk and village levels is missing. Although forestry planning is carried out by the district forest department, its most significant aspect pertaining to energy is extremely weak and receives very little attention in the planning exercises of the sector. The biomass situation in hilly taluks has, therefore, gradually worsened and has reached a point of crisis. This deteriorating situation obviously demands immediate attention in two directions.

1. Strengthening of local institutions for energy development.
2. Promotion of coordination between institutions concerned with the energy development and overall planning at different hierarchical levels on the one hand and between institutions concerned with research and development on the other.

Strengthening of Local Institutions for Energy Development

Local government institutions at the district level (zilla panchayath) and below (village panchayath) can contribute positively in many ways towards energy planning and development. These include: (a) generation of energy databases, (b) promotion of community participation, and (c) extension and training.

Generation of Energy Databases

The elaborate structure of the local government, which goes down to the village panchayath and its electoral wards can be effectively used for the generation of useful data. A simple methodology for obtaining information at both village panchayath and household levels has been demonstrated in this study. It may be pointed out that, besides collection of basic facts and figures, this kind of micro-level survey can also be used to assess problems and solutions perceived by local groups. This was particularly true of fuel wood for which the rapid rate of forest depletion, and not the limited area under forest, was conceived as a major problem or stress. This reckoning obviously is a positive factor and needs to be used effectively by involving representatives of such groups in the energy planning and development processes at the grassroots level. The household survey generated extensive data on energy which provided insights into energy consumption patterns (communitywise and landholding categorywise) use of cooking devices, possession of energy appliances, and the changing trends in energy use in the domestic sector. These surveys also indicated that the existing system of local government can be easily mobilised to build an effective energy information system for planning and development at the district and local levels without incurring any significant additional financial burden.

Promotion of Community Participation

The local government institutions also need strengthening to promote community participation in the planning and development process. These grassroots institutions, besides carrying out local projects with the involvement of communities within their jurisdiction, can also provide a powerful lobby through which communities can negotiate for services from sectoral agencies or departments of the Government.

Unfortunately, the role of local councils in development efforts has been mostly underrated by planners, and is quite often overlooked in the implementation of energy projects, resulting in their failure to achieve the desired objectives. Energy plantation projects provide a case in point. It has been observed that, even when the political will is there and the funds are allocated, implementing a large-scale afforestation (plantation) campaign is an unexpectedly complex and difficult process. Planting millions of trees and successfully nurturing them to maturity is not purely a technical task, like building a dam. Further, tree planting projects almost invariably get enmeshed in the political, cultural, and administrative tangles of a rural locality. The nature of their success, therefore, is largely governed by the intensity of community involvement through local government or other means. Central or State Government stimuli in technical advice and financial assistance in such cases are ineffective unless community members clearly understand why lands to which they had traditionally free access for grazing and wood-gathering are being demarcated into plantations. Therefore, it is expected that they will view the project with suspicion or even hostility.

Also, the conservation efforts cannot succeed without strong commitment from the community. A major source of energy in the rural hill districts, is biomass/bioenergy. Slight improvements in the efficiency of energy use from this source can substantially improve the physical quality of life of the rural people in such districts without any increase, or even decrease, in the supply of primary energy. Adoption of appropriate cooking devices (improved cooking stoves) alone can bring a major change in this direction. Likewise, the replacement of dung fuel with biogas can provide both energy and manure on one hand and improve the quality of the environment on the other.

There is a need to distinguish the difference between subsistence energy requirements and energy required for economic development. As far as the subsistence energy requirement is concerned, the existing energy consumption pattern, with the major chunk being met through bioresources for thermal energy requirements, indicates the importance of intervention in this sector. The low conversion efficiency of energy devices (using bioresources) is a significant aspect in the context of designing energy intervention plans. In areas with surplus resources, the implementation of the efficiency measures have to follow an effort to convince and educate local people about the importance of efficient usage of resources. In the biomass scarce region, the significance of the interventions for fuel switching (such as solar energy for water heating, drying, etc.), improvement in end use efficiencies and augmenting supplies (through social forestry and energy plantations on barren land) are to be adopted.

Extension and Training

Usually, energy programmes require a system by which end use devices, such as Improved Cook stoves (IC's) and biogas are disseminated in accordance with the programme objectives. Dissemination mechanisms become extremely important when the end use device is new to the user. Unfamiliar technology obviously raises a number of questions that can be answered only when the technology is successfully implemented and comprehensively evaluated. In order to strengthen the dissemination process, there is a need for rural energy centres. The purpose is to demonstrate the energy techniques that are suitable for local conditions and see that these techniques are practical and reliable from the farmers and locals' point of view. The objectives of the Regional Energy Centres should be to:

(i) study energy supply and consumption patterns to identify village needs,
(ii) demonstrate the use of efficient energy devices and disseminate, monitor and evaluate appropriate technologies,
(iii) augment the fuel supply situation through energy plantations and other decentralised means, and
(iv) analyse the impact of energy-related activities on the socio-economic development of the village and improvement of its environment.

Besides promotion of energy, the local panchayaths by themselves constitute a very strong extension network. Currently, the energy development agencies at the State level have little or no field staff. As a result, their rural energy programmes have suffered. The village panchayat can help fill this gap and can provide valuable assistance through quick dissemination and extension work.

