A Technology Assessment & Development Brief
by the
APPROPRIATE TECHNOLOGY TEAM
PRAGYA

RENEWABLE ENERGY APPLICATIONS IN LAHAUL & SPITI

PRAGYA

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1. NEED AND CONTEXT

Energy plays a dual role in the development of regions and communities - as a consumer good, i.e., energy consumed in household, it has a direct impact on the quality of life, and as an input into the productive sectors of the economy, i.e., agriculture and industry, it impacts the development of the entire region. The demand for energy however is increasing at an escalating rate resulting in an acute pressure on wood, oil and coal, and not only depleting our resources rapidly but also threatening the global environment. Especially in developing countries like India, excessive use of wood is leading to accelerated deforestation, silting due to soil erosion, flooding, and deepening of the fuelwood crisis. It is imperative therefore to investigate new sources of energy which are renewable in nature to complement and ultimately to replace fossil fuels.

The Himalayan region has suffered severe development neglect and remains among the poorest regions in the lower Himalayan land. The energy availability or rather the lack of it, remains one of the key constraints for the region's developmen. Many of the villages in the valleys are still not electrified.

In the Himalayan region, people have to rely completely on fuelwood gathered from the forests, both for heating as well as for cooking. Other productive activities, viz, any kind of processing plant, and even pumping of water for irrigation, are dependent on fossil fuels. Fossil fuels however are also scarce because of transportation difficulties. Fuelwood alone accounts for 60-80% of the energy consumed. No productive activity that requires quality and consistent power, and can provide sustainable and relatively large-scale employment, can be carried out. Especially winter activities like handicrafts have suffered terribly due to the growing energy shortage. Less and less of the living space can be heated and hence activities like weaving, carpentry, etc., which also require heated space have been abandoned. Traditional knowledge for managing the energy issue has been developed in the region, but these too are eroding today. For instance, buildings in the cold deserts of the Western Himalayas are made of mud, an excellent insulant. Recent microclimatic changes have affected the stability of the buildings and are forcing people to shift to other building materials. Traditionally, all families reared animals and these were housed either in the basement of the family home or around it; the animals' body heat helped in keeping the home warm.

There is thus an acute need of renewable forms of energy in the Himalayas - to improve the quality of life of the indigenous communities, as well as to enable sustainable economic development of the region.

Lahaul & Spiti in the state of Himachal Pradesh is one of the frontier districts in India. The temperature variation in the region is from -40^{O}C in winter to +25^{O}C in summer. It is a cold desert and has a very difficult terrain with ice-fields, snow-covered peaks and a most inhospitable climate. The region of Lahaul & Spiti is basically a cold desert and is not rich in natural resources. The region is deficient in natural resources, with poor soil quality and depth, and water primarily from glacier-fed streams. Fuelwood and other forest products thus are also limited. Although 88% of the villages have power supply, the power available is inadequate and of very poor quality. For domestic heating and cooking purposes, the local community is dependent on government supplied wood and kerosene. Depleting forests are resulting in rapidly escalating cost of such fuel. As glaciers recede because of global warming, more and more previously cultivated lands lie fallow because of the lack of irrigation. The paucity of power disallows any other occupation and is resulting in outmigration of the youth. Winters are bitter stretches and the traditional winter activities of handicrafts are gradually dying out because of the lack of warmth to ease these activities.

While Pragya is aiding the local population to cultivate medicinal & aromatic plants, the growers cannot get adequate returns unless they do some value addition on site. Energy availability would make possible the establishment of plants for the part processing and packaging of the medicinal & aromatic plants cultivated. This would contribute in terms of occupational diversity of the region and increased economic returns for the growers.

The beautifully embroidered traditional stoles called 'lingches' are woven no longer because the looms are very big and the weaving rooms that traditionally held these looms cannot be heated in these days of fuel shortage. The use of renewable sources of energy can help run weaving centres even in winter.

2. MAJOR SOURCES OF ENERGY IN LAHAUL & SPITI

Energy lights our cities, powers our vehicles, and runs machinery in factories. It warms and cools our homes, cooks our food, plays our music, and gives us pictures on television.

Lahaul and Spiti being a cold desert region with altitude of above 10,000 ft and temperature variations from -40 to 40 degrees, primary usages of energy are for meeting the space heating needs in winters. Apart from this there are other uses like water heating, lighting, cooking etc.

Major energy requirements of Lahaul & Spiti region are met using sources like wood, coal, kerosene oil, LPG, electricity from grid. In recent times people have also started using solar photovoltaics for lighting, water heating etc.

2.1 BIOMASS

Any organic material, such as wood and wood wastes, agricultural residues, municipal waste, and animal waste- is the oldest source of energy known to mankind. For thousands of years, people have burned wood to generate heat and to cook food. Biomass accounts for more than 10 percent of global energy use; in parts of the developing world, it accounts for up to 90 percent. Biomass is an indigenous fuel source that is often readily available and inexpensive throughout much of the developing world. It can also be effectively converted to electricity and heat due to recent technological developments. It is because of these two factors that biomass will most certainly play a significant role in the development of energy sectors in these parts of the world.

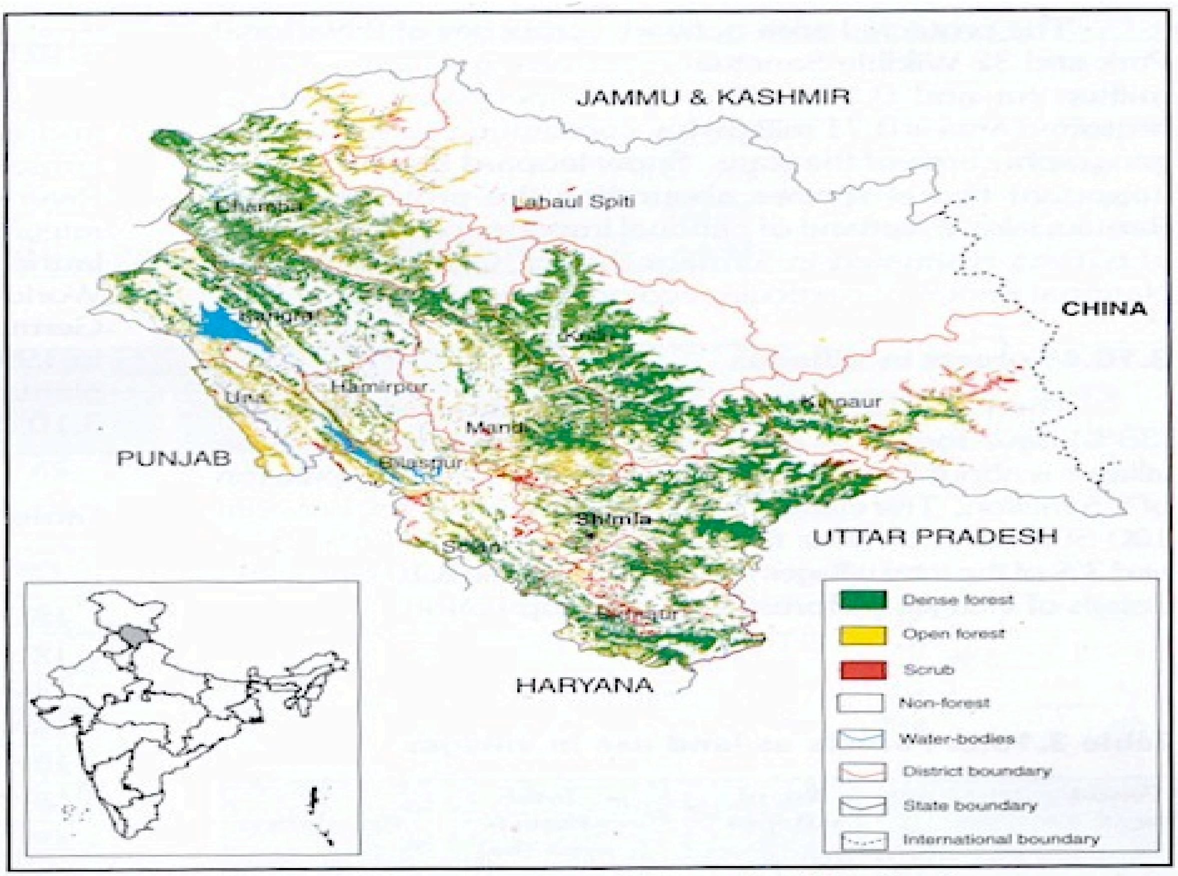
The two most common types of biomass resources are:

- *plant biomass* which includes woody and non-woody biomass and processed waste and fuels, and
- a*nimal biomass* which includes animal manure as a feedstock to generate energy using biogas technologies or directly as a cooking fuel.

In India, biomass combustion includes fuel for domestic cooking in stoves (henceforth referred to as biofuels), forest fires and open burning of crop waste after harvest. Biofuels used in rural India include wood, crop waste and dung-cake.

In Lahaul & Spiti biomass consumption is highest in the winter months when temperatures plummet down to sub zero levels. All biomass in form of fuelwood and dung cakes, is collected in the summers for their use in winters. For these the womenfolk have to go to far flung areas thereby wasting their valuable time and energy. In a survey conducted in Poh village of Spiti, it was found that the major consumption of biomass is in form of fuelwood. Fuelwood serves the dual purposes of room heating and cooking in winters. On an average from Nov to April a household consumes 4-6 qts of wood in a month, with wood costing at Rs 200/- per qt. A family's stock of wood is stored in the month of Nov and is available from the government godowns at subsidized rates. In summers wood is generally not in use except for in a few villages which are at high altitudes, and that too is in very small quantities (1-2 qts per month).

The forest cover of Lahaul & spit is very low which is evident from the map and figures released by Forest Department of Himachal Pradesh. Thus biomass collection in the form of fuelwood is depleting the already scarce forest coverage of Lahaul & Spiti. This is also adding to the problems of soil erosion, air pollution, changing snowfall patterns etc.



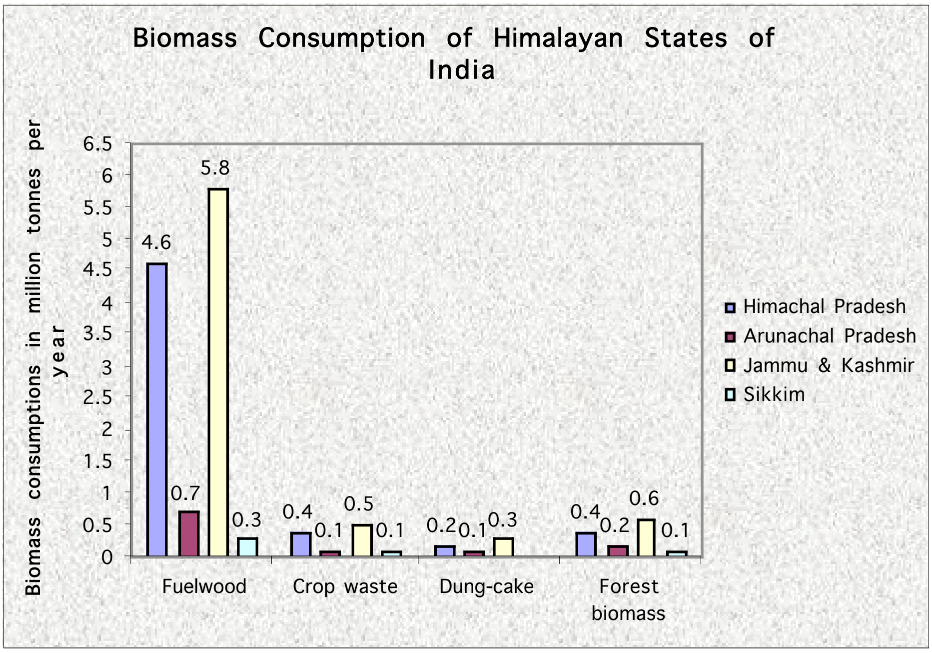
Forest cover of Himachal Pradesh

The entire cattle population of Lahaul & Spiti is about 63,647[1] . Hence biomass collection in form of dung cake is also low. Thus very little potential exists for electricity generation with biomass in the region. There are also dry toilets in each household specially in Spiti region and the human waste is stored in these and used as manure for growing crops. This however leads to problems of hygiene and health.

The cropping season of the region is also very short and people take only one crop in this short season, hence biomass availability by crop residues are also minimal. The major chunk of the crop residue goes towards meeting the fodder requirements for cattle in the winter. The two major crops grown in the region are potatoes and peas.

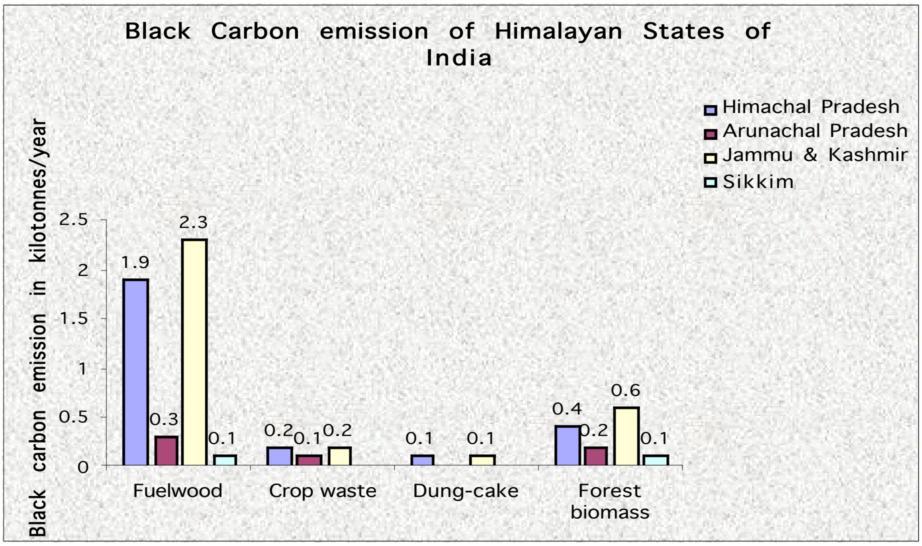
The region in short has very little biomass availability for power generation and whatever is available is utilised for space heating in winters and as manure for crops.

