diesel and other conventional power generating plants, a GBI (Generation Based Incentive) policy has been formulated.

- In this case, feed-in tariff would be determined by the SERC (State Electricity Regulatory Commission) for the metered electricity generated from such applications (whether consumed by the grid connected owner of the rooftop/ground mounted installation or fed into the grid). Utility will pay a minimum of Rs.5.50/kWh- increasing annually @ 3%.
- The GBI payable to the utility would be a tariff fixed by CERC minus notional tariff of Rs.5.50/kWh. The payment of GBI would be through IREDA (Indian Renewable Energy Development Agency)-the financial arm of the MNRE (Ministry of New and Renewable Energy)

Opportunities through this mission

The mission provides huge opportunities for an active perusal of research and development initiatives towards promoting solar power. A Solar Research Council will be set up to oversee the strategy, taking into account ongoing projects, availability of research capabilities and resources and importantly, possibilities of international collaboration. This would also reduce the cost of the technology and further increase the contribution of solar energy utilization in total power generation.

In addition, the mission also targets an ambitious HRD (human resource development) programme, across the skill-chain. This will be established to support an expanding and large-scale solar energy programme, both for applied and R&D sectors.

Issues to be confronted and suggestions for way forward

Manufacturing capabilities

Currently, the bulk of India's solar PV industry is dependent on imports of critical raw materials and components-moreso silicon wafers. Transforming India into a solar energy hub would include a leadership role in low-cost, high quality solar manufacturing, including balance of system components. The Union Budget 2010/11 has duly recognized the importance of promoting clean and renewable energy technologies besides providing some incentives for solar energy and wind energy system use. A concessional custom duty of 5% to machinery and appliances for solar PV and solar thermal power generation units has been provided. These have also been fully exempted from the central excise. In addition, an amount of Rs 631 crores has been allocated to MNRE for its various schemes and incentive mechanisms to promote renewable energy. Hence, given the incentives under the mission and the current budget, building manufacturing capabilities should be the focus in Phase I.

Uneven distribution of the solar energy

Not all parts of the country receive equal amount of solar energy. Therefore, to harness the maximum possible potential, there needs to be technological advancement in terms of higher efficiency and regulatory frameworks to promote solar installations in sunny areas. In this case, innovative mechanisms such as solar RECs (renewable energy certificates) should be used to promote solar power, as they are not bound by location or time.

Solar specific renewable purchase obligation

The JNNSM has proposed a 0.25% mandatory obligation for utilities regarding the purchase of solar power. This would help in promoting development of grid connected solar power. Also, the CERC envisages that this obligation is met through solar specific

RECs. However, the REC scheme can only be used for that solar power, which is not tied up in PPA (power purchase agreement). The issue here is that, the solar RPO is yet to be notified either by the CERC or any of the state regulatory commissions. So far, only the Gujarat Electricity Regulatory Commission has come out with draft regulations for solar RPO. Thus, by the time it is notified, solar projects which have already come up would have tied up their generation through long term PPAs and new solar projects will take another 2–3 years in making their generation available for RECs. Thus, there would be a phase lag between the notification of solar RPO and the REC scheme to be implemented to meet them. One suggestion for the REC scheme to be successful can be that NVVN, which is the nodal agency in phase-I be allowed to issue RECs for already tied up solar capacity. This would ensure that the time lag is minimized and full utilization of REC scheme can be made.

Implementation strategies

Under an implementation strategy for Phase I (that is up to 2013), solar power connected to grid above 33 kV will be routed through NVVN. This may make market uncompetitive as other traders may not get an equal market share. In addition, the allotment of unallocated power (that is 15% of NTPC power plants) is kept reserved for emergency supply to the states. The units generated by this reserved capacity will be allotted to NVVN; and based on PLF calculations about four units of conventional power will be available for each unit of solar power. This will bring down the selling price of solar units to about Rs 5–6 per kWh (this is because each unit of unallocated power is usually sold at Rs 2.00-2.50 per kWh) making it competitive for trading. However, for long term and augmentation of further capacities beyond Phase I, this arrangement will need some reconsideration. Also trading through other agencies should be explored to avoid a possible monopolistic approach.