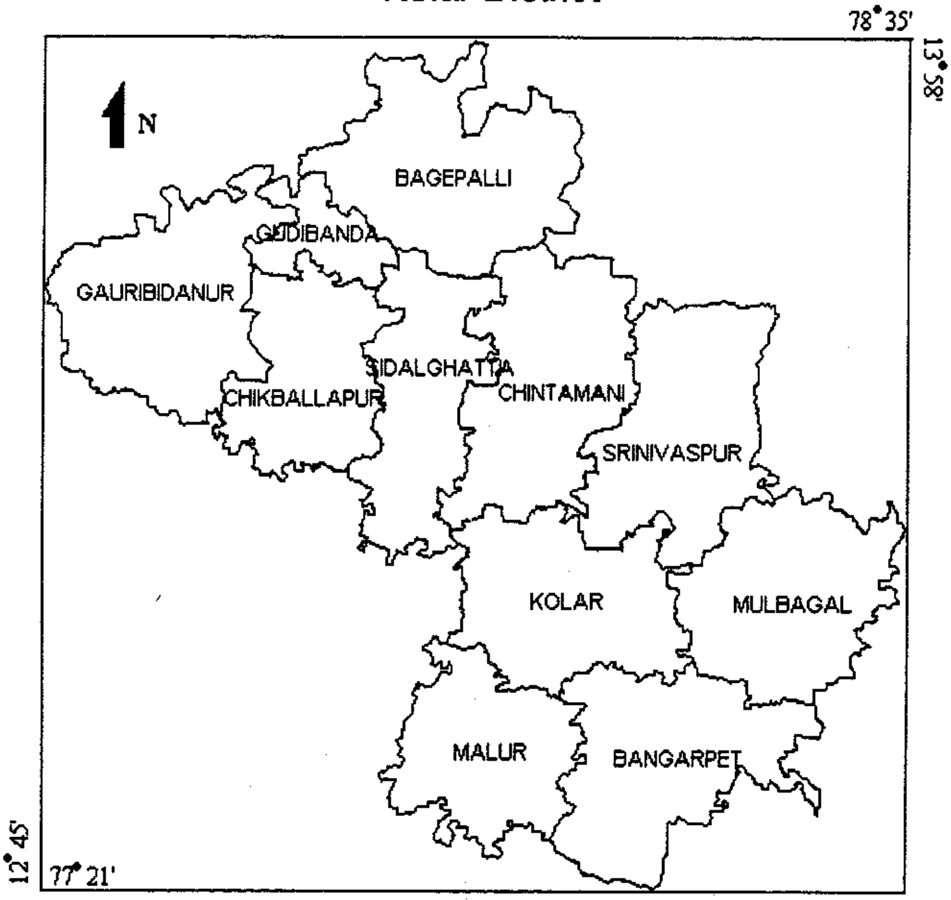
Institutional Coordination and Energy Development Strategy

The implementation of rural energy programmes requires the involvement of a large number of official agencies working under different departments, private and public manufacturers, voluntary agencies, artisans, R and D institutions, village communities, social organisations and private individuals. This requires a considerable degree of coordination at the village, taluk and district levels.

At the district level, this function should be performed by the District Planning Officer who can also assist as a district level Project Implementation Officer. Besides coordination among the different tiers of planning institutions, there is a great need for networking R and D institutions, manufacturers and other concerned groups, e.g., community organisations and NGO's involved in rural energy planning and implementation. Finally, the success or failure of regional energy programmes/projects in a district will also be determined by strategies adopted and logistics provided. After a rural energy technology has been field-tested and found suitable for large-scale implementation in a district, the major task for its implementation will involve formulation of strategies based on the following factors.

(i) Speed or rate of progress of programme implementation,
(ii) Provision of funds and procedures for disbursing loans and subsidies,
(iii) Making raw materials available for installation of energy transmitting devices,
(iv) Creation of infrastructure for manufacturing energy equipment (it has also to be decided whether the public organisations should manufacture it or whether private entrepreneurs should be encouraged by providing incentives),
(v) R & D and maintenance networks to promote the design of energy equipment, training of artisans and mechanics for fabrication, installation as well as maintenance, and
(vi) Monitoring and evaluation to facilitate timely feedback and assess the success of the programme.

Kolar District



Taluk	Area (in hectares)	Population (1991)	Population density (per hectare)		Livestock density (per hectare)
			Rural	Urban + Rural	
BAGEPALLI	93,265.58	1,45,900	1.44	1.56	0.67
BANGARPET	85,815.60	3,87,830	2.50	4.52	0.85
CHIKBALLAPUR	64,383.91	1,69,233	1.92	2.63	0.73
CHINTAMANI	88,933.46	2,35,711	2.09	2.65	0.91
GAURIBIDANUR	89,457.56	2,40,115	2.36	2.68	0.78
GUDIBANDA	22,703.53	45,794	1.69	2.02	1.09
KOLAR	79,071.88	2,84,079	2.55	3.59	0.73
MALUR	64,482.21	1,73,860	2.39	2.70	0.68
MULBAGAL	82,382.65	2,02,893	2.04	2.46	0.83
SIDALGHATTA	66,478.91	1,68,251	2.16	2.53	0.99
SRINIVASPUR	86,588.30	1,63,196	1.71	1.88	0.74
TOTAL	8,23,563.59	22,16,862	2.09	2.69	0.80

Kolar District: Case Study

The Kolar District is located in the southern plains region of the Karnataka State, India. It lies between 77^0 21' to 78^0 35' east longitude and 12^0 46' to 13^0 58' north latitude and extends over an area of 8,225 sq. km. The population was 16.99 lakhs in 1991 (as per census report). For administrative purposes the District has been divided into 11 Taluks. There are 15 towns and 3,325 inhabited villages in the District.