[1]Source :http://hplahaulspiti.nic.in/fact_file.htm Fact File Lahaul



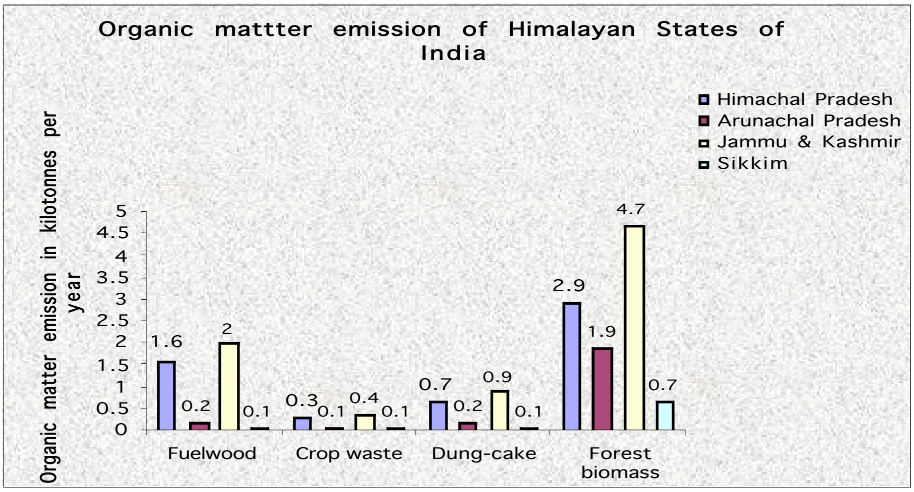
State/Country	Fuelwood	Crop waste	Dung-cake	Forest biomass	Total
Himachal Pradesh	4.6	0.4	0.2	0.4	5.6
Arunachal Pradesh	0.7	0.1	0.1	0.2	1.1
Jammu & Kashmir	5.8	0.5	0.3	0.6	7.1
Sikkim	0.3	0.1	0	0.1	0.5
India	302.1	115	120.6	39.3	577

Biomass consumption (million tonnes per year)



State/Country	Fuelwood	Crop waste	Dung-cake	Forest	Total
Himachal Pradesh	1.9	0.2	0.1	0.4	2.6
Arunachal Pradesh	0.3	0.1	0	0.2	0.6
Jammu & Kashmir	2.3	0.2	0.1	0.6	3.2
Sikkim	0.1	0	0	0.1	0.2
India	122.7	53.5	30.4	38.5	245.1

Black carbon emissions from biomass combustion
(kilo tones per year)



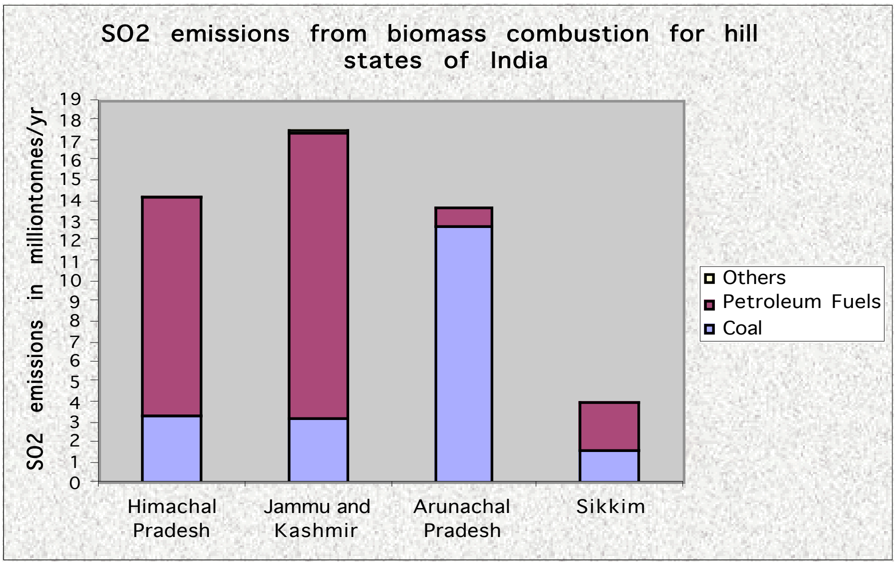
State/Country	Fuelwood	Crop waste	Dung-cake	Forest	Total
Himachal Pradesh	1.6	0.3	0.7	2.9	5.6
Arunachal Pradesh	0.2	0.1	0.2	1.9	2.5
Jammu & Kashmir	2	0.4	0.9	4.7	8
Sikkim	0.1	0.1	0.1	0.7	1
India	106.3	104.4	418.8	313.2	942.7

Organic matter emissions from biomass combustion (kilo tones per year)

2.2 FOSSIL FUELS:

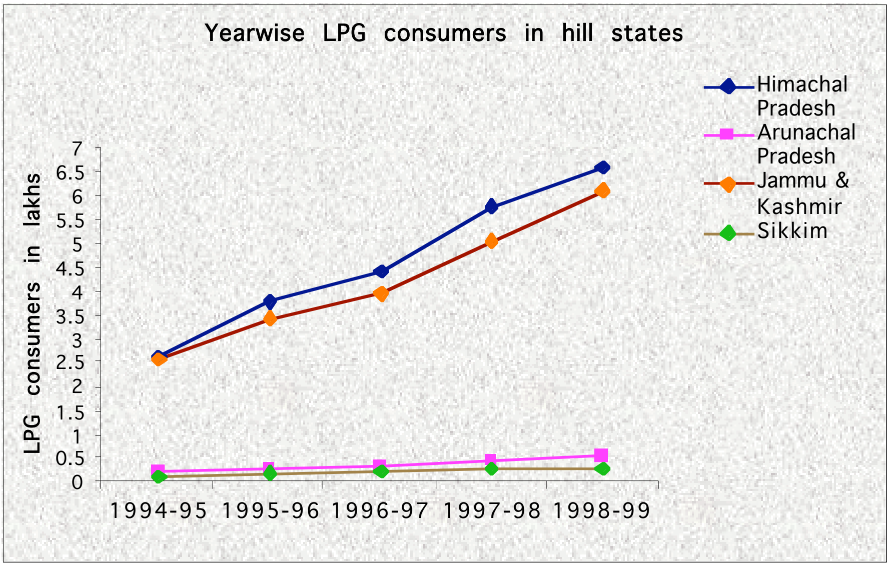
Fossil fuels including coal, kerosene oil, natural gas etc., are used in a major way in Lahaul & Spiti, as the area is unable to meet its energy requirements with its scarce biomass reserves. Further, the increase in population and modernisation has also added to the increased energy demands of the region. With each passing year, the influx of tourists, domestic as well as foreign, is also increasing, thereby adding to the energy requirements. Like elsewhere the region has not remained untouched by the environmental impacts of using fossil fuels. In the recent past, there have been changes in the pattern of snowfall in the region, which have directly impacted the drinking water and irrigation needs of the area. Further, much of the supply of fossil fuels comes from neighbouring districts which makes the region very dependent.

Apart from the deficient fossil fuel availability, there are also the environmental concerns associated with the use of fossil fuels and biomass. The region being an important tourist destination sees the influx of large no. of tourists specially foreign tourists. All this has meant the increasing no. of vehicles in the region and hence the emissions associated with the same. The following charts and tables are an illustration of the emissions associated with various fossil fuels and biomass combustion. An attempt has been made to compare emission values of various hill states of India. Though these figures are not exactly representative of the cold desert region, they are indicative of the situation in this region, as well. And in times to come the situation may worsen if corrective measures are not taken now.



State/Country	Coal	Petroleum Fuels	Others	Total
Himachal Pradesh	3.4	10.7	0.1	14.2
Jammu and Kashmir	3.3	14	0.2	17.4
Arunachal Pradesh	12.7	1	0	13.7
Sikkim	1.6	2.5	0	4.1
India	2444.5	1553.1	30.9	4028.5

State-wise* SO_2 emissions from India for 1996-97.



Year	1994-95	1995-96	1996-97	1997-98	1998-99
Himachal Pradesh	2.65	3.78	4.46	5.8	6.61
Arunachal Pradesh	0.27	0.31	0.36	0.47	0.55
Jammu & Kashmir	2.59	3.47	3.99	5.1	6.16
Sikkim	0.13	0.21	0.24	0.3	0.31
India	231.37	256.91	293.05	337.43	381.01

NUMBER OF LPG DOMESTIC CONSUMERS (in Lakhs)

LPG: Liquified Petroleum Gas

Source: Ministry of Petroleum and Natural Gas,Govt. of India, New Delhi.

2.3 HYDROELECTRIC POWER:

The last two decades have seen a significant growth in hydropower development throughout India. Himachal Pradesh has a vast hydel potential to the tune of approx. 21,000 MW in the five river basins and 3950 MW (approx.) have been harnessed so far. Of this, a potential of approximately 750 MW is estimated to be in the small hydro sector, on the basis of remote sensing data. Eight projects have been taken up in HP under this programme. Of these, two projects, viz. Kothi (200 KW) and Juthed (100 KW), have been commissioned by HIMURJA, while 3 other projects namely Solang (1000 KW), Raskat (800 KW) and Titang (900 KW) have been commissioned by private investors. Other projects viz. Lingti (400 KW) in Spiti, Purthi (100 KW) and Sural (100 KW) in Pangi valley of Chamba District are also in the initial stages of functioning.

But in Lahaul & Spiti, the hydel projects have not been very successful. For example in Spiti, the Lingti hydel power plant of capacity 2x200 KW has not been very successful and is unable to generate its full capacity. The primary reason behind this being the heavy silt load in the rivers of the region. Silt removal is a big problem, and even after plant's installation, many are not able to meet the designed load due to high silt accumulation. Also the region being a cold desert, the water in the streams freezes, thereby affecting the generation capacity in winters. Most of the hydropower plants hence remain non-functional during the winters. There is thus an urgent need to look at alternate energy sources to meet the power needs of the region especially in winters.

2.4 SOLAR PV MODULES:

Most parts of India get 300 days of sunshine a year, which makes the country a very promising place for solar energy utilisation. So far, photovoltaic (PV) generation has been limited to very small installations, but throughout the country there are more than 750,000 of them, generating a total of about 58 MWe.

In Lahaul & Spiti, there are almost 325 sundays per year and an average of 8 hours of sunshine per day round the year, hence the solar energy option will be best suited for meeting the daily energy needs of the people of the region. Presently people of these regions use solar PV module primarily for water heating and lighting. But still the use is very limited. Most of these modules have been installed by HIMURJA at subsidised rates.

There is a lack of awareness among the local population about the benefits of renewable sources and use of these devices is minimal.

3. IMPACTS OF EXISTING ENERGY INFRASTRUCTURE

3.1 ENVIRONMENTAL IMPACTS:

As has been described earlier, the major energy requirement of the region is essentially for space heating in winters and is met by consumption of biomass and fossil fuels such as coal, kerosene oil, etc. But the region being a cold desert, the vegetation of the region is limited to shrubs and grasses. This limited green cover is being considerably depleted due to collection of shrubs for fuelwood requirements of the local population. The fragile environment is under significant threat as a result of this. The map showing the forest cover of Himachal is self explanatory. Overuse of firewood is also leading to environmental imbalances like soil erosion and changing trends of snowfall. Over the past few years there has also been scarcity of water in summers due to inadequate snowfall. Greenhouse gas emissions have also had an impact in the region. A very recent example has been the maximum temperature recorded at Tabo in Spiti last year when the temperature went up to 40^{0} C,a variation of about 85^{0} in a single year.

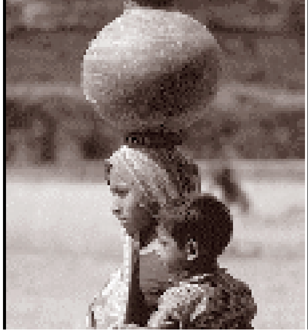
3.2 FINANCIAL IMPACTS:

The inadequacy of power in the region is a critical factor in the region's continued underdeveloped state. The economy remains completely based on agriculture and animal rearing and incomes are only through the primary produce through these activities. No other occupation, for instance cottage industries, and no processing of these primary produce - that could have led to greater occupational diversity, and enhanced employment and incomes - have been possible. People generally do not do any kind of work in winters due to the severe cold and inadequate power.

People also spend a considerable chunk of their income on buying fuelwood from the govt. at subsidised rates.

3.3 SOCIAL IMPACTS:

The decreasing fuelwood availability has shrunk the energy available as well, leaving the region's activities and quality of life under stress. Winter activities, typically related to the region's arts & crafts have been curtailed because of the decreasing energy availability. This has had the impact of the declining practice of these arts & crafts, and even severe erosion of some.



If this woman spends four hours every day hauling water her chances of escaping poverty are very low.

If this boy collects firewood instead of attending school his child will probably do the same thing.

For instance, weaving of 'lingches', the traditional shawls of the region, has been abandoned since heating the weaving rooms containing the lingche looms has become a struggle. Apart from this, too much dependance on fuelwood has added to the miseries of women in the region as they spend considerable time and energy in collecting fuelwood from far flung places. Inadequate and poor quality of power supply has also deteriorated the important sectors of health, education, telecommunications, entertainment, etc. Huge sums of money spent by the govt. agencies on development projects have also suffered due to the poor power situation in the region.

4. TECHNOLOGY OPTIONS

Having overviewed the energy scenario of cold deserts it is obvious that renewable energy options are best suited to meet the energy needs of the area. A number of renewable energy technologies are available that can be used for the region for a variety of uses.

4.1 SOLAR ENERGY:

As mentioned, most parts of the region get more than 300 days of sunshine a year, which makes it a very promising place for solar energy utilisation. So far, photovoltaic (PV) generation has been limited to very small installations. The Indian government is also promoting direct use of solar energy, in the form of solar water heaters and solar cookers. The cookers are large parabolic reflector-based systems that are meant to meet the needs of small, isolated communities, but so far they have not found widespread acceptance. Solar water heaters are doing better, and have seen use at hotels, hospitals, textile mills and other industries, and dairies. There has also been some use in individual residences. Nearly 500,000 square meters of conventional solar flat plate collectors are now in use throughout India.

4.2 SOLAR ENERGY APPLICATIONS:

4.2.1 Photovoltaics Technology

Photovoltaics (PV) technology, which converts sunlight directly into electricity, provides power for a full range of household and business functions. Around the world, PV systems are used in refrigeration, lighting, telecommunications and agricultural applications, as well as in centralized-grid electricity production.

PV systems are operating in every region of the world. Because of its versatility, PV technology is in demand, and worldwide PV markets will continue to grow as costs continue to decline. Whether on a very small scale (such as in a telephone callbox) or in larger scale applications (such as in homes and commercial buildings), PV can provide clean energy from an abundant and free fuel source - the sun.

At the household level (or smaller) PV systems can either replace or supplement utility-generated electricity. In stand-alone PV electric systems, the power generated is stored in a battery and used as needed. In grid-connected systems, power from the utility grid can serve as a back-up source on cloudy days or when electricity use is unusually high.

The following are some examples of existing PV operations and the functions that they support:

Communications - In thousands of locations, PV systems are providing electricity for remote telecommunications functions. Such installations range in size from a few watts to several hundred kilowatts of capacity. They electrify microwave repeater stations, remote control systems, radio communications, telephones, emergency call boxes, and other remote equipment.