Integration of policies

Other central level schemes for promoting solar such as solar specific RPO and RECs will have to be integrated with the mission. The phase I strategy of the mission only includes that solar power, which is tied in a PPA, while a solar REC would be issued only for a solar power unit, which is not tied up under a PPA. Hence, an effective coordination between the two schemes is missing. This needs to be included in Phase-II strategy for the mission, as solar RECs can go a long way in promoting solar especially at the utility level.

Funding

Similarly, funding mechanism is clear only for phase I. Further, the phase I strategy may not be scaled up in the next phases of the mission, as total capacity targetted is 20 000 MW, while an equivalent unallocated power capacity may not exist. Thus, for the next two phases of this mission, funding mechanism consisting either of subsidy or GBI (generation based incentive) will need to be devised. This would ensure a smooth transition between the respective phases as well as achievement of the targetted solar capacities. Also steps must be taken for mobilizing international finance through a clear policy mechanism in the remaining phases of the mission.

Off-grid application

A key opportunity for solar power lies in decentralized and off-grid applications. In remote and far-flung areas, where the grid penetration is neither feasible nor cost effective, solar energy applications are cost-effective. The key problem is to find an optimum financial strategy to pay for the high-end initial costs for these applications through an appropriate government support, which is provided through this mission.

Existing schemes such as RGGVY (Rajiv Gandhi Grameen Vidyutikaran Yojana) and VESP (Village Energy Security Programme) should be integrated with JNNSM in its next phases so as to have a robust scheme for the rural electrification through off-grid applications.

Storing the Sun for conventional gains

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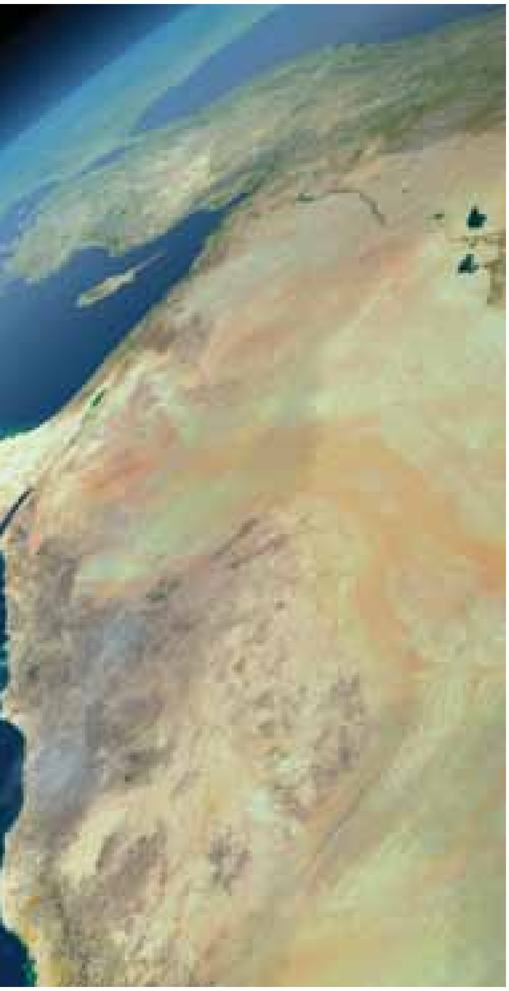
Background

Just think of a day when we would like to witness a world run mostly by the renewable energy technologies. But, whether is it realizable in actual practice is a million dollar question? Yes, it is quite possible to develop a lot of intermittent sources like the solar and wind energy without any storage medium. However, we may very well requite both the short-term and long storage technologies to help stabilize the available grid. Solar energy is quite widely distributed and free from the geographical demarcations. As we know, in a single hour, more solar energy strikes the surface of the Earth than is provided by all of the fossil energy consumed globally in one full year. Solar PV (Photovoltaics) market is making useful inroads and currently expanding by about 35% per annum. However, its cost to efficiency ratio must reduce considerably in order to witness its large scale deployment for various end-use applications. This calls for extensive research and development to realize the needs of scale up, cost and importantly, field performance reliability. It is no less important to develop large scale energy storage medium(s) for a true market worth of solar to be realized.