Kolar belongs to the semi arid zone of Karnataka. In the semi arid zone apart from the year to year fluctuations in the total seasonal rainfall, there are also large variations in the time of commencement of rainfall adequate for sowing as well as in the distribution of drought periods within the crop growing season. Kolar district depends upon the distribution of rainfall during the southwest and northeast monsoon seasons. Out of about 280 thousand hectares of land under cultivation 35% is under well and tank irrigations. There are about 951 big tanks and 2934 small tanks in the district.

The average population density of the district is 2.09 persons/hect (rural) and 2.69 persons/hect (rural+urban). The population density ranges from 1.44 (Bagepalli), 1.69 (Gudibanda), 1.70 (Srinivaspura) to the maximum of 2.55 (Kolar). While, the population density in taluks lies within this range - Bangarapet (2.52), Malur (2.38), Gauribidanur (2.36), Sidlaghatta (2.16), Chintamani (2.10), Mulbagal (2.04), Chikkaballapur (1.92). The average livestock density of the district is 0.81. It ranges from 0.68 (Bagepalli, Malur), 0.70 (Kolar) to a maximum of 1.09 (Gauribidanur). Extent of forest cover in the district is about 6.5%. It ranges from 1.71 % (Bangarpet), 2.3% (Malur), 2.78% (Kolar) to 15% (Srinivaspura) and 20% (Chikballapur). Taluks are grouped in to three groups (<10 %, 10-20%, and >20% cover) based on percentage of forest cover . Chikballapur and Bagepalli have forest cover > 20%, Gudibanda and Srinivaspur are in the range 10 - 20% while remaining taluks have forest cover < 10%.

Assessment of Energy Resources in Kolar district:

During last decade various developed nations all over the World have demonstrated successfully the advantages of adopting new and evolving spatial and temporal analysis tools such as Geographic Information System (GIS), Remote sensing (RS), Image processing and Computerised Data management in Planning of Management of natural resources. But in developing nations GIS still remains unexploited for natural resources and environmental planners. Water and Biomass resources constitute major component in planning of regional energy systems. Through this study we try to chart an economically and environmentally sustainable regional energy supply and demand (sectorwise) data base for Kolar district in Karnataka. Kolar district is situated in dry arid zone. The change in land use patterns and various large scale developmental projects has affected the fragile ecosystem considerably. Due to this short sighted development approaches have resulted in severe water scarcity and fuelwood shortage in some of taluks. In view of these, it is necessary to identify, measure and monitor the cumulative effects of land use decisions across space and time. Regional energy planning encompasses the simultaneous consideration of hydrological, soil and bio resources, the need for making better use of analytical tools and approaches which address spatial and temporal variability is critical. The application of innovative information technologies such as GIS in planning exercises helps in better understanding multi variate dimensions of ecosystem management. Hydro and bio resources are the areas where the use of GIS holds great promise as an integrative planning tool. Hydro resources development and management includes issues such as arable and non arable land issues such as crop and livestock management, surface and ground water management and conservation, soil conservation, forest utilisation and human settlement concerns. Secondary data collection: such as demographic, geographic, social, economic, ecological and cultural (all these are found to have indirect influence on energy system (supply and demand) from government agencies at district and state head quarters is collected and are being computerised. Field survey is being undertaken in Kolar district, to assess the availability of various fuels presently meeting the energy needs. Assessment include both the availability and supply of biomass fuels (fuelwood, crop residues and animal residues) as well as commercial fuels (electricity, kerosene, diesel, LPG etc.)

An integrated approach involving compilation of data from government agencies and institutions, application of spatial and temporal analyses using remote sensing data, Geographic Information System (GIS technique) and conventional field survey (ground truthing) have been adopted in this study. The vegetation map for Kolar were prepared based on the interpretation of IRS-1C satellite imageries, using the visual interpretation keys such as tone, colour, texture, pattern, association, size, shape, topography and drainage.

The resource base in Kolar under each sector such as forests, agriculture, horticulture and animal residues are analysed spatially. Also, an attempt is made to illustrate the present role of biomass energy, the resource base for future development, some promising conversion technologies and uses. Biogas, energy plantation and biomass gasification are the most promising bioenergy technologies.

RESULTS AND DISCUSSION

The bioresource availability and demand situation in Kolar Taluk is analysed using a spatial and temporal tools such as GIS and imagery analyses. This approach helps in accurate assessment of resources in a region especially in bioresource assessment. The results of each of the thematic maps generated are discussed below:

Forests provides both tangible and non tangible benefits towards amelioration of soil, protection of environment besides economic benefits through timber, minor forest produce, fuel and other products.. Both conventional (quadrat sampling techniques) and recent method of usage of satellite imagery (remote sensing) are used to assess bio resources available in the region. Secondary data collected from the forest department shows that 7 taluks have forest cover less than 10%, 2 taluks are in the range 10 - 20% (Gudibanda and Srinivaspura) while, remaining two taluks (Bagepalli and Chikballapur) have forest cover greater than 20%. Actual resource cover based on conventional method and satellite remote sensing was carried out for Kolar taluk. Woody biomass annual availabilities in Kolar taluks taking into account woody biomass productivity of 3.6 t/h/yr (evergreen, semi evergreen), 3.9 t/ha/yr (deciduous) and 0.9 t/ha/yr (Scanty and Scrub vegetation).