Lighting - These systems power lighting for billboards, highway signs, rural buildings, parking lots, and vacation cabins. Many PV-powered lamps include timers, or "photo cells", that sense darkness and activate the bulb when it is needed.

Refrigeration - In many parts of the developing world, solar technologies like PV are the sole source of electricity for refrigeration. PV systems make it possible to refrigerate medical supplies and food items in remote areas, bringing improved quality of life to remote communities.

Water Pumping - In almost every climate, PV systems are used to power irrigation, drinking water pumps, and industrial water pumping operations. Like refrigeration systems, these installations bring significant quality of life and health benefits to the communities they serve.

4.2.2 Benefits of Using PV Systems

Free Fuel: Once the equipment is purchased and installed, the bulk of PV costs are complete. Fuel costs are zero for the lifetime of the project, so PV systems will be more economical in many cases even though the up-front capital costs are relatively high.

Simple Maintenance: Because of the simplicity of PV systems, maintenance and repair costs are very low.

High Reliability. PV systems are very durable and can work effectively for years. With no moving parts, PV is a reliable energy source in all types of climates and weather conditions.

Environmentally Benign: PV systems are silent and do not emit environmentally damaging substances into the air or water.

Modularity: Panels can be installed as needed and upgraded as the demand for power grows. Furthermore, additions can be made while the original system continues to operate.

4.3 SOLAR THERMAL ENERGY:

Solar thermal technologies enable us to produce hot water from the sun's energy for use in homes, factories, hotels and for many other applications. Solar water heating is not only a suitable and economical alternative to water heating with electricity in towns, it can also provide hot water efficiently and in a reliable manner in rural off-grid areas. Solar thermal systems are used in homes, hospitals, and industrial plants around the world.

Solar thermal facilities can operate effectively in virtually any climate, from hot deserts to the earth's coldest regions.

In addition to direct-use applications, solar thermal technology can be used to generate electricity. Today's solar thermal power plants produce about 0.005 Quads (480 million kWh) of energy each year - that's enough energy to power more than 45,000 homes. At their current production rate, solar thermal power plants displace 325,000 tons of carbon dioxide emissions every year.

4.3.1 Solar Thermal Systems

Solar thermal systems can use flat plate collectors to capture the sun's energy and transfer it either *directly* or *indirectly* to household, water or heating systems. Each collector contains an absorbing surface (called an absorber plate) and an insulating container (generally a metal box) that supports a transparent glazing material (usually glass). Heat from the sun is trapped by the collectors and absorbed by the plate. The heat is transferred to a heat-transfer media, which can be either liquid or gaseous, for immediate use or storage.

Direct solar systems transfer the sun's heat to water, which flows through the faucet to the end user. *Indirect* systems transfer heat to an intermediary heat-transfer fluid such as an anti-freeze, a refrigerant, or treated water. The heat transfer fluid passes heat on to the household water through a heat exchanger (such as a coil wrapped around the water storage tank).

In typical installations, collectors are mounted on the roof of a building and oriented to achieve maximum exposure to the sun. One or two collectors are used in a typical household system. During cloudy weather or periods of excessive hot water use, backup heating can be used. These systems can save homeowners up to 3,000 kWh annually.

4.4 SOLAR PASSIVE SPACE HEATING SYSTEM

Space heating to provide adequate warmth inside residential houses, lodges, restaurants and other facilities in the hills and mountains can be done with solar heating. The solar space heating system can be:

- an active system which requires conventional energy to operate it,
- a passive system which operates entirely on a renewable energy available in the immediate environment.

It can be used for heating homes and commercial spaces during the cold months. The passive heating of buildings through solar energy involves the integration of the system into the structure of the building itself. The system works in three ways:

- collection of the sun's rays,
- storage of the heat collected, and
- release of the heat in a useful way.

Passive heating of buildings is achieved by understanding and using the knowledge of heat and its relationship with building materials. Operation of the passive heating system takes advantage of the natural characteristics of materials such as shown below:

- the convective flow of air and water
- the absorption qualities of dark colours and dense materials
- the heat storing properties of dense materials and water
- the poor heat conductivity of insulating material.

The buildings are designed in such a way that the heating needs of the occupants are met by the sun as a heat source and the night sky as a heat sink. The techniques that can come under solar passive heating are:

- Direct Gain
- Indirect Gain
- Isolated Gain
- Solarium

The Direct Gain System includes the use of sealed double-glazed windows. Other techniques are architectural components which can be incorporated in new and/or existing buildings.

4.4.1 Types of passive space heating systems:

1. Direct Gain

The south side of the house is provided with as much window area as needed according to calculations based on the total heat needed to keep the house warm and the solar energy available. The windows are glazed with two layers of glass or plastic, textured on the inside surface of the inner pane to diffuse the light to interior surfaces. This radiation is absorbed by the thermal mass surfaces (concrete, brick, rock and water containers) which make up the walls, partitions, floors and ceilings. This can help collect up to 60-70% of the available solar energy.

Thermal mass surfaces are ideally a dark colour, whilst other surfaces are preferably light so that they do not overheat the interior air. A vapour barrier and ample insulation are placed outside the wall mass. This prevents the stored heat from escaping, except from room to room. Small windows are preferable to large windows with little insulation.

2. Water Wall

A custom steel water tank is a good way to add thermal mass to a house because the water is much more effective at collecting and reradiating heat than concrete or plaster. The water tank stores the sun's energy during the day for nighttime heating. The water wall absorbs 60-70% of the available radiation. (However, once the water is frozen in a water wall, it takes many days to melt it.)

3. Trombe Wall or Thermal Mass Wall

In this technology, the south side of the house is a solid wall, painted black on the outside and covered with double glazing. There are two ways that heat enters the building:

i) the thermal mass of the wall absorbs the sun's heat all day and releases it to the interiors at night.

ii) if openings are made through the wall at floor or ceiling level, the heated air between the wall and the exterior glass can convect into the room, being replaced below by cooler air from the room.

The thermal mass wall can also be used in conjunction with the direct gain or solar greenhouse technologies. It is 35-45% efficient. Houses that already have a good exposure on the south side can readily be adapted to this system. Generally insulation must be added however.

4. Solar Greenhouse

A solar greenhouse is built onto the south wall of a house and through heat convection transmits excess heat into the house during the day, whilst heat stored in the mass wall, radiates to the interior in the night as well. This system provides an added sunny place to live in and can also be used as a place to grow vegetables or flowers.

5. Roof Ponds

In a roof pond, the thermal mass wall is located above the ceiling in the form of bags of water, thus having access to the solar radiation from above and the night sky. Movable insulation is however required to make the system effective. The system is very good for cooling, since it faces the night sky, but it does not have an ideal angle for the collection of heat. This can be provided with reflectors.

6. Self-Insulating Water Wall

A self-insulating water wall may have advantages when used with the direct gain system in some situations. This system can be used for heating as well as cooling and has the advantage of in-built insulation. It involves water filled tanks insulated on the inside installed on the south side.

Heating Mode: Water heated through the surface of the tank convects over the insulation to a large storage compartment and is replaced by cold water entering from an opening in the lower part of the tank. In the nights, reverse convection is prevented by a valve, and the insulation prevents heat loss from the main compartment.

Cooling Mode: The valve can be manually reversed, so that convection cannot take place during the day but is allowed during the night. Then the warmer water from the main compartment over the insulation, radiates the heat to the night environment and returns cooled. The cooled water acts as a heat sink for the building during the day.

The convection in either selected mode is passive, and the day-night valving action is also passive. These modules are best used in conjunction with direct gain and/or solar greenhouse. The absorbing efficiency is between 55-65% of available radiation, and very little heat is lost at night.

If used in conjunction with the direct gain system, the south side of the house is made up of self-insulating water wall modules and windows. The inner surface of the modules radiate heat to the interior and the rate of radiation can be controlled by a curtain. The same considerations as above, apply to this system. This system is suitable for retrofitting into existing houses.

4.4.2 Advantages

- A passive heating system does not need any devices or power to operate it.
- It does not use up resources.
- In most cases, the system can be constructed from environmentally clean materials such as earth, rocks, water and iron.
- In most cases, it can be made from local materials.
- The various systems need very little maintenance.
- Lodges, hotels, restaurants and residences in cold regions in the hills and mountains could be built incorporating passive heating systems.
- The systems are environmentally friendly.
- The design and construction methods are well within the reach of local craftsmen.
- Ordinary measuring and carpentry tools are sufficient for the construction of

passive solar buildings.

- The need for additional materials and skilled craftsmen makes this system more expensive than ordinary buildings. This cost is however off-set by recurring benefits and no cost in subsequent years.
- The PSSH systems do not, in any way, cause any socio-cultural disturbances or social acceptability/adaptability problems.
- The initial cost is extremely high which gives rise to diffusion/dissemination problems.

4.4.3 Disadvantages/Limitations

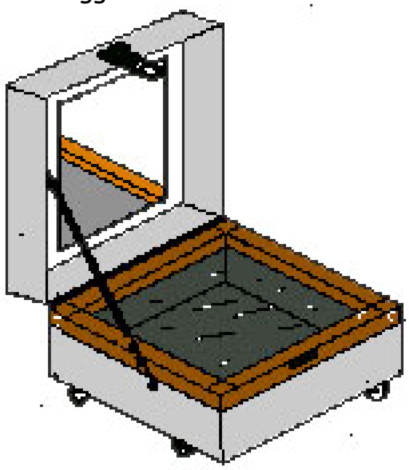
- The buildings have to be south facing, although satisfactory results have been produced by an off-set of no more than 30^{o} to the south.
- The efficiency depends on the materials used for construction and their thickness.
- Promotion and extension of the technology is needed.
- Village craftsmen need to be trained on the technology.

4.5 SOLAR ENERGY DEVICES:

Some of the devices which run on solar energy are as follows.

4.5.1 Solar Cooker

A solar cooker is like a hot box, in which we can cook our food without any cooking gas or kerosene, electricity, coal or wood. Bigger size solar cookers are also available for cooking food for upto 15 persons.



The important parts of a hot box solar cooker include- the outer box, the inner cooking box or tray, the double glass lid, the thermal insulator, the mirror and the cooking containers. Each of these are described below:

1. ***Outer Box***: The outer box of a solar cooker is generally made of G.I. or aluminium sheet or fibre reinforced plastic.
2. ***Inner Cooking Box (Tray)***: This is made from aluminium sheet. The inner cooking box is slightly smaller than the outer box. It is coated with black paint to enable easy absorption of solar radiation and transfer of the heat to the cooking pots.
3. ***Double Glass Lid***: A double glass lid covers the inner box or tray. This cover is slightly larger than the inner box. The two glass sheets are fixed in an aluminium frame with a spacing of 2 centimetres between the two glasses. This space contains

air which insulates and prevents heat from escaping from inside the cooking box. A rubber strip is affixed on the edges of the frame to prevent any heat leakage.

4. ***Thermal Insulator***: The space between the outer box and the inner tray including the bottom of the tray is packed with insulating material such as glass wool pads, to reduce heat losses from the cooker. This insulating material should be free of volatile material.
5. ***Mirror***: A mirror is used in a solar cooker in order to increase the radiation input in the absorbing space. It is fixed on the inner side of the main cover of the box. Sunlight falling on the mirror gets reflected from it and enters the cooking tray through the double glass lid. This radiation is in addition to the radiation entering the box directly and helps to quicken the cooking process by raising the temperature inside of the cooker.
6. ***Containers***: The cooking containers (with cover) are generally made of aluminium or stainless steel. These pots are also painted black on the outer surface so that they can also absorb solar radiation directly.

How a Solar Cooker Works?

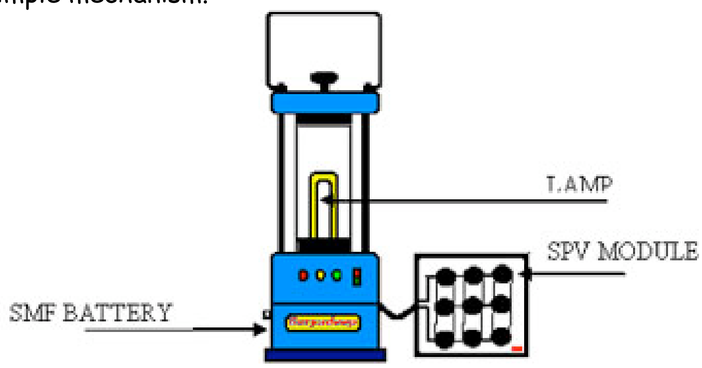
* Keep the solar cooker in the sun in an open space free from any shadow. Keep the cooker in the sun for at least 45 minutes before loading it with cooking pots. This will keep the cooker ready for cooking and reduce the cooking time.
* Adjust the cooker in such a way that the reflecting mirror faces the sun and the reflected rays fall on the transparent glass lid. Tighten the position fixing hinges of the mirror in this position.
* Open the glass lid of the solar cooker, place the cooking pots inside it and close the lid properly. Once the cooking pots have been placed inside the cooker, the lid should not be opened.
* While removing the cooking pots after the food has been cooked, gloves or cloth napkins should be used. The lid should be opened fully.

System Cost and Subsidy:

A domestic solar cooker costs Rs. 1500/- with a subsidy upto 50% whereas a community solar cooker will cost as much as Rs. 60,000 with a subsidy upto 75%.

4.5.2 Solar Lantern

A solar lantern is a simple application of solar photovoltaic technology, which has found good acceptance in rural regions where the power supply is irregular and scarce. Even in urban areas, people prefer a solar lantern as an alternative during power cuts because of its simple mechanism.



How a Solar Lantern works?

A solar lantern is made of three main components- a solar PV panel, a storage battery and the lamp. The operation is very simple. The solar energy is converted to electrical energy by the SPY panel and stored in a sealed maintenance-free battery for later use during the night hours. A single charge can operate the lamp for about 4-5 hours.

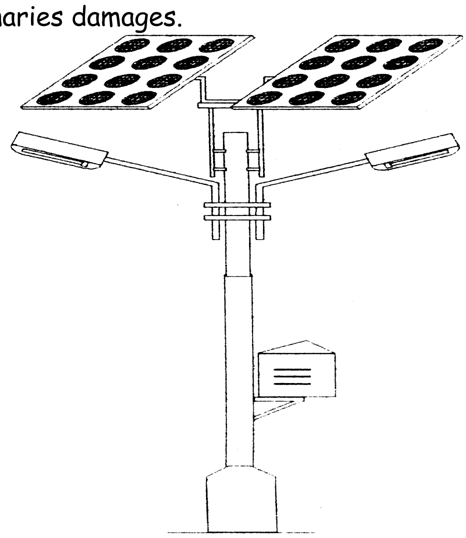
4.5.3 Solar Street Light

This system is designed for outdoor application in un-electrified, remote, rural areas. It is also an ideal application for campus and village street lighting. The system is provided with battery storage backup that is sufficient to operate the light for 10-11 hours per day. It is also provided with an automatic ON/OFF time switch for dusk to down operation and an overcharge / deep discharge prevention cut-off with LED indicators.