Why large scale energy storage

Solar PV technology is gradually inching forward to tune in new areas of power use. The growing environmental concerns together with an ever increasing cost of the petroleum products is prompting a new expectation of bringing in technologies like solar PV on a noticeable scale of utilization in the urban areas. One may argue for solar PV working only during the available hours of sun shine and not beyond that. The moot question is, we have an option of deploying a huge solar capacity and storing the charge, and thus generated in the batteries. An instant liking for this idea may not be found as there seems to be nothing new in this context. After all, that is precisely the way any off-grid PV application (minus a solar water pumping system) functions. But, we are now talking about very high capacity monolithic battery units unlike a battery bank for example. It may be akin to a huge storage unit, which is put to use



as and when needed either as a standby demand-side management measure or otherwise. Assuming for a moment that we can put up such huge energy storage units, would it meet the safety standards required for urban rooftop applications. This makes some sense as there are both natural and man-made perils at work. It may be quite interesting to find out if, solar PV based storage units can at some time or the other replace in part or full the current use of diesel generating units in a straight contest of sorts. Wind energy may also be used to charge the battery unit beyond the usual sunshine hours thus maximizing the role of two of the fastest growing technologies. The following section runs through a few innovative battery technologies, that may perhaps respond to the expectation of mega energy storage of solar and wind derived energy.

Latest innovations in battery technologies

MIT megawatt technology

MIT (Massachusetts Institute of Technology) has recently developed a prototype unit of 1 MW capacity to serve as a rooftop storage battery. Solar PV panels are now being increasingly considered to gradually replace the diesel generating sets for commercial and institutional uses. A rooftop battery converts the chemical energy into electrical energy using the solar panels. It can store up to 1 MW or 1 million Watts for supplying uninterrupted power to cities, an entire district or for that matter a cluster of villages across the country. Taking a strong cue from its immense potential, the Indian Ministry of Power has sought a tie-up with MIT under the auspices of Indo-US Science and Technology Forum to develop the prototype storage battery into a commercial venture. The underlying intention is to meet a part of India's escalating energy demand. To begin with, the Ministry will fund a pilot project, which will be jointly implemented by the Central Public Sector Enterprises that is Bharat Heavy Electricals Ltd and NTPC (National Thermal Power Corporation).

Operational details

As per the available information, selective few sites will be identified to evaluate the cost and quality of energy produced so as to ensure an uninterrupted power supply to the low-tension power users. India being a tropical country can derive the maximum possible advantage of avoiding long-hours of blackouts in the peak season. A good thing is that the storage battery can also be charged with wind energy, which is plentiful across the peninsular India for most parts of the year. Generally, sunlight happens to be less during the monsoon and winter periods. That is precisely the time, when wind energy can be harnessed to charge the storage battery. The accompanying objective is to maintain the power supply to the end-users via smart-grids. With solar panels still priced on a higher side, there is an undeniable need to take up mission oriented research programmes so as to ensure a cheap availability of these batteries. Once the technology becomes affordable, the power can be supplied from the storage battery directly through a local grid on a stand-alone basis. It can also be pooled with a national grid in order to rationalize its generation cost with that of thermal or hydro power.