Bio Energy from Animal Residues:

Livestock:

Livestock are an important component of an agro ecosystem. For instance, livestock provide the critical energy input to the crop lands required for ploughing, threshing and other farm operations. Animal dung provides essential nutrients required for soil fertility and crop yields in the form of organic manure. Data collected from respective Taluk's Veterinary Department regarding livestock population. Livestock density (cattle and buffaloe), talukwise in Kolar district is given in Table 1.

Table 1: Talukwise density (number of villages in each range) in Kolar District:

Taluk	<0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5	>2.5
Bagepalli						
Bangarpet	138	114	70	33	12	23
Chikballapur	100	65	22	26	14	27
Chintamani	140	121	69	42	17	19
Gauribidnur	81	81	37	18	7	13
Gudibanda	41	28	15	9	5	8
Kolar	132	130	70	15	15	0
Malur	143	123	57	18	11	13
Mulbagal	160	96	54	17	6	13
Sidalghatta	140	49	35	13	5	48
Srinivaspur	151	92	47	22	9	27

This shows that in Kolar taluk 132 villages have an average density less than 0.5 (livestock/hectare), 130 villages have density in the range 0.5 - 1.0, 70 villages have a density 1.0 -1.5, while remaining 30 villages have density greater than 1.5.

Quantity of the dung yield per cattle varies from place to place - It is seen that dung available per animal (cattle) is about 3-7.5 kg/adult animal, buffaloes 12-15 kg, stall fed buffaloe about 15-18 kg, hybrid ones about 15-18 kg. By considering lower figures (such as 3 kg per animal for cattle, 12 kg/animal for buffaloes), total dung available is about 3,71,991 kg/day. With the assumption of 0.036 m^3 of biogas yield per kg of cattle/buffaloes dung, we estimate that total quantity of gas available (if all is used for biogas) is about 13,391 m^3/day. It is estimated that per capita requirement of gas is about 0.34-0.43 m^3/day for domestic purposes. Which means, that gas generated by animal dung is sufficient to meet the requirement of 19.62% of total population of Kolar taluk.

Fuelwood demand in Kolar:
Fuelwood requirement ranges from 1.3 kg/person/day to 2.5 kg/person/day in Kolar.

Commercial energy consumption in Kolar:
Household survey shows that the electricity consumption for domestic purposes is about 1.16 kWh/person/month and Kerosene is about 0.72 litres/person/month.

Total energy Consumption in Kolar:
Kolar depends mainly on non commercial forms of energy. Non commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues, charcoal and cowdung, while commercial energy's share is 16%, met mainly by electricity, oill etc. The data is compiled from various agencies shows that the commercial energy sources like oil, electricity provides only a small part of the energy scene of Kolar. The major energy share of non commercial energy comes from firewood (Table 2).

Table 2: **Sourcewise Energy Consumption**

Energy Source	% share
Fuelwood. Bio residues etc.	83.995
Electricity	11.940
Kerosene	2.993
Diesel, Petrol etc.	1.072

Status of Bio Resource:
The ratio of productivity and fuelwood demand is computed to get an idea of level of bioresource availability in Kolar. The availability to demand ratio ranges from 0.33 (if fuelwood demand is taken as 2.5 kg/person/day) to 0.64 (if fuelwood demand is taken as 1.3 kg/person/day). The ratio being less than one indicates that there is bio resource scarcity. Bioenergy planning builds an adequate data and also supports effective policy making. Bioenergy planning 'works' if it directs resource allocation and leads to further sound government interventions amongst other energy options.

ENERGY ALTERNATIVES

Fuel Efficient Stoves:
Ssaving of about 42% in the quantity of fuel is possible, switching over to IC's from TC's.

Biogas Technology:

Villagewise biogas availability and demand is computed and mapped for the following four cases.:

Case I: taking dung yield for cattle as 3 kg/animal/day, for buffaloe 12 kg/animal/day. Per capita requirement of biogas as 0.34 m^3/day. Table 3a lists, percentage population domestic energy requirement can be met by biogas option.

Kolar taluk data shows that in 132 villages biogas can meet energy demand of 15% of population. In 130 villages biogas potential is sufficient to meet 15-30% of population's energy requirements. In 30 villages Biogas can meet energy demand of more than 45% of village population.

Case II: taking dung yield for cattle as 3 kg/animal/day, for buffaloe 12 kg/animal/day. Per capita requirement of biogas as 0.43 m^3/day. Results are tabulated in Table 3.2.

This shows that in 171 villages biogas can meet energy demand of 15% of population. In 137 villages biogas potential is sufficient to meet 15-30% of population's energy requirements.

Case III: taking dung yield for cattle as 7.5 kg/animal/day, for buffaloe 15 kg/animal/day. Per capita requirement of biogas as 0.34 m^3/day. Results are tabulated in Table 3.3.

This shows that in Kolar 116 villages can meet domestic energy requirement of more than 45% of population, In 84 villages potential can meet 30 - 45% of population.

Case IV: taking dung yield for cattle as 7.5 kg/animal/day, for buffaloe 15 kg/animal/day. Per capita requirement of biogas as 0.43 m^3/day. Results are tabulated in Table 3.4.

This shows that in 99 villages of Kolar taluk, biogas can meet energy demand of 15% of population. In 112 villages biogas potential is sufficient to meet 15-30% of population's energy requirements. 30-45% of population energy requirements is met in 86 villages by switching over to biogas. About 65 villages have potential which can meet more than 45% of population requirements.