The solar street light system comprises:

* 74 Wp Solar PV Module
* 12 V, 75 Ah Tubular plate battery with battery box
* Charge Controller cum inverter (20-35 kHz)
* 11 Watt CFL Lamp with fixtures
* 4 mtr. mild steel lamp post above ground level, with weather proof paint and mounting hardware.

The SPV modules are reported to have a service life of 15-20 years. Tubular batteries provided with the system require lower maintenance, have longer life and give better performance, as compared to the pasted plate batteries used earlier. The system's electronics provide for over-charge and over-discharge cut-off, essential for preventing battery and luminaries damages.



System Cost & Subsidy

75% subsidy on the cost of the system is being provided by GEDA with prior approval. The approximate cost of such a system is Rs. 20,000/-, inclusive of installation & commissioning charges.

4.5.4 Solar Water Heaters:

Solar water heating is not only a suitable and economical alternative to water heating with electricity in towns, it can also provide hot water in an efficient and reliable manner in rural off-grid areas.

Solar water heaters typically consist of a collector and an insulated water storage tank that is similar to a conventional electric hot water tank or geyser. The collector is a box with a see-through glass (or acrylic) cover containing a number of black coloured pipes attached to or laid on a black heat absorbing surface. Water or any other liquid flows through these pipes and is warmed by the sun, and then stored in the water storage tank. This process is repeated over and over in the sunlight hours; every time the fluid passes through the pipes, a small amount of heat is added to it. Typically, the water reaches a temperature of 60-80°C in a solar water heater intended for human use.

Solar Water Heater Components

- Solar Collector: This is usually a flat metal box or frame with pipes. Collectors include:
  - Transparent covers that let solar energy in are either made of a special glass that resists breaking and scratching or ultra violet radiation resistant acrylics (plastic).
  - Absorber plates are dark surfaces that trap heat. These are generally metal sheets or containers filled with water, rocks or bricks that are painted black or some other dark colour that helps retain the heat.
  - Insulation materials prevent heat from escaping to colder places.
  - Vents, tubes and pumps carry the heated water from the collector to the places where it can be used.
- Storage tank: This is similar to that in most gas or electric water heaters and stores the water to be heated. The tank is made of steel and sometimes copper or even plastic. The amount of hot water that is produced by a solar water heater depends on the size and type of the system and on the amount of sunlight available at the site. There are many types of solar water heaters, but in general, they can be classified as direct or indirect systems that employ either active or passive fluid flows in their design. Domestic Solar Water Heaters usually have storage tanks with a capacity of 100, 150, 200 and sometime 300 litres. The size of the system selected will depend on the expected household consumption and the budget available.

Working of solar water heating systems:

The heart of a solar heating system is the collector. A flat-plate solar collector, the most prevalent collector form, is made of a selectively layered absorber that serves to absorb the incoming solar radiation and transform it into heat. This absorber is embedded in a thermally insulated box with a transparent cover (usually glass) to minimize thermal loss.

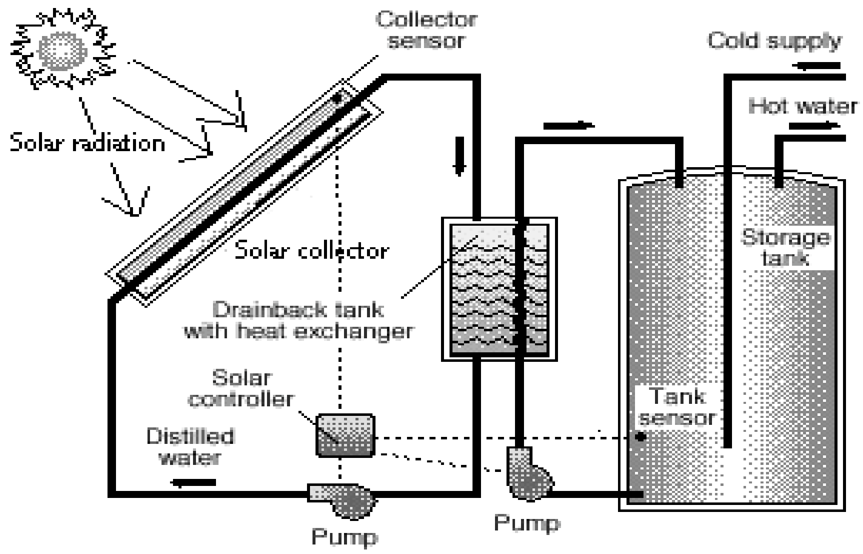
A heat conducting liquid (usually a mixture of water and a non-environmentally damaging anti-freeze) flows through the absorber and circulates between the collector and the warm water storage tank. Thermal solar energy systems are brought into operation through a solar automatic controller. As soon as the temperature on the collector exceeds the temperature in the storage tank by a few degrees, the regulator switches on the solar circulation pump and the heat conducting liquid transports the heat received from the collector to the storage tank.

Elements of a solar heating system for hot water:

* Automatic solar controller
* Temperature sensor on collector
* Temperature sensor on storage tank
* Solar circulation pump
* Cold water inflow
* Hot water run-off

* Expansion tank
* Temperature sensor for additional heating
* Charging circuit- solar circulation pump

The conventional heater guarantees, with the charging circuit, that enough warm water will be available even when the solar heating system supplies little or no heat at all.



Types & applications of solar water heaters:

Solar water heaters are available in various sizes, designs and for various applications. Small systems, with a hot water storage capacity of less than 500 litres, are called domestic systems. These systems are usually installed in residential homes or facilities such as visitor centres and campground showers. Larger size systems (more than a 500 litres per day) are normally referred to as industrial systems. Examples of the application of large systems are found in agriculture, industry, and tourism and hospitality sectors of the economy. Special systems that produce a water temperature of several hundred degrees are sometimes used in industry and for power generation. Another popular application of solar water heating is the heating of swimming pool water in less temperate climates.

As mentioned, various types and different sizes of Solar Water Heaters are produced. Changes in design are required depending on the climate of the place where the system is installed, the water quality and the specific use for the hot water. The systems can be very similar to the traditional electric water heaters, where water is stored in a tank and then heated. The difference is basically that instead of heating the water with electricity or a gas flame, the water flows through a solar collector panel, where the sun's rays heat it.

The different designs of solar water heaters available in the market allow for their application in many sectors of a developing country's economy. Examples of these applications include:

Households: Water heated by solar power is used for bathing, dish washing and laundering in numerous households. Pool heating is another popular application of solar energy in houses of the more affluent in temperate climes.

Health: Clinics and hospitals use solar heated water in ablutions and laundries. Hot water in excess of 80°C can also be used for sterilisation purposes.

Education: Many dormitories in schools and universities use Solar Hot Water systems for the communal shower facilities.

***Tourism and recreation**:* Hotels and accommodation in nature reserves use solar heated water in laundries, bathrooms and sometime for swimming pools.

***Industry**:* Apart from the application of Solar Water Heating systems for worker ablutions, hot water is also required in many industrial processes. Solar hot water applications have been particularly popular in abattoirs due to the cost savings that they bring about. The water is used for the cleaning and sterilisation of the abattoir facility.

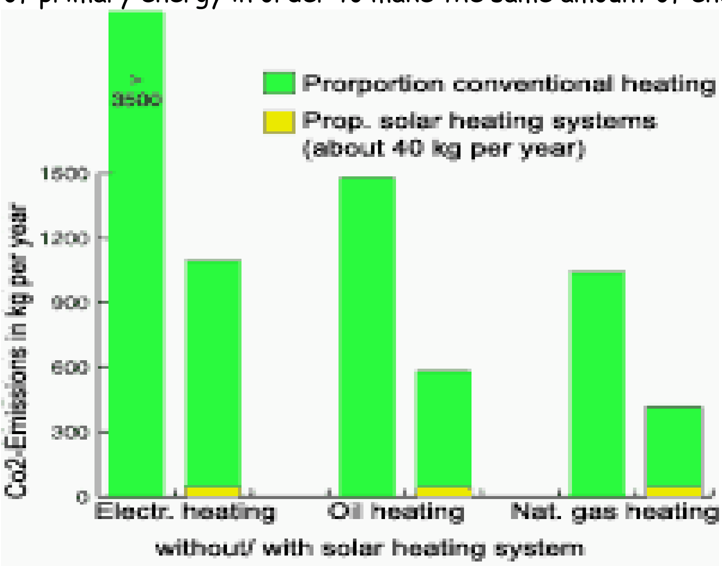
Farms: A wide range of uses are also found in agriculture. These range from heating water in crocodile farms to pasteurisation and sterilisation on dairy farms.

Advantages of solar water heating systems:

A Solar Water Heater (SWH) is a device that uses solar energy to heat water. Solar Water Heaters have several advantages over conventional water heating systems. For consumers, they save electrical energy, save interior space (because they are usually located on rooftops,) and eliminate the risk of accidents in bathrooms due to electrical water heating equipment.

Homeowners who install solar water heating systems to replace water heating by electricity could expect electricity cost savings in excess of 40%. The use of solar water heating therefore is not only environmentally beneficial, it is also economically wiser. In general, it is possible to recover the capital expenditure on a solar water heater within 2 to 5 years, out of the savings realised. Solar heating systems can be integrated into buildings without a problem. Thus, a modern solar heating system, with at least twenty years life expectancy exceeds that of a boiler, and ideally supplements conventional heating technology. These systems also require little or no care and attention while providing hot water for about 300 days a year in most parts of India.

To avoid excessive CO_2 emissions, no electric heating systems may be used. Solar water heating on the other hand, is a renewable energy technology that is proven and reliable. The use of a solar heating system, combined with efficient energy technology (a modern condensing boiler) with the lowest possible energy consumption, is environmentally ideal. The period of energy amortisation (the time until the solar heating system has produced as much energy as was needed to manufacture the system) in the case of a thermal solar heating system is between half a year and two and a half years. Conventional systems never pay back as much in energy terms - they need a much larger amount of primary energy in order to make the same amount of energy available.

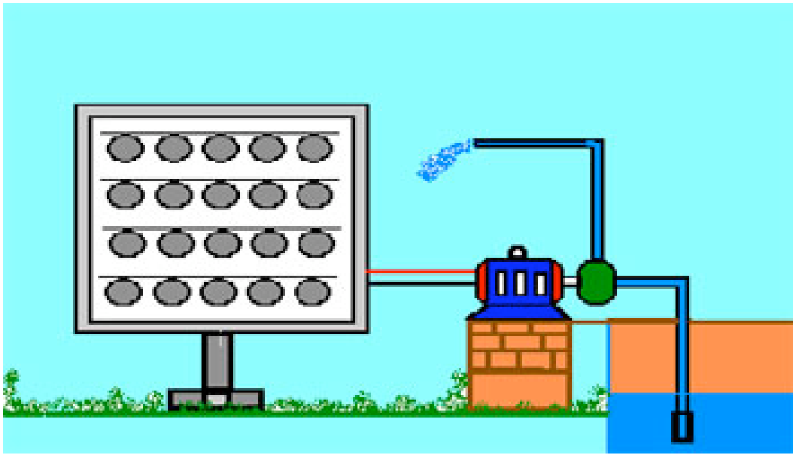


For society at large, they reduce the need for fossil fuels for electricity generation and for fuels such as firewood, coal, furnace oil, etc, that are used in domestic, commercial and industrial boilers. Thereby, they also reduce degradation of the environment.

System Costs
The cost of solar water heaters varies depending on their size and type. Direct *passive* solar water heaters of capacities between 100 and 200 litres usually cost between Rs. 37,500/- and Rs. 62,500/- including installation, while indirect passive heaters are usually in the Rs. 50,000-1,00,000 price range depending on their size and level of sophistication. Active systems for domestic use are usually in the Rs. 1,00,000-2,00,000 price range.

4.5.5 Solar Water Pumps:

The solar water pumping system is a stand-alone system operating on power generated using solar PV (photovoltaic) system. The power generated by solar cells is used for operating a DC surface centrifugal mono-block pumpset for lifting water from a bore / open well or water reservoir for minor irrigation and drinking water purposes. The system schematic is shown in the figure below. The system requires a shadow-free area for installation of the solar panel.



The system is provided with a 1800 W solar PV panel (24 nos. X 75 Wp) and a 2 HP centrifugal DC mono-block / AC submersible with inverter. The average water delivery of a 2 HP solar pump will be around 1.38 to 1.40 lakh litre per day, for a suction head of 6 metres and a dynamic head of 10 metres. The size of the suction & delivery lines is 2.5 inches (62.5 mm).

System Cost & Subsidy Scheme
The MNES is providing assistance of Rs. 135 per peak watt on the cost of SPV modules only for irrigation purpose. The MNES assistance is limited to a maximum of Rs. 2.50 lakh per system. The total subsidy under the GEDA Solar Pump Scheme (2002-03) will be 56.5% on the total cost of the system inclusive of installation & commissioning.
Soft loan to users at a subsidized rate of 5% per annum for the unsubsidized portion of the system cost, upto 90%, is provided by IREDA. Similarly, upto 90% loan can be availed from IREDA on the total cost of the system, at the rate of 5%, in cases for which the subsidy benefit has not been availed. Such a loan shall be payable over a

period of 10 years.

Advantages of solar pump sets

* No fuel cost- uses abundantly available, free sunlight
* No conventional grid electricity required
* Long operating life
* Highly reliable and durable performance
* Easy to operate and maintain
* Eco-friendly
* Saving of conventional diesel fuel

4.5.6 Solar Dryer:

Solar drying has been in practice for long, for the preservation of food and agricultural crops. This was done particularly by sun drying under the open sky. This process however has several disadvantages, like the spoilage of products due to adverse climatic conditions like rain, wind, moisture and dust, loss of material due to birds and animals, deterioration of the material by decomposition, insects and fungus growth. Further, the process is highly labor intensive and time consuming and requires a large area. With cultural and industrial development, artificial, mechanical drying has come into practice. This process is highly energy intensive and expensive however, which ultimately results in an increase in the product cost. Thus, solar drying is the best alternative and a solution to all the drawbacks of the processes of natural drying and artificial, mechanical drying.