Ice Bear energy storage system

In a building, air-conditioning constitutes a major cooling load during the hot summer months. Solar powered air conditioning has been tried in a very selective few cases. There are other alternative mediums of storage at work to meet this important use quite effectively. A company by the name of Ice Bear has developed a distributed energy storage system, which is designed to absorb off-peak load and dispatch it on-peak. During this process, it consumes an equal or lesser amount of energy on each building. The breakthrough technology features of the Ice Bear unit includes the industry's first effectively loss less storage with unlimited deep discharging, unlimited storage cycles, very low maintenance, no chemicals or heavy metals, and importantly a 25-year asset life.

Power cube battery technology

Lead-acid batteries are perhaps the most widely used batteries in use with the solar PV systems. The valve regulation lead-acid type still does not come cheap. Majority of the off-grid solar systems use the batteries, which need to be replaced at regular intervals thus incurring a certain replacement cost as well. The conventional lead-acid batteries use negative electrodes made of sponge lead pasted onto a lead grid current collector. In direct comparison, the technology developed recently by a Delaware based company uses negative electrodes made of micro porous activated carbon with a very high surface area. The resultant outcome is a battery super capacitor that uses less lead. It is being regarded as a major advance in the lead-acid battery technology.

The developer of this new generation technology is Axion Power International Inc. It has been awarded a $ 3 00 000 grant from the solar energy programme of the state's commonwealth Financing Authority. The purpose is to demonstrate the advanced energy storage technology of the lead-carbon batteries within a smart grid system. In this case, the power generated from renewable energy sources such as the sun or wind is stored during overnight periods. It is then delivered to the grid during times of peak demand. These batteries are intended to be coupled with a UPS power conditioner, a solar panel besides an electric vehicle charging station.

Global battery market

Solar power applications depend on battery storage to meet various end-use applications. This is just one small segment of battery use, which runs the whole range of conventional applications. Be it a backup power for the highly critical remote telecommunication site, or energy storage for a hybrid electric vehicle or for that matter a laptop and more recently a highly penetrative market application of mobile phones, not to talk of the automobile use. While choosing a battery, following few choices become quite evident in order to ensure a smooth operation of any application under consideration.

- a battery should have highest energy density
- best safety factor
- longest life in terms of discharge cycles
- ease of maintenance
- environment friendly

These are widely regarded as the key drivers behind the rechargeable battery research around the world today. Rechargeable batteries are also known as storage batteries and are enjoying a huge market volume. As per the available estimates, the worldwide sales of batteries crossed $ 36 billion in 2008. Market experts put this figure at $ 51 billion as we move along to 2013. So, it is a huge market with an ever increasing demand both for the existing and upcoming market applications. As already mentioned, batteries are of many different types. Let us now take a look at the best competing options for batteries. Lithium-ion is being seen as the battery of choice for the future generations of portable electronics together with hybrid and plug-in hybrid electric vehicles. It is evident from the fact that this particular battery technology obtained the highest possible support for intensive R&D as compared to any other battery form. Within this, nanotechnology and chemistry advances in electrode design are the prominent subject areas of research. Various companies are keen to see lithium-ion based energy storage technology edging past rest of the battery storage technologies. As of now, the portable rechargeable market of which lithium-ion has a 75% share happens to be the fastest growing segment. This specific segment recorded a market growth of almost 20% in 2008. It is important at this stage to mention a growing global concern for the use of cadmium in the nickel-cadmium batteries. Expectedly, stricter environmental controls on cadmium may come into force by 2013, which also imply a decreasing market share. Also the growing presence of two other battery technologies like Silver-Zinc and Nickel-Zinc may push back the market share of nickel cadmium batteries further.