Table 3.1: Case I - Talukwise Biogas potential (number of villages in each range) in Kolar District:

	Percentage of population - Domestic Energy requirement met by Biogas option					
Taluk	<15	15 -30	30- 45	45 -60	>60	
Bagepalli						
Bangarpet	235	119	17	5	14	
Chikballapur	123	59	30	15	27	
Chintamani	152	149	70	23	14	
Gauribidnur	80	96	42	8	11	
Gudibanda	45	40	12	3	6	
Kolar	132	130	70	15	15	
Malur	184	131	26	11	13	
Mulbagal	195	108	23	6	14	
Sidalghatta	135	65	32	8	50	
Srinivaspur	147	120	45	14	22	

Table 3.2: Case II - Talukwise Biogas potential (number of villages in each range) in Kolar District:

Taluk	<15	15 -30	30- 45	45 -60	>60	
Bangarpet	294	71	9	9	7	
Chikballapur	132	70	23	9	20	
Chintamani	181	172	37	9	9	
Gauribidnur	105	98	23	2	9	
Gudibanda	60	34	6	1	5	
Kolar	171	137	37	9	8	
Malur	249	81	18	8	9	
Mulbagal	234	83	14	6	9	
Sidalghatta	156	61	22	14	37	
Srinivaspur	176	118	31	9	14	

Table 3.3: Case III -Talukwise Biogas potential (number of villages in each range) in Kolar

Taluk	<15	15 -30	30- 45	45 -60	>60	
Bangarpet	109	100	105	46	30	
Chikballapur	85	38	33	34	64	
Chintamani	106	53	91	78	80	
Gauribidnur	47	46	64	41	39	
Gudibanda	28	13	29	17	19	
Kolar	81	81	84	61	55	
Malur	112	94	83	37	39	
Mulbagal	130	56	92	31	37	
Sidalghatta	102	36	42	30	80	
Srinivaspur	94	49	77	59	69	

Table 3.4: Case IV-Talukwise Biogas potential (number of villages in each range) in Kolar:

Taluk	<15	15 -30	30- 45	45 -60	>60	
Bangarpet	131	149	78	11	21	
Chikballapur	97	41	46	20	50	
Chintamani	115	87	113	51	42	
Gauribidnur	60	64	68	25	20	
Gudibanda	31	27	27	11	10	
Kolar	99	112	86	39	26	
Malur	129	123	67	20	26	
Mulbagal	143	99	63	19	22	
Sidalghatta	114	50	43	17	66	
Srinivaspur	105	82	83	41	37	

Solar Energy:

The empirical relationships between global radiation (GR) and climatological parameters such as sunshine, mean daily temperature, relative humidity, specific humidity, minimum and maximum temperature and rainfall (based on data at Bangalore) are used to compute global radiation (GR-kWh/Sq.m.) for Kolar. Kolar has GR range of 5.2-6.77 during January-May and is in range of 4.6 - 5.1 during monsoon months, July-September.

Table 4: **Global Radiation (monthwise) in Kolar, kWh/day**

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
GR	5.28	6.69	6.77	6.80	6.41	5.43	4.64	4.96	5.16	5.48	5.20	4.70

Amount of solar energy that could be harnessed by utilising 5% of present waste land available in Kolar district as solar collector area, is found to be of the order of 169 million units (mkWh). Cost of electricity generated from Solar-Thermal technology ranges from Rs. 6.85 (at 30% efficiency, 0.45 load factor), Rs. 4.74 (at 30% efficiency, load factor 0.65) and Rs. 3.62 (at 30% efficiency and load factor 0.85).

The abundance of the solar resource can be illustrated by comparing the land requirements of solar (thermal or PV) with those of hydro or energy plantation projects. Except for run-of-river projects and for high head sites in deep gorges, the land requirements for hydro electric projects at today's conversion efficiencies, averaging around 25 to 45 times. This means that solar energy is capable, in supplying 5 to 10 times electricity demand of our state while occupying land areas less than currently used by hydro electric projects.

Wind Energy:

The monthly average hourly wind speed with monthly average power density (W/Sq.m.) is computed for Bagepalli and Chintamanii based on hourly wind speed data of 24 months. The monthly average hourly wind speed is maximum in the month of July for Bagepalli (17.9 kmph) and Chintamani (17.8 kmph). The mean annual wind speed at Bagepalli is 10.84 kmph and corresponding power density is 20 W/Sq.m.