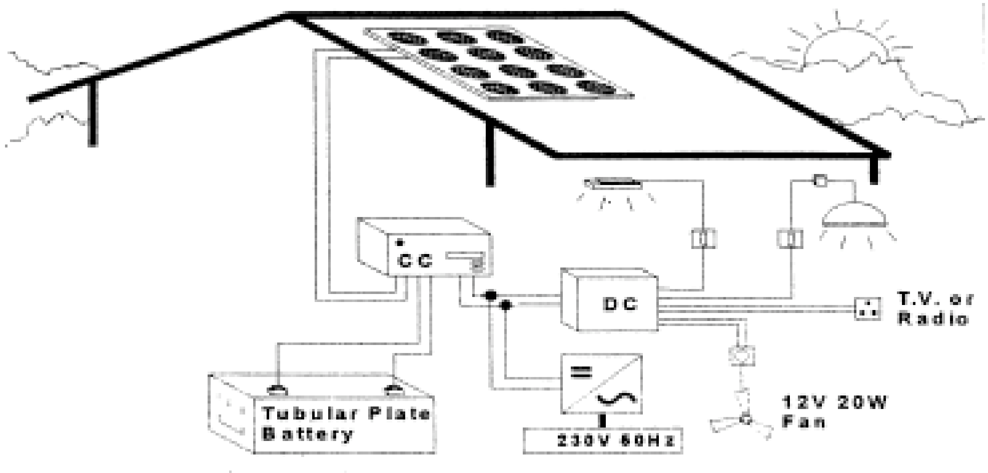
Solar dryers have proved to be very useful devices in agriculture for food and crop drying as well as in industrial drying processes, from the energy conservation point of view. Not only so they save energy, but they also save a lot of time, occupy less space, help improve the quality of the product, make the drying process more efficient, and protect the environment as well. Solar dryers circumvent some of the major disadvantages of the classical drying process. Solar drying can be used for the entire drying process or for supplementing artificial, drying systems, thus reducing the total amount of fuel energy required. The solar dryer is a very useful device for-

* Agricultural crop drying
* Dehydration of fruits, potatoes, onions and other vegetables, in food processing industries
* Production of milk powder, casein, etc., in dairy industries
* Seasoning of wood and timber
* Drying of fabric in textile industries

4.5.7 Solar Home Light System:

Home Lighting Systems may be powered by solar energy, by using solar cells that convert solar energy (sunlight) directly to electricity. This electricity is stored in batteries and used for the purpose of lighting whenever required. These systems are useful in non-electrified, rural areas and as reliable emergency lighting systems for important domestic, commercial and industrial applications. The SPV systems have also found important application in the dairy industry for lighting and milk collection/chilling centres mostly located in rural areas.

The Solar Home Lighting system is a fixed installation designed for domestic application. The system comprises a Solar PV Module (Solar Cells), a charge controller, a battery and the lighting system (lamps & fans). The schematic of the Solar HLS is given below.



The solar module is installed in the open, on roofs/terraces and left exposed to the sunlight, and the charge controller and battery are kept in a protected place inside the house. The solar module requires periodic dusting for an effective performance.

The above systems are designed to give a daily working time of 3-4 hours with a fully charged battery. The system also provides for buffer storage for 1-2 non-sunny /cloudy days.

System Cost & Subsidy
Under the subsidy scheme of GEDA /MNES, 50% subsidy is being provided on the cost of each of the four models approved by the MNES. The specifications of the models included in the subsidy scheme (2002-03) are shown in the table below.

Models	System Capacity	No.of Lights	Tubular Battery
II	37 Wp	2 nos. – 9W CF Lamps	12V, 40 Ah
III	37 Wp	1 – 9W CFL + 20W DC Fan	12V, 40 Ah
IV	74 Wp	2 – 9W CFL + 20W DC Fan	12V, 75 Ah
V	74 Wp	4 nos. – 9W CF Lamps	12V, 75 Ah

4.5.8 Solar Space Heating by Solar Collector:

Solar collectors transform solar radiation into heat and transfer that heat to a medium (water, solar fluid, or air). This solar heat can then be used as a back-up heating system for heating water or for heating swimming pools.

Absorber surfaces:

The heart of a solar collector is the absorber, which is usually composed of several narrow metal strips. The carrier fluid for heat transfer flows through a heat-carrying pipe, which is connected to the absorber strip. In plate-type absorbers, two sheets are sandwiched together allowing the medium to flow between the two sheets. Absorbers are typically made of copper or aluminium.

Absorbers are usually black, as dark surfaces demonstrate a particularly high degree of light absorption. The level of absorption implies the amount of short-wave solar radiation being absorbed that is not being reflected. As the absorber warms up to a temperature higher than the ambient temperature, it gives off a great part of the accumulated solar energy in the form of long-wave heat rays. The ratio of absorbed energy to emitted heat is indicated by the degree of emission.

In order to reduce energy loss through heat emission, the most efficient absorbers have a selective surface coating. This coating enables the conversion of a high proportion of the solar radiation into heat, simultaneously reducing the emission of heat. The usual coatings provide a degree of absorption of over 90%. Solar paints which can be mechanically applied on the absorbers (with brushes/sprays), are less or not at all selective, as they have a high level of emission. Galvanically applied selective coatings include black chrome/nickel, and aluminium oxide with nickel. A relatively new coating is that of a titanium-nitride-oxide layer, which is applied via steam through a vacuum process. This type of coating stands out not only because of its quite low emission rates, but also because its production itself is emission-free and energy-efficient.

Types of collectors:

i) Flat-plate collectors:

A flat-plate collector consists of an absorber, a transparent cover, a frame, and insulation. Usually an iron safety glass is used as a transparent cover, as it transmits a great amount of the short-wave light spectrum. Simultaneously, only very little of the heat emitted by the absorber escapes the cover (greenhouse effect). In addition, the transparent cover prevents wind from carrying the collected heat away (convection). Together with the frame, the cover protects the absorber from adverse weather conditions. Typical frame materials include aluminium and galvanized steel; sometimes fibreglass-reinforced plastic is also used.

The insulation on the back of the absorber and on the side walls lessens the heat loss through conduction. Insulation is usually of polyurethene foam or mineral wool, though sometimes mineral fibre insulating materials like glass wool, rock wool, glass fibre or fibreglass are also used.

Flat collectors demonstrate a good price-performance ratio, as well as a broad range of mounting possibilities (on the roof, in the roof itself, or unattached).

In order to reduce heat loss within the frame by convection, the air can be pumped out of the collector tubes. Such collectors can then be called evacuated-tube collectors. They must be re-evacuated once every one to three years.

ii) Evacuated-tube collectors:

In this type of vacuum collector, the absorber strip is located in an evacuated and pressure proof glass tube. The heat transfer fluid flows through the absorber directly into an U-tube or in countercurrent in a tube-in-tube system. Several single tubes, serially interconnected, or tubes connected to each other via manifold, make up the solar collector. A heat pipe collector incorporates a special fluid which begins to vaporize even at low temperatures. The steam rises in the individual heat pipes and warms up the carrier fluid in the main pipe by means of a heat exchanger. The condensed liquid then flows back into the base of the heat pipe. The pipes must be angled at a specific degree so that the process of vaporizing and condensing functions.

There are two types of collector connections to the solar circulation system. Either the heat exchanger extends directly into the manifold ("wet connection") or it is connected to the manifold by a heat-conducting material ("dry connection"). A "dry connection" allows the exchange of individual tubes without emptying the entire system of its fluid. Evacuated tubes offer the advantage that they work efficiently with high absorber temperatures and low radiation. Higher temperatures also may be obtained for applications such as hot water heating, steam production, and air conditioning.

Type of Collector	Conversion Factor	Thermal Loss Factor in W/m? °C	Temperature Range in °C
Absorber (uncovered)	0.82 to 0.97	10 to 30	up to 40
Flat-plate collector	0.66 to 0.83	2.9 to 5.3	20 to 80
Evacuated-plate collector	0.81 to 0.83	2.6 to 4.3	20 to 120
Evacuated-tube collector	0.62 to 0.84	0.7 to 2.0	50 to 120
Reservoir collector	about 0.55	about 2.4	20 to 70
Air collector	0.75 to 0.90	8 to 30	20 to 50

How much energy does a solar collector provide?

The efficiency of a solar collector is defined as the quotient of usable thermal energy versus received solar energy. Besides thermal loss, there always is optical loss as well. The conversion factor or optical efficiency h0 indicates the percentage of the solar rays penetrating the transparent cover of the collector (transmission) and the percentage being absorbed. Basically, it is a product of the rate of transmission of the cover and the absorption rate of the absorber.

The heat loss is indicated by the thermal loss factor or k-value. This is given in watt per mtr. collector surface and the particular temperature difference (in °C) between the absorber and its surroundings. The higher the temperature difference, the more heat that is lost. Above a specific temperature difference, the amount of heat loss equals the energy yield of the collector, so that no energy at all is delivered to the solar circulation system. A good collector will have a high conversion factor and a low k-value.

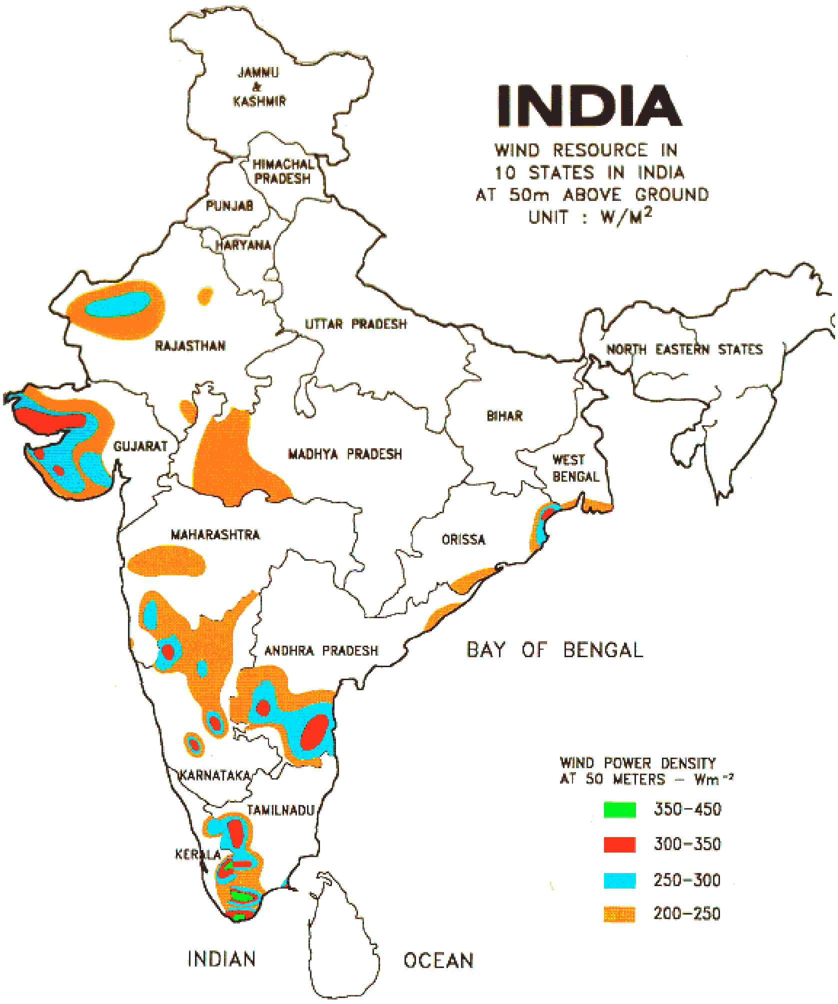
Which collector is suitable for which situation?

The desired temperature range of the material to be heated is the most important factor in choosing the correct type of collector. An uncovered absorber is certainly not suitable for producing process heat. The amount of radiation on that spot, exposure to storms, and the amount of space must all be carefully considered when planning a solar array.

5. WIND ENERGY

India has abundant wind resources to harness for power generation. Strong seasonal winds blow across the Indian subcontinent April through September. The Ministry of Non-Conventional Energy Sources has estimated that the gross wind power potential of India is about 45,000 MWe and has identified more than 200 sites suitable for wind power facilities. Southern India in particular has excellent wind resources, with the states of Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Kerala, Madhya Pradesh, Maharashtra, and Rajasthan having the highest potential. A map of India's Wind Resources is as shown below:

India's Wind Resources



Source: Ministry of Non-Conventional Energy Sources

India ranks fifth in the world in terms of the number of wind power installations; wind power installed capacity is now more than 1,700 MWe, with almost all of the capacity located in the southern half of the country.

Wind power can be used to serve a full range of energy needs, from grid-connected, utility-scale power plants, to small village power systems, to remote water-pumping operations. Turbine sizes vary accordingly, from small wind turbines with a few watts of generating capacity to huge machines with power ratings of 1 MW or more.

Wind turbines can be installed singly for individual home or commercial use. They can also be built in small clusters of three or four to serve several homes or farms, or in even larger groups to provide power for the utility grid.

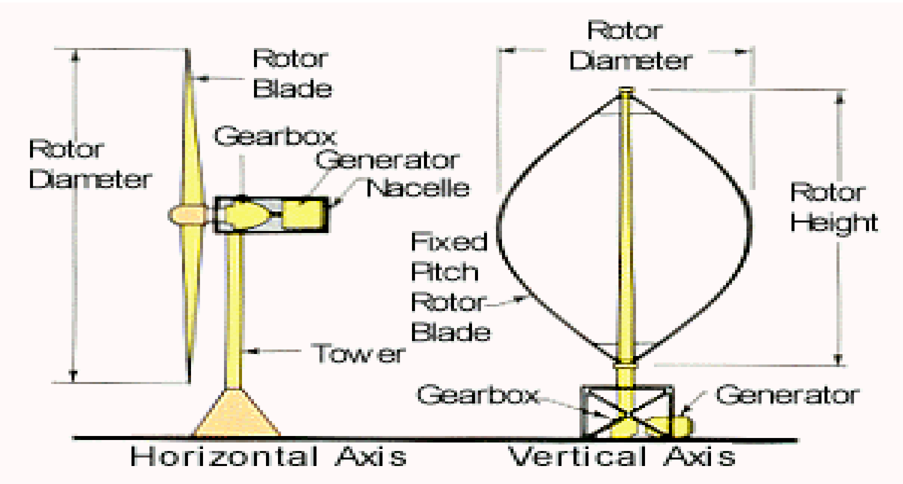
Wind is an indigenous, renewable, and free energy source that generates no pollution and has few environmental impacts. Wind technology is being recognized around the world as an excellent means of serving growing energy supply needs.

5.1 WIND TURBINES

A wind turbine generator converts the wind's kinetic energy into electricity or mechanical energy that can be harnessed for productive use. The mechanical energy generated by a wind turbine can be used for water pumping, irrigation, or water heating in rural or remote locations. Wind electric turbines provide electricity for direct residential or business use or for use by utilities.

Each turbine uses a rotor with one or more blades to turn a power shaft which either activates a mechanical pumping system or an electric generator. When the wind passes the rotor, an aerodynamic lift is created causing the rotor to spin.