Table 5: **Wind Potential at Bagepalli, Chintamani (Kolar district)**

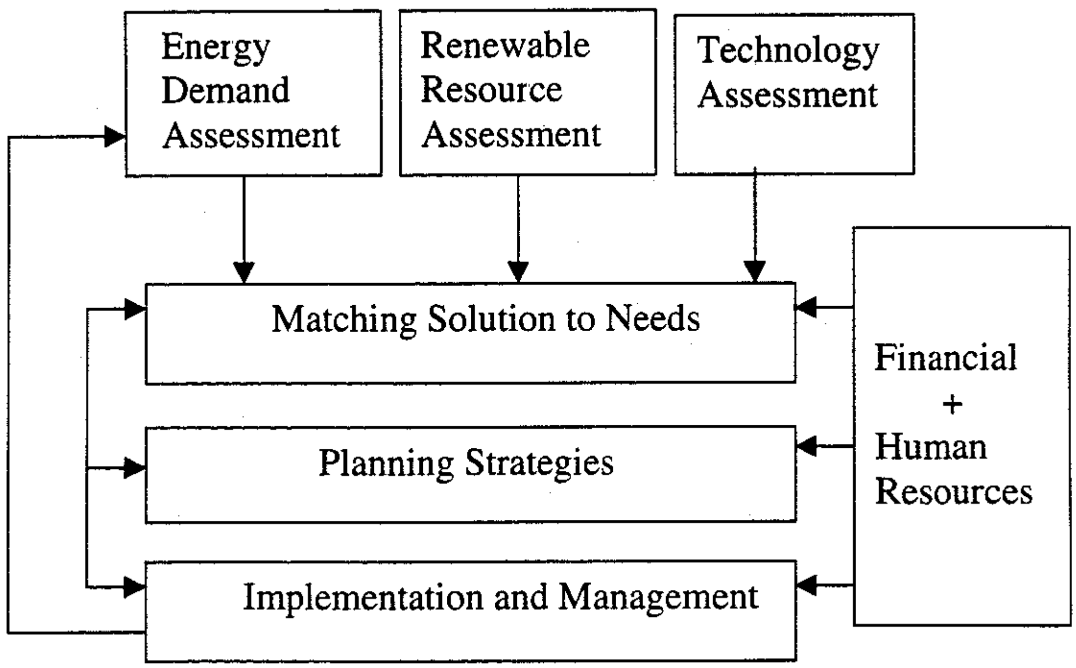
Month	wind Velocity (kmph) Bagepalli			Power Density (W/sq.m) Bagepalli			Wind velocity (kmph) Chintamani			Power Density (W/sq.m) Chintamani		
	M	M1	M2	M	M1	M2	M	M1	M2	M	M1	M2
Jan	11.1	12.3	10.4	7.88	10.72	6.48	8.7	11.4	7.0	3.79	8.54	1.98
Feb	10.9	13.4	9.4	7.41	13.76	4.75	10.0	13.0	8.1	5.72	12.56	3.04
Mar	11.8	13.4	10.8	9.29	13.61	7.12	11.7	13.5	10.5	9.06	13.91	6.55
Apr	10.3	12.1	9.3	6.13	9.93	4.51	10.6	12.1	9.8	6.68	9.93	5.28
May	13.2	15.6	11.7	12.89	21.28	8.98	13.0	14.8	12.0	12.32	18.17	9.69
June	17.9	23.1	15.0	32.46	69.77	19.10	15.8	19.2	13.8	22.33	40.06	14.88
July	15.9	20.0	13.3	22.79	45.37	13.34	13.9	16.6	12.2	15.23	25.94	10.30
Aug	17.3	23.1	13.9	29.39	69.97	15.24	17.8	21.2	15.8	32.01	54.08	22.39
Sept	9.9	12.9	7.9	5.51	12.18	2.80	10.4	12.2	9.2	6.38	10.31	4.42
Oct	7.0	9.6	5.5	1.95	5.04	0.95	6.8	9.7	5.2	1.79	5.20	0.80
Nov	11.1	15.1	8.9	7.84	19.73	4.04	8.8	13.4	6.1	3.90	13.79	1.30
Dec	12.2	12.6	11.7	10.47	11.54	9.24	9.6	11.4	8.4	5.10	8.54	3.42
Annual	12.4	15.3	10.7	10.84	20.37	6.97	11.4	14.0	9.8	8.43	15.60	5.35

Where: M: mean daily wind speed

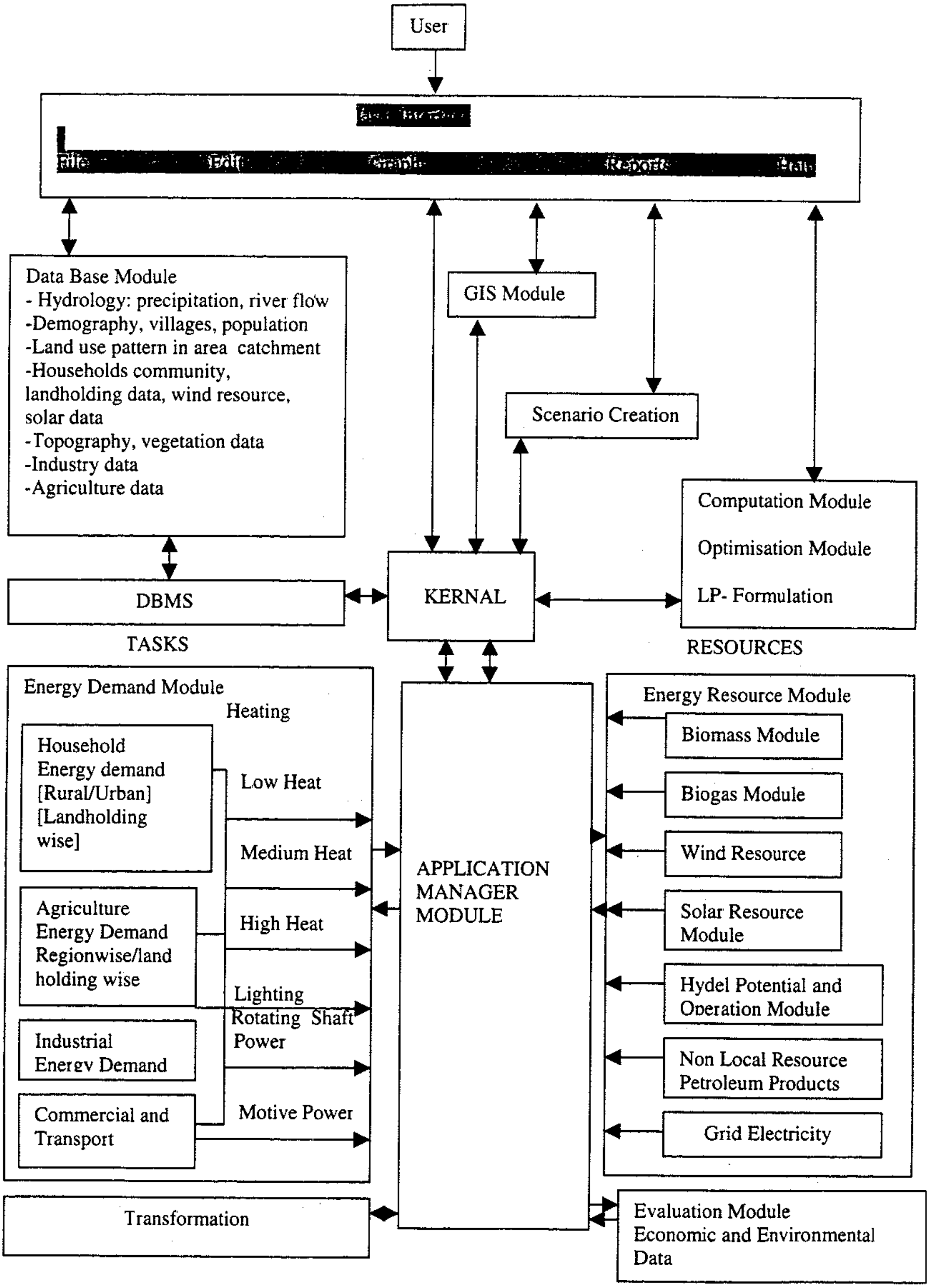
M1: mean wind sped for the period 0830 - 1730 IST