Commercial wind turbines are found in two basic configurations:
• horizontal axis (with propeller-like blades) and
• vertical axis (with curved blades that resemble egg-beaters).
Most of the world's operating wind turbines are horizontal axis machines.



Wind Turbine Configurations

The figure above illustrates the two types of turbines and typical subsystems for an electricity generation application. The subsystems include-
- a blade or rotor, which converts the energy in the wind to rotational shaft energy,
- a drive train, usually including a gearbox and a generator,
- a tower that supports the rotor and drive train, and
- other equipment, viz controls, electrical cables, ground support equipment, and interconnection equipment.

Each wind machine has its advantages and disadvantages. Horizontal-axis machines need a way to keep the rotor facing the wind. This is done with a tail on small machines. On large turbines, either the rotor is located downwind of the tower to act like a weather vane, or a drive motor is used. Vertical-axis machines can accept wind from any direction.

Both types of turbine rotors are turned by air flowing over their wing shaped blades. Vertical-axis blades lose energy as they turn out of the wind, while horizontal-axis blades work all the time. At many sites, the wind increases higher above the ground, giving an advantage to tall horizontal-axis turbines. The small tower and ground-mounted generators on vertical-axis turbines make them cheaper and easier to maintain.

Turbines vary in size depending on the type of service they provide. A rural water pumping operation would likely use a small machine with a few kilowatts of generating capacity. A 10-kW turbine located in a moderate wind regime can generate an average of 30 kWh of power each day. Remote villages might use a group of small turbines supplemented with power from a back-up energy source. Most larger-scale systems, such as those serving groups of homes or farms and electric utilities, utilize 250-kW or larger wind turbines.

5.2 WIND ENERGY DEVICES:

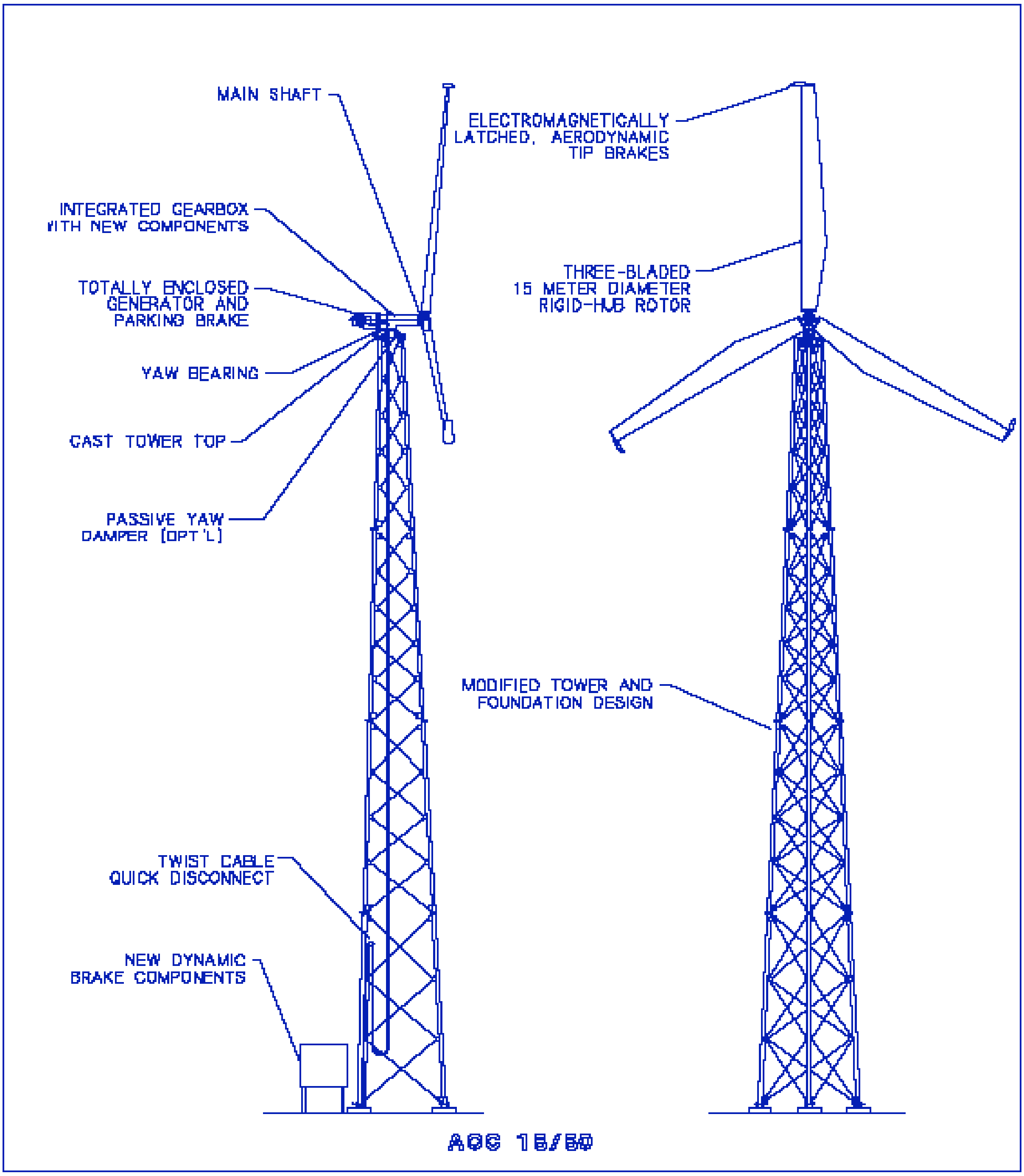
5.2.1 Windmill

As mentioned above, two types of wind machines are commonly used today, the horizontal–axis with blades like aeroplane propellers, in which the axis of rotation is horizontal with respect to the ground (and roughly parallel to the wind stream) and the vertical–axis in which the axis of rotation is vertical with respect to the ground (and roughly perpendicular to the wind stream), and which looks like an egg-beater.

Horizontal-axis wind machines are more common because they use less material per unit of electricity produced. About 95% of all wind machines are horizontal-axis. A typical horizontal wind machine stands as tall as a 20-story building and has three blades that span 200 feet across. The largest wind machines in the world have blades longer than a football field. Wind machines stand tall and wide to capture more wind. Vertical-axis wind machines make up just five percent of the wind machines used today. The typical vertical wind machine stands 100 feet tall and 50 feet wide.

A typical water pumping Windmill comprises of an 18 bladed rotor of 3 metre diameter installed on a tower of 10 metre height. The rotor, through the gear mechanism, drives a connecting rod and the pump, which can pump water from a maximum depth of 30 meter, at an average wind speed of 8-10 km per hours. The approximate rate of pumping under ideal conditions ranges from 1000 to 1200 litres per hour, which could cater to the irrigation needs of about half to one hectare area depending upon the cropping pattern and its water requirement.

A Windmill could be installed on an open well, bore well, pond, etc., at a site which is free from any obstacles such high rise buildings, tall trees, etc., that could restrict the availability of wind to the rotor of the windmill.



System Costs

A typical Windmill of above specification including erection, commissioning, etc., would cost approximately Rs. 65,000. The Windmill is available to the beneficiaries at subsidized rates as per the prevailing subsidy norms.

5.2.2 Windmill Operation:

The wind blowing at 8-10 km per hour at a height of 10 metres, rotates the blades of the windmill, which in turn drives the gear box. The gear box increases the speed of rotation and converts the rotary motion into reciprocating motion. The reciprocating motion drives the pump rod which is connected to an appropriate size of pump at the other end, which pumps the water from the well/bore well.

The tail provided at the opposite end of the rotor, guides the rotor to face perpendicular to the direction of the wind, at all times. The windmill is provided with a manually operated, locking mechanism, which allows the windmill to be locked when it is not required to be used.
Apart from water pumping, the power generated by a windmill can be used for various other purposes such as:

- Lighting
- Water heating
- Space heating
- Home lighting system
- Rural Electrification etc.

Grid-connected power plants generate electricity for the local electric utility. Utilities can own their own wind plants or can purchase wholesale wind power to sell at retail rates to their customers. Large-scale (at least 50-MW) wind plants are very cost-competitive with conventional electricity generating technologies.

Dispersed, grid-connected systems can be used to generate power for homes, businesses, and farms. During low-wind periods, back-up power is purchased from the local utility. When the wind system generates surplus electricity, power is fed back into the utility grid.

Off-grid, stand-alone systems provide cost-effective energy for consumers that are not connected to the utility grid. Such facilities include rural residences, water pumping, and telecommunications operations. Batteries can be used to store electricity and diesel generators can be used for back-up power. Wind hybrid systems, which use any combination of wind, photo voltaics, batteries, and diesel, are a cost-effective way of providing reliable power to remote areas.

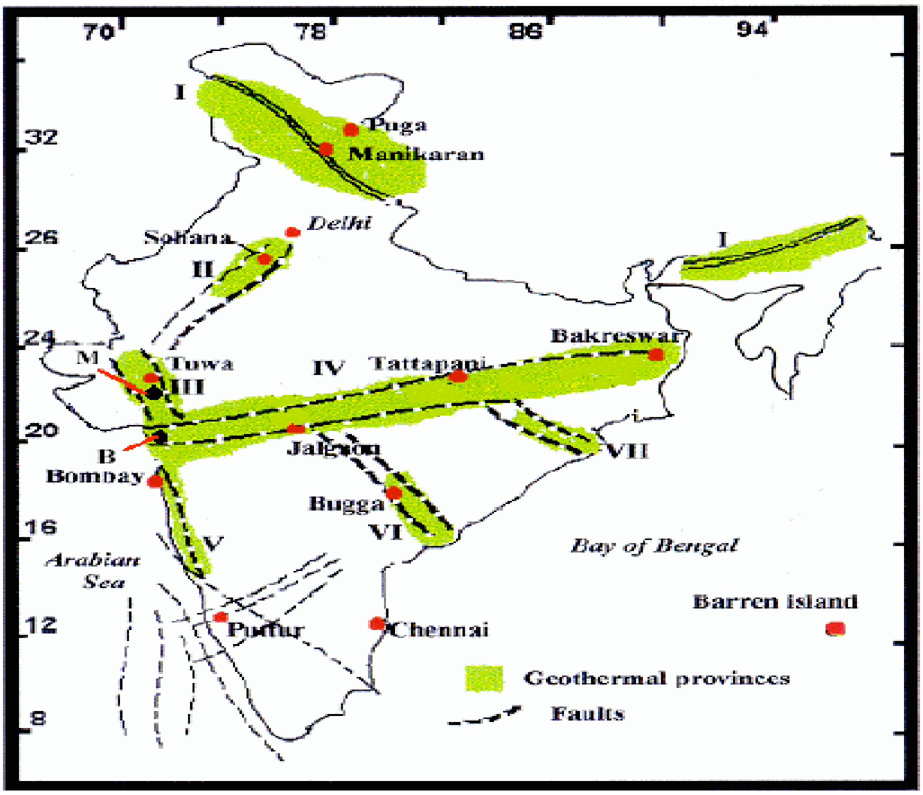
5.2.3 Wind Resource

The amount of energy in the wind is proportional to the cube of the wind speed. Although wind speeds vary over time, they do follow general daily and seasonal patterns which are predictable and which can be tracked through scientific assessment.

A thorough assessment of a site's wind resource is crucial to determining whether a wind power system will provide cost-effective and reliable energy. In general, small turbine systems require annual average wind speeds of at least 9 mph (4 meters per second). Utility-scale wind power plants require wind speeds of at least 13 mph (6 meters per second). Wind resource assessment specialists recommend at least 12 months of consistent observation and recorded wind measurement for large-scale projects. However, three months is often sufficient for small systems.

6. GEOTHERMAL POWER

There are seven main geothermal regions in India, which contain a total of about 400 thermal springs. The major geothermal area is the Son-Narmada-Tapi (SONATA) rift zone, which follows the Narmada river valley from Gujarat into Madhya Pradesh, and then continues into eastern India. An additional place of interest is Barren Island in the Andaman Islands, which has the only active volcano on the Indian subcontinent. A map of India's geothermal regions is as shown below:



Geothermal Regions of India

KEY: I - Himalaya; II - Sohana; III - Cambay; IV - SONATA; V - West Coast; VI - Godavari; VII - Mahanadi; M - Mehmadabad; B - Billimora

Source: Indian Institute of Technology

The state of Gujarat seems to be the hub for geothermal activities in India. The Gujarat state government passed a resolution theoretically aimed at creating incentives for geothermal and other forms of renewable energy, but any actual effect has been minimal and there remain significant financial barriers. Despite this, there are some geothermal pioneers. Avin Energy Systems Ltd. of Ahmedabad has been exploring the possibility of building a 5 MWe geothermal power generating plant in Gujarat as a demonstration that geothermal energy can be commercially successful. Avin believes that the geothermal potential of Gujarat alone could support about 1,000 MWe in generating capacity.

Geothermal energy in India is currently being used mostly for direct heating applications such as heating of bathing pools and drying of agricultural produce. For power generating purposes, the overall geothermal potential of India is about 10,000 MWe. The Geological Survey of India (GSI) has developed an atlas identifying more than 300 potential sites for generating power.

Geothermal resources can serve a substantial portion of the world's energy demand, and use of this renewable energy technology is growing. More than 6,700 MW of geothermal electricity generating capacity is installed in 20 countries in virtually every region of the world. In addition, the world has more than 11,300 thermal megawatts operating in direct-heat geothermal applications. In the United States alone, the geothermal industry provides 2,750 MW of electricity generating capacity and 700 MW of thermal capacity. The world's geothermal capacity saves the equivalent of 150 million barrels of oil each year.

Despite this success, geothermal energy could provide significantly more electricity if its full potential is tapped. Many view geothermal energy as a key resource for meeting the growing demand for power in developing countries. Clean, efficient resources and energy efficiency measures are essential for satisfying the explosive demand in these markets. The Geothermal Energy Association estimates that over the next 30 years, as much as 80,000 MW of electricity generating capacity could be constructed in developing countries.

6.1 GEOTHERMAL ENERGY - THE BENEFITS:

Minimal Environmental Impact: Geothermal plants generate far fewer and more easily controlled environmental impacts compared with conventional technologies. Air emissions are virtually zero; water used in geothermal plants is returned to reservoirs at a depth well below groundwater levels; and geothermal plants re quire a very small amount of land.

High Reliability: Existing geothermal systems have proven to be highly reliable. They are available for power generation 95% of the time with excellent efficiency and production values.

Modularity: Geothermal plants can be built over time to serve the growing demand. A 10-MW geothermal power plant can be built in as little as six months. Clusters of plants totalling 250 MW or more can be built in two years.

Indigenous resource: By tapping its geothermal resources, a community or nation can avoid costly energy imports. Also, plants generate local jobs and economic development. As part of a diverse resource base, geothermal energy can help insulate against fuel price increases and provide greater energy security for consumers.

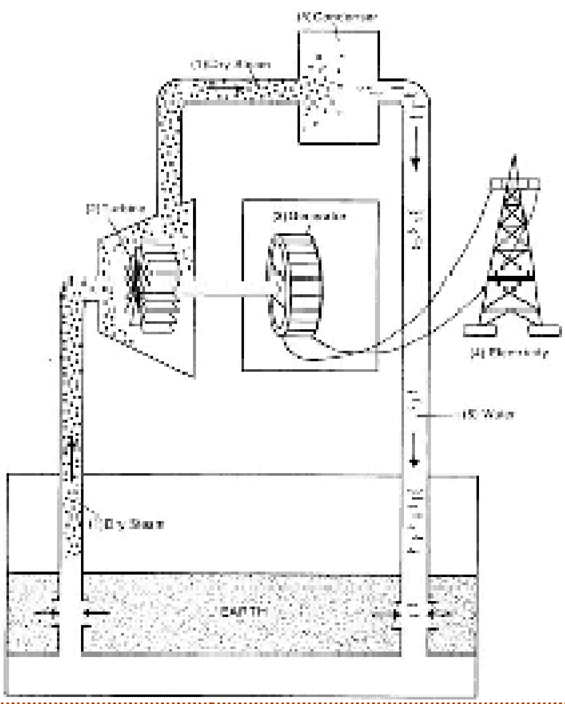
6.2 GEOTHERMAL ENERGY TECHNOLOGY

Geothermal energy is the energy contained in the heated rock and fluid that fills the fractures and pores within the earth's crust. It originates from radioactive decay deep within the earth and can exist as hot water, steam, or hot dry rocks.

Commercial forms of geothermal energy are recovered from wells drilled 100–4,500 metres below the earth's surface. The technology is well proven, relatively uncomplicated, and involves extracting energy via conventional wells, pumps, and/or heat exchangers.

Geothermal energy can be used directly or indirectly, depending on the temperature of the geothermal resource. Geothermal resources are classified as low temperature (less than 90°C), moderate temperature (90°C-150°C), and high temperature (greater than 150°C). The highest temperature resources are generally used only for electric power generation and are found in volcanic regions. Low and moderate geothermal resources are found in most areas of the world. Geothermal energy can be used directly in temperatures ranging from about 35°C to 150°C, to heat buildings, greenhouses, aquaculture facilities and to provide industrial process heat. Indirectly, high temperature geothermal steam can be used to drive a turbine and create electricity or in heat pumps. Using geothermal energy directly is 50-70% efficient compared to the 5-20% possible in the case of the indirect use of generating electricity (although using the waste heat from generating electricity can also be used and thus boost the overall efficiency). Applications that use geothermal energy directly can also draw from both high and low temperature geothermal energy resources, where useful energy can be produced for as low as Rs 1/kilowatt-hour (kWh). Low temperature geothermal energy can also be recovered almost anywhere with special "ground source" heat pumps. These pumps can use the earth as either a heat source for heating or as a heat sink for cooling. Using resource temperatures of 4°C to 38°C, the heat pump transfers heat from the soil to the building in winter and from the building to the soil in summer. In order to generate electricity, geothermal developers drill deep into the earth to tap naturally occurring hot water or steam. Water temperatures found thousands of metres beneath the earth's crust can reach 400°C. Heat is brought to the surface and harnessed to power electricity-generating turbines.

Three geothermal regimes exist within the Earth's crust- hydrothermal, hot dry rock, and earth energy. Hydrothermal energy and earth energy provide economically competitive power for today's consumers. Geopressured, hot dry rock, and magma energy all require additional technology improvements in order to be cost-competitive.



Geothermal Power Plant

6.2.1 Hydrothermal energy, geopressured energy, and magma energy

These result when heat is concentrated in specific regions of the Earth's crust The most obvious indicators of this type of energy are volcanoes, geysers, and hot springs. In many places, however, significant geothermal resources exist in locations where such indicators are not present on the Earth's surface.

6.2.2 Hot, dry rock energy

This is found eight to 16 kilometers (five to 10 miles) everywhere beneath the Earth's crust. Hot, dry rock energy is difficult and expensive to extract since the rocks are either too dry or impermeable to transmit water in useful amounts.

6.2.3 Earth energy

This is used in geothermal heat pumps throughout the United States. This thermal energy is found just beneath the surface and is the normal temperature of shallow ground. Without enhancement, earth energy can be tapped by heat pumps to help alleviate electricity demand.

For generating electricity, hot water (ranging in temperature from 177° to about 370° C, or 350° to greater than 700° Fahrenheit) or steam is pumped from an underground reservoir to the surface. The steam is transferred to a turbine which turns an electricity generator. The remaining geothermal fluid is pumped back to peripheral parts of the reservoir to help maintain its pressure.

Low-temperature resources (lower than 177°C or 350°F) can be harvested through binary power plant technology. A binary plant taps geothermal fluid to heat a "working" fluid that vaporizes at low temperatures. The working fluid vapour is fed to a turbine and is recondensed and then reheated repeatedly in a closed-loop cycle.

In direct-heat applications, geothermal water is usually fed into a heat exchanger which transfers heat to the household. The geothermal water cycles through the heat exchanger and then returns to the reservoir. Direct-heat applications can be used for home heating, greenhouse heating, vegetable drying, and other uses.

Geothermal heat pumps use yet another process. A heat exchange fluid runs through a closed-loop system, absorbing heat from the earth and transferring it to the home.

7. HYDROPOWER

The last two decades have seen a significant growth in hydropower development throughout the world. While large projects were built in the 1970s to provide utility-scale, grid-connected power and flood management, smaller scale hydropower projects are now helping to address one of the developing world's most pressing problems: the need to bring electricity to remote, rural areas.

Few developing countries are able to satisfy the rapid energy demand growth that is fueled by their exploding populations. Power is desperately needed in these countries to satisfy a full range of needs, from electrifying village schools and health facilities to grinding grain and pumping clean water. Electricity sector restructuring in many of these countries, along with the ability for private development of hydropower projects, can bring electricity to these growing communities.

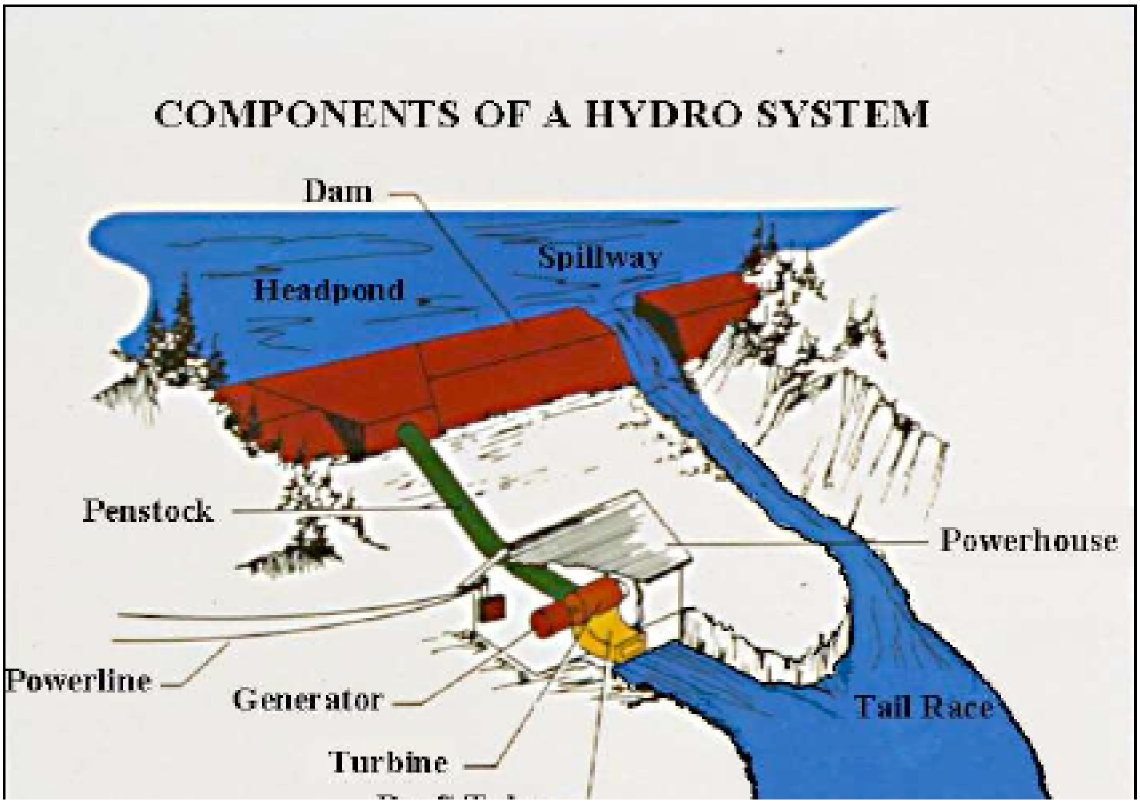
Less than 10% of the world's technically usable hydropower potential is being used today. However, small-scale hydropower plants are proving to be very cost-effective for strengthening grid-connected systems and for rural electrification. These plants provide a number of benefits to the communities that they serve. For example -

- Thousands of existing facilities sited around the world have proven their reliability and effectiveness.
- With sufficient water resource, these facilities can provide a 24-hour energy source.
- They have no fuel costs and cause minimal environmental impact.
- Operation and maintenance requirements are minimal and can be performed by local staff.
- Properly maintained facilities can perform well for 50-100 years.
- Existing hydropower projects invest in local resources and provide energy for local activities (like grain grinding, milling, and drying) and electricity for lighting, communications, and small industries. In addition, hydropower plants are used to fuel water purification efforts and agricultural processes.

7.1 HYDROPOWER TECHNOLOGY

Hydropower systems capture the energy of falling water. This energy is converted into reliable electricity to efficiently and cost-effectively meet market demand.

Hydropower plants are configured in one of two ways. "Run of river" operations use the natural flow of a river by diverting it into canals that lead to a power plant. In the second configuration, water is stored in a reservoir and sent to the power house as needed.



7.1.1 System Components

In general, hydropower systems include the following basic components:

i) ***Powerhouse***, which contains turbines, generators, excitation, control systems, and hydraulic systems used to convert water energy into electric power.

ii) ***Scroll case***, a pipe that supplies water to the turbine.

iii) ***Fore bay***, which funnels water from the canals or reservoir into the scroll case. Usually, a grate or trash rack cover prevents debris (trees, branches, rocks, etc.) from entering the turbine.

iv) ***Wicket gates or guide vanes*, to** meter water into the turbine from the scroll case.

v) ***Water supply system canals***, made of either earth or concrete provide direct flow into the plant's fore bay, and **pen stocks** (pressurized pipes) direct water from the reservoir to the scroll case.

vi) ***Tailrace***, a draft tube by which the water exits the powerhouse and passes through a concrete or rock-lined outlet structure.

Three basic types of turbines are used to generate hydropower:

A. ***Francis turbine:*** a fixed-blade turbine;

B. ***Kaplan turbine:*** a variable-pitch blade turbine similar to a propeller; and

C. ***Impulse turbine:*** a fixed-blade turbine with blades shaped like buckets or half circles. Water is metered to the turbines through one to six “needle valves” instead of through wicket gates. The needle valves send jets of water into the turbine buckets to turn the turbine.

7.1.2 Working of a Hydro Dam:

The water behind the dam flows through the intake and into a pipe called a penstock. The water pushes against blades in a turbine, causing them to turn. The turbine is similar to the kind used in a power plant. But instead of using steam to turn the turbine, water is used.

The turbine spins a generator to produce electricity. The electricity can then travel over long distance electric lines to your home, to your school, to factories and businesses. Hydro power today can be found in the mountainous areas of states where there are lakes and reservoirs and along rivers.

7.2 HYDROPOWER DEVELOPMENT:

There are obstacles that challenge hydropower development in many countries around the world. However, there are many efforts under way to minimize these barriers and encourage the use of hydropower to electrify rural and developed areas. These efforts are being made by the government, industry, and non-governmental and research organizations. They range from programs offering tax incentives for renewable energy development to policies that welcome private investment in power generation projects.

One such measure is the standardisation of equipment. By standardizing equipment design and manufacture processes, many governments in nations with developing economies are reducing the costs associated with hydropower development. Standardized equipment and standardized project designs can be used to build a hydropower plant that serves specific end-user needs. For example, if a plant is to be build in a remote area with no major roadways, equipment can be made more modular than those used in urban, developed areas.

8. APPROPRIATE RE TECHNOLOGIES

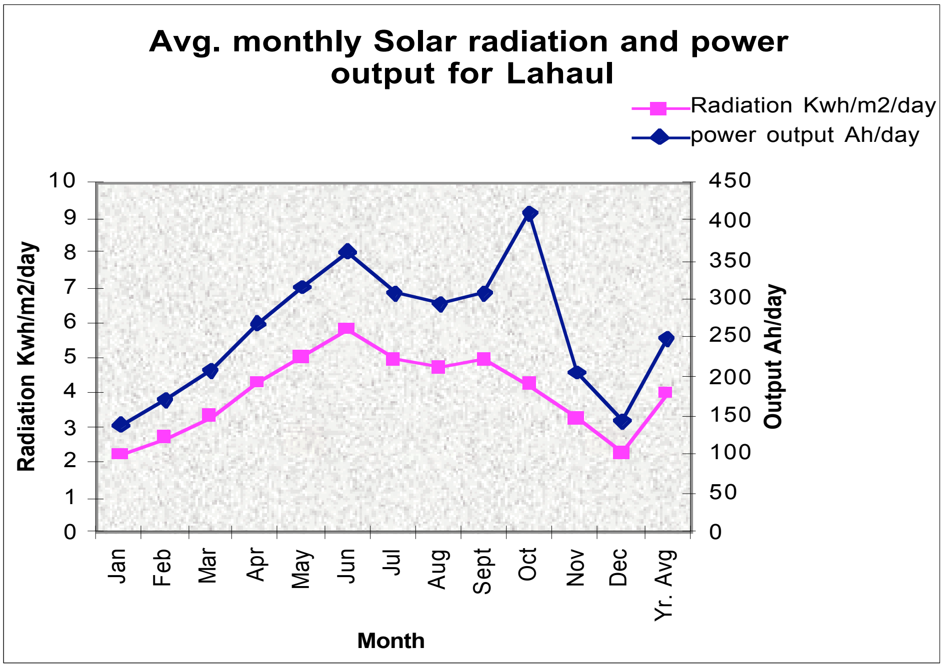
Realizing all the problems of the region, renewable energy sources like sun, wind, water, as well as geothermal would be the best replacements for the conventional energy sources. The Himalayan region is best suited for renewable energy options because of the following:

- Large no. of sunny days in the region make the region suited for installation of solar energy options - the Western Himalayan cold deserts have around 8 sunshine hours per day almost round the year and 325 sunny days per year.