M2: mean wind speed for the period 1730-0830 IST

FRAME WORK OF REGIONAL ENERGY PLANNING AND MANAGEMENT



DETAILED STRUCTURE OF INTEGRATED REGIONAL ENERGY PLANNING



Regional Integrated Energy Plan (RIEP)

Regional Integrated energy plan (RIEP) developed at Energy Research Group, Centre for Ecological Sciences, Indian Institute of Science, is a computer assisted accounting and simulation tool being developed using Visual Basic and MS Access to assist policy makers and planners at district level(/taluk / village / block level) in evaluating energy policies and develop ecologically sound, sustainable energy plans.

Energy availability and demand situation may be projected for various scenarios (base case scenario, high energy intensity, transformation, state growth scenarios) in order to get a glimpse of future patterns and assess the likely impacts of energy policies.

Regional Integrated Energy Plan (RIEP) serves several purposes:

1. As a Database
   - Demography (population during 1941-1991)
   - Natural resource (land use, land cover, forest types, wastelands,
     - agriculture- crop types, production, yield, irrigation details,
     - horticulture- crop types, residues.
     - plantation - area, type (social forestry programme)
   - Electricity, Kerosene consumption (talukwise, categorywise)
   - Spatial maps of resources and demand (temporal data, spatial data)

2. Maintains energy information: data entry, data append, edit, unit conversions, querying, data retrieval, generation of reports, generation of graphs, link to spatial maps (district/taluk/village)

3. Forecasting tool - to make projections of energy supply and demand at 5 years interval

4. Policy analysis tool - simulates and assesses the effects of alternative energy programmes (technical economic, environmental effects).

5. Bibliography (Abstracts of papers published in journals) and energy database of other regions.

6. Links to various energy sites (URL of prominent sites dealing with energy and environment).

Energy resources database (renewable and non renewable), energy demand database(sectorwise), environmental database, data aggregation, data analysis (energy scenarios, techno economic analysis) and integrated plan are the various modules being incorporated in the Integrated Regional Energy Plan. The energy scenarios module along with energy demand, transformation, techno-economic and environment module are used (in integrated module) to perform an integrated energy-environment planning exercise for a region (village / blocks/ taluk / district / state). Environmental database is used automatically calculate environmental impacts of energy scenarios.

Scenario analyses aids in creating a picture of the current energy situation and estimated future changes based on expected or likely plans and growth patterns. Base case or business-as-usual is based on present population growth, industrialisation, agricultural energy requirement.

It also helps in developing policy scenarios with alternative assumptions such as
1) transformation - through introduction of energy efficient devices such as fuel efficient stoves, improved furnaces, boilers, dryers, compact florescent lamps etc.
2) projection based on high energy intensity (such as rapid industrialisation with an energy demand increase of 20%)
3) projection based on state averages (growth in household, industry, agricultural and commercial sectors)
4) introduction of renewable energy technologies (solar, hydro, bio energy etc.) and agroforestry (conversion of wastelands with locally accepted species)

Data aggregation allows for coordinated planning at more than one spatial level. Such as energy scenario can be developed at village level and then aggregated to the taluk / district level.

Techno-economic analyses provides technical and economic viability of alternatives. This programmes draws upon the analytical methodology of "life-cycle" analysis. For each energy sources and technology option it also traces energy inputs and environmental impacts.

Integrated module integrates energy supply and demand analysis with energy scenario programmes and provides a full range of optimal policy alternatives in a common framework. This enables the policy maker / decision makers to examine the critical relationships between supply and demand, land use, bio resource issues, environmental sustainability and economic development.