- Good solar heat intensity also makes the solar options more efficient. The region has one of the highest insolation levels in the world. Solar radiation data for Lahaul & Spiti for a year is given below:

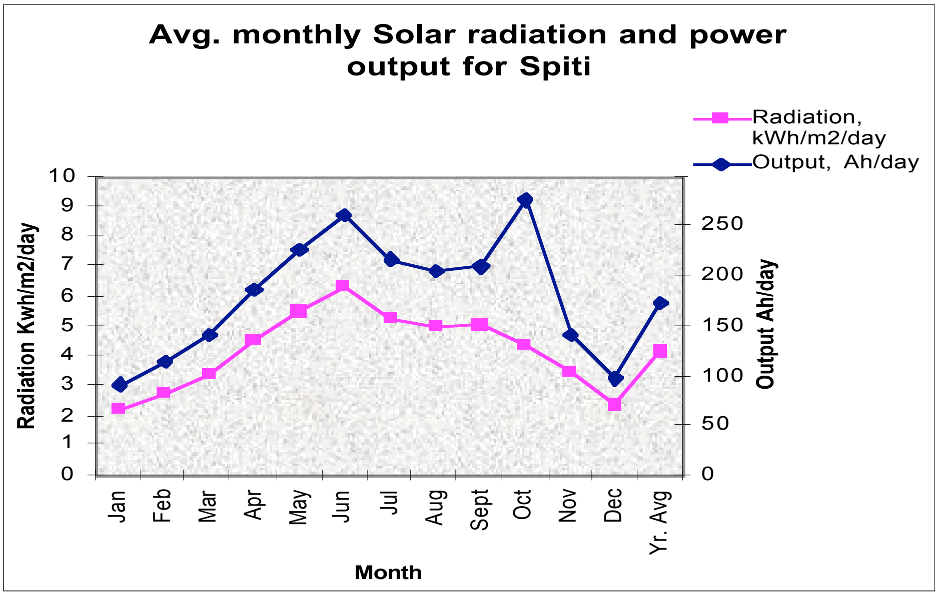
1. ***Solar Radiation in Lahaul:***

Month	**Radiation, kWh/m2/ day**	**Output, Ah/day**
January	2.23	139.38
February	2.75	171.88
March	3.34	208.75
April	4.3	268.75
May	5.05	315.63
June	5.82	363.75
July	4.94	308.75
August	4.73	295.63
September	4.95	309.38
October	4.26	411.88
November	3.3	206.25
December	2.33	145.63
Yearly Average	4	250



2. Solar Radiation in Spiti:

Month	Radiation, kWh/m2/day	Output, Ah/day
January	2.22	92.5
February	2.76	115
March	3.4	141.67
April	4.51	187.92
May	5.46	227.5
June	6.28	261.67
July	5.24	218.33
August	4.95	206.25
September	5.05	210.42
October	4.34	277.92
November	3.41	142.08
December	2.33	97.08
Yearly Average	4.16	173.33

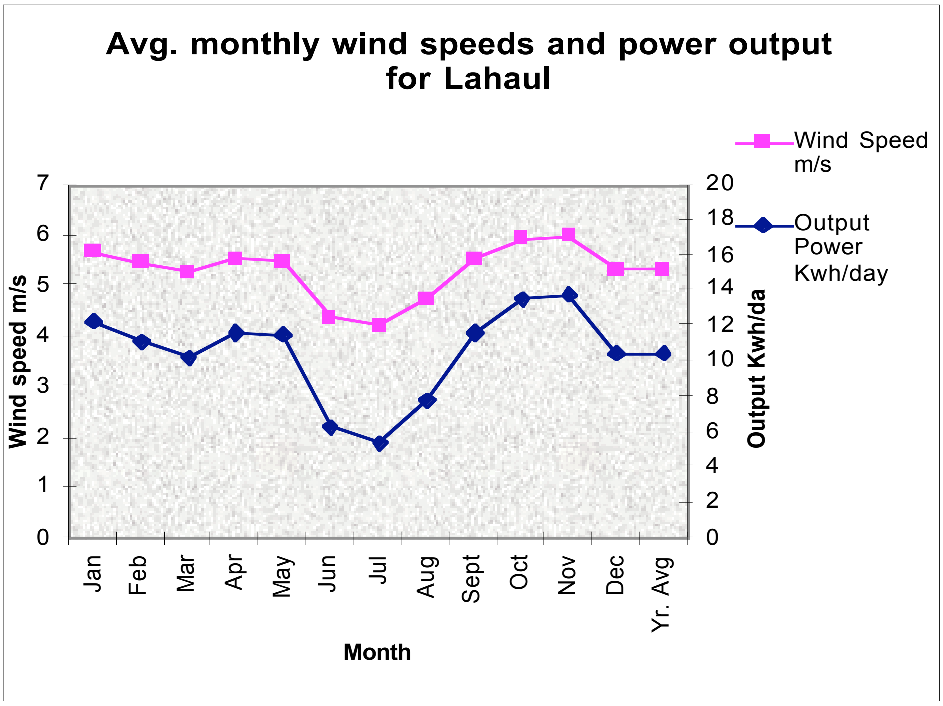


The above table also gives us the total Ampere-hour output per day.

- Similarly there are high velocity winds available round the year, which can be tapped using windmills. The wind speed data for both Lahaul & Spiti for the year 2002 is as follows:

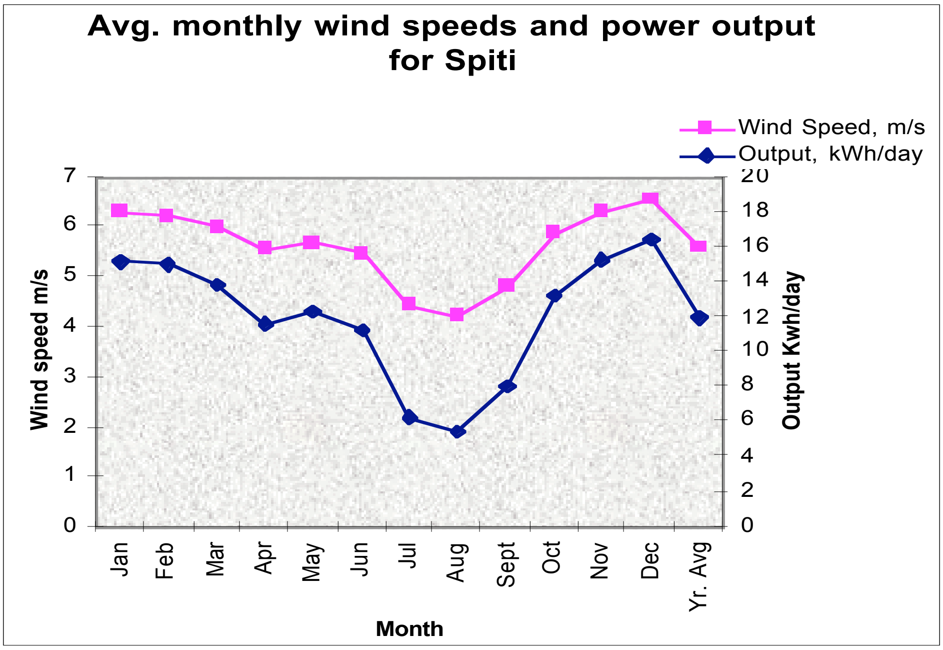
1. Wind Speeds & Estimated Power Output for Lahaul:

Month	**Wind Speed, m/s**	**Output, kWh/day**
January	5.68	12.3
February	5.43	11.1
March	5.27	10.3
April	5.53	11.6
May	5.51	11.5
June	4.4	6.3
July	4.22	5.5
August	4.76	7.9
September	5.53	11.6
October	5.94	13.6
November	5.99	13.8
December	5.32	10.5
Yearly Average	5.3	10.5



2. Wind Speeds & Estimated Power Output for Spiti:

Month	Wind Speed, m/s	Output, kWh/day
January	6.29	15.2
February	6.23	15
March	5.99	13.8
April	5.54	11.6
May	5.69	12.3
June	5.45	11.2
July	4.42	6.3
August	4.23	5.5
September	4.8	8.1
October	5.88	13.3
November	6.3	15.3
December	6.55	16.5
Yearly Average	5.61	11.9



From the above data the average power output can also be found out.

- The use of renewable energy equipment also reduces our dependence on foreign and/or centralized sources of energy, and is an important strategy in the process of creating a truly secure and sustainable energy future.

- Traditional houses in Lahaul and Spiti are best suited to be retrofitted with the RE sources.

Hence it is very clear that renewable energy has a wide scope for growth in the region. Of the various renewable energy options available two have been chosen as the most suitable for adoption in Lahaul & Spiti. The region is rich in solar radiation and wind. Hence RE technologies tapping these sources would be the most suitable.

Some of the problems that would be faced in RE implementation in the region are listed below:

i) ***Inadequacy of data:*** While selecting the technologies for adoption in Lahaul & Spiti unavailability of data for coming to a final and conclusive design is a major obstacle. Accurate and complete solar radiation and wind data for the region is unavailable as measurements have not been carried out for the same.

ii) ***Inaccessibility of the area:*** As it is a cold desert region, all roads in the region are snowbound and unfordable in winters - for a period of nearly four to six months. Hence it is not possible to monitor or note the readings of the weather kit throughout the year.

iii) ***Lack of awareness:*** As it is a high altitude region that remains inaccessible for a quite long period every year, the people of the region also remains unaware of the technological developments in the world, including the latest low-cost energy technologies being developed.

iv) ***High RE costs and subsidies fuelwood:*** The lack of awareness among the local people about renewable energy technologies and their advantages is compounded by the high initial cost of the RE devices, and the easy access to subsidised fuelwood.

v) No wind energy experience: Although some solar applications have been installed in the region, no previous attempts have been made to install windmills in the region. Hence no data exists about the post installation performance of such devices.

vii)No local suppliers: The state govt. has been supplying solar energy devices in the region. But HIMURJA has limited offices in a few select locations only. Since there is no other accessible local supplier, the local people hardly get to know about the subsidy schemes and RE devices available.

viii)Monopoly of hydropower: Although Himachal is one of the power rich states of India, most of its power is based on hydropower which however is not feasible for Lahaul and Spiti due to the high silt load in the rivers of the region.

Understanding these problems and needs of the local people, the following actions should be taken:

i) Installation of weather kits at potential sites: Small weather kits should be set up at various potential sites in Lahaul & Spiti region so that a throughout the year data of the region may be generated for future reference. The weather monitoring kit should comprise the following equipment:

- Anemometer, to measure wind speed and direction.
- Thermo-hygrometer, to measure outdoor temperature and humidity.
- Rain gauge, to measure the total rate and amount of rainfall.
- Baro-thermo-hygrometer, to measure the atmospheric pressure, temperature and humidity.

ii) Community mobilisation: Since renewable energy is not an urgent need for the locals of the region, there may be a lack of interest among them in these technologies. This is where community mobilisation and awareness generation about renewable energy technologies will play a major part. PRA techniques for community mobilisation should be applied for the same. The village heads, literates and financially well-off persons should be targeted first. Through Venn diagrams it can be shown that renewable energy is the only practical energy source which has a wide future scope. The drawbacks of using biomass and fossil fuels should be explained to the local people. It is also necessary to make them understand that although the initial cost of the devices is high, there would be no post installation cost.

iii)Arranging for local suppliers: After the mobilisation is completed, the people should be guided to the suppliers of these devices. A list of suppliers comprising details of the HIMURJA outlets in the region as well as other suppliers in nearby locations, would need to be published and distributed in the region. The suppliers of RE equipment in nearby locations will need to be interacted with to motivate them to open outlets in and/or provide supplies and services, including the subsidies, to the target region.

iv) Training for Local People: A group of local people from various villages in the region will need to be trained in the installation, handling and servicing of the RE devices. Thus they will be able to promote the use of the devices, train others on the operation of these devices, and also carry out the post installation maintenance work.

9. RE FUTURE IN THE HIMALAYAS

Renewable energy technologies have the potential to be replicated for a wide variety of uses in the cold deserts. Some of these potential applications are:

9.1 RURAL ELECTRIFICATION

Since the power situation in the region is very grim, village electrification using solar or wind energy can be taken up. This becomes all the more imperative for villages which have never seen electric power and are not connected to the grid due to the remoteness and inaccessibility of their locations.

9.2 SPACE HEATING

Since temperatures go down to sub-zero levels in winter, space heating becomes very important. Using active solar heating techniques combined with retrofitting of the houses with solar passive features, could help the local people meet their energy needs for heating. This will also bring down the consumption of environmentally polluting conventional fuels.

9.3 COMMUNITY CENTRES

All energy needs of a community centre can be met using RE solutions. Apart from power generation for heating and lighting of the centre, sources of entertainment like television can also be attached, thereby linking the community with the outer world.

9.4 HEALTH

Solar PV systems can help power vaccine refrigeration, general hospital facilities and task lighting, and communication with district hospitals.

9.5 EDUCATION

The provision of solar power to rural schools allows the lighting of classrooms at night, which could aid programs providing basic adult education. Solar power systems also make the introduction of teaching aids such as computers, television, video and overhead projectors possible.

9.6 MANUFACTURING & COMMERCIAL

Numerous possibilities exist for the use of solar power in the manufacture or processing of the region's produce and the retailing of goods in rural communities. Processing units can be established for the distillation of essential oils from medicinal & aromatic plants of the region, as well as post-harvest processing of other local produce. For example, seabuckthorn grows wild in the region and has been successfully used to produce juice and jelly by DRDO in Leh. Similar units can be set up elsewhere in these region as well. All the power requirements of such units can be met with renewable energy. This will also help in generating employment for the locals.

9.7 TOURISM

Through the installation of solar power, accommodation facilities within nature reserves can be greatly improved.

9.8 TELECOMMUNICATIONS

Solar power may also be used to power two-way radios and telephones. Service providers can use solar power to relay messages through repeater towers instead of establishing direct wire links.

9.9 AGRICULTURE & WATER PUMPING

Fetching water from great distances to meet irrigation and drinking water needs is a common feature of the Himalayan region. This can be facilitated by using renewable energy technologies for water pumping. Agriculture in developing countries benefits from solar power through applications such as water pumping and electric fencing.

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Cent. Coordn. Off.: A-212A, Sushant Lok - I, Gurgaon - 122002, India.
Website: www.pragya.org
Phone/Fax: 91-124-2385932, 2386104.
E-mail: info@pragya.org

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