The environmental database provides a comprehensive summary of data on the environmental consequences of energy use and production. This database would be linked to the energy scenario programme to provide information on the environmental impacts of energy alternatives.

Conclusions:

Kolar depends mainly on non commercial forms of energy. Non commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues, charcoal and cowdung, while commercial energy's share is 16%, met mainly by electricity, oill etc.

The largest single user of bioenergy is the domestic sector, followed by industries. Increased shortage of wood fuels have forced many users to shift to substantial use of agricultural residues. Bio energy users are faced with limited options of accessible and affordable fuels.

A major constraint to effective planning and management in rural areas is the insufficiency of data and environmental information. The data are essential for the formulation of essential polocies and strategies for local energy (bio energy) production and use.

Government planning institutions, both centralised and decentralised, often display a lack of interest in traditional fuels including bio energy. the most direct effect of neglecting bio energy planning have lead to severe scarcities and drudgery for weaker groups, over-exploitation of local resources.

Energy plan for a region should include bioenergy plans and be linked to area-based planning and/or rural development planning. Decentralisation allows close interaction between planning and implementation, whether in projects, programmes or policies at large. Experiences have shown that such interaction is vital for successful interventions which address local and site-specific issues like bio energy.

The interventions in bioenergy sector could be supply-oriented (aiming at increasing, redistributing or substituting supply), or demand oriented (aiming at managing demand by conservation or other measures which enhances rational consumption), or both.

Severity of the energy crisis (bioenergy) in several blocks of Kolar demands for implementing area based micro-level integrated energy plan through least cost (and improved efficiency) mix of different sources of energy.

Energy saving devices and alternate devices / technologies should be introduced, taking in to consideration the suitability and potential of the area.

The land use pattern is to be analysed to identify potential areas for energy plantations with the species acceptable to the local people.

Recommendations in this regard are:

Include regional energy where relevant as one of the key elements in the overall strategy for sustainable development. Integrate programmes for food, water, energy and social development.

Establish regional centres of excellence for renewable energy, to provide training, technology support, and resource databases appropriate to the regional needs. Develop and implement regional demonstration programmes as showcases of the best elements of renewable technologies.

Gather, review and publicise success stories involving renewable energy, to give realistic examples of what has been done and is possible.

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REGIONAL INTEGRATED ENERGY PLANNING USING G.I.S

(UNDP-NRDMS Sponsored Project)

Sponsored by: **DEPARTMENT OF SCIENCE AND TECHNOLOGY,**
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This project information is available on web. Details of URL is

ENERGY HOMEPAGE - http://144.16.65.194/energy/Welcome.html

Details of the project - introduction, objective, study area, DSS, results, progress of work apart from this the energy bibliography and links to URL's related to energy, energy modeling, ecological modeling and NRDMS.

REFERENCE TABLE OF ENERGY UNITS

	1 toe	1 tce	1 MWh	1 GJ
tonne of oil equivalent - toe	1.000	0.700	0.086	0.024
tonne of coal equivalent -tce	1.429	1.000	0.123	0.034
Megawatt-hour - MWh	11.630	8.141	1.000	0.278
Giga Joule - GJ	41.900	29.300	3.600	1.000

	1 Wh = energy of 1 watt acting for 1 hour
k = kilo =10/3 =thousand	1kWh=1,000 Wh
M = mega =10/6 =million	1MWh=1,000 kWh =1,000,000 Wh
G = giga =10/9 =billion	1GWh=1,000 MWh =1,000,000,000 Wh
T = tera =10/12=trillion	1TWh=1,000 GWh =1,000,000,000,000 Wh
P = peta =10/15 =quadrillion	1PWh=1,000 TWh=1,000,000,000,000,000 Wh
E = exa =10/18 =quintillion	1Ewh=1,000PWh=1,000,000,000,000,000,000 Wh

Coal Replacement units of Fuels

Fuel	Coal replacement units (mtcr[a])
Commercial	
Soft coke/coal (1 mt[b])	1.500
Kerosene(one billion litres)	
For lighting	2.086
For cooking	5.623
LPG (1 mt)	10.184
Electricity (1 TWh)	0.706
Non-commercial	
Firewood (1 mt)	0.655
Charcoal (1 mt)	1.807
Dung cakes(1 mt)	0.301
Crop residues(1 mt)	0.527

[a] million tonnes of coal replacement
[b] million tonnes

Calorific value of Different Fuels (kcal/kg)

Fuels	Values
Commercial fuels	
Coal (gross calorific value)[a]	
Hard coal	5000
Lignite brown coal	2310
Charcoal	6900
Petroleum products (net calorific value)	
LPG	10800
Gasoline/naptha	10500
Kerosene	10300
Jet fuel	10400
Fuel oil	9600
Natural gas	8000 - 9480
Electricity	860
Biomass	
Agricultural residues	
Paddy straw	3000
Rice husk	3040
Mango leaves	3390
Groundnut	4200
Sugarcane	3800
Wheat straw	3800
Cotton stalks	3800
Maize stalks	4700
Maize cobs	3500
Bajra stalks	3850
Gram straw	3950
Masoor straw	3810
Moong straw	3980
Forestry residues	
Wood wastes	2500 - 3850
Bark	2500 - 2850
Animal wastes	
Cowdung	3290
Cowdung cake	3140

[A] useful heating values for various grades of coal are given in the section on Energy Supply