Lead-acid batteries always deserve a special mention in the sense that these continue to lead the sales of rechargeable battery sales. To put it in perspective, the US rechargeable battery market enjoyed a market share of about 80% in 2008. Solar PV applications incorporate mostly the use of lead-acid batteries. In fact, automotive, industrial, and telecommunication segments rely heavily on the use of lead-acid batteries. Currently an innovative development is underway, which envisages the use of carbon based cathodes. Let us now turn our attention to the use of Nickel metal hydride batteries or simply NiMH. These are regarded to have a high power to weight ratio and quick recharging times. In 2008, such batteries had a market share of about 1.7% of the global market for rechargeable batteries. There are indications of its expansion to about 4.2% together with lithium-ion batteries. One more emerging segment of batteries is that of sodium-sulphur. These are expected to grow from a $235 million per year market to about $ 900 million a year by 2013 in the likelihood of increasing deployment of renewable energy based power generation.

The battery types dealt with in this section are amongst the most widely used, but may soon have new technologies like ultra capacitors as well by their side. Worldwide, applications of batteries are fast growing and there will always be a huge demand of batteries. Like for example, about 1.5 billion people in the world still do not have any access to basic electricity. Solar PV technology, if, deployed for this purpose could mean a huge demand for the rechargeable batteries, not to talk about a far heavy demand in areas of portable electronics and power tools.

The tricky grid energy storage

In general, the grid energy storage also known as large scale energy storage pertains to the techniques used to store large scale electricity within an electrical system. The grid storage market is expected to grow from nearly $ 365 million at present to almost $ 2.5 billion by 2015 as per the latest findings of GTM research. Lithium-ion batteries may steal the show in this arena with advanced lead-acid battery technologies also contributing its bit. In fact, energy storage is being viewed with a larger dimension now to add sizable amount of intermittent power available from solar and wind based power generation to the grid. Few key applications receiving major attention as of now are as follows.

- frequency and voltage regulation
- load shifting applications (saving electricity generated at night)
- power the peak loads during the intense summer conditions

Presently, energy storage markets are at evolving stage barring the exception of a few already well tried systems in a chosen few locations. These mainly include the following.

- Japanese Utility that is Tokyo Electric has installed about 300 megawatts of electricity of Sodium Sulphur batteries developed exclusively by NGK Insulators of Japan. Temperatures involved in the process are quite high
- France's EDF has in its kitty a 150 MW capacity unit for the purpose
- The Water and Electric Authority of Abu Dhabi has procured a 50 MW system
- American Electric Power has put up a 7 MW unit

Perhaps quite advanced versions of lead-acid batteries may very well compete with the sole large scale battery technology that is sodium sulphur, in near future. India may also witness some developmental scenario of this kind taking into account solar-grid interactive power generation too.

The national initiative

MNRE (Ministry of New and Renewable Energy) has been actively supporting the R&D as well as technology development in the fast emerging area of solar PV since a long time now. Significant progress has been made under various programmes of the ministry through an involvement of all possible stakeholders. MNRE has recently enunciated various thrust areas of research under the ambit of Eleventh Five-year Plan for consideration of financial support at the academic and research centres. One such area concerns the development of novel energy storage systems, which may be characteristically different from the existing range of commonly used battery technologies in the following few, ways mainly.

- develop batteries with long life (5000 cycles or more) for use in PV systems/ applications
- develop new and alternative storage systems up to MW scale with a possibility to store electricity for at least 8--10 hours
- limit storage losses to just about 10%

The larger purpose is to enhance the viability of megawatt capacity PV power generation facilities, which are now receiving a heightened impetus under the recently inaugurated Jawaharlal Nehru Solar Mission. Currently, research proposals are being sought by the ministry for this specific mode of energy storage too. Let us hope that mega capacity energy storage systems would also become available now that megawatt range PV power plants are becoming a reality in this part of world too. There are still a few issues connected to grid interfacing of PV receiving attention from the viewpoint of early redressal and a reliable energy storage medium in-between the solar power generating unit, and the grid line may very well serve the desired purpose of proper synchronization.

Solar Power

Tracing its potential in Uttarakhand

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Figure 1 Map of Uttarakhand

Introduction

Energy is considered as a prime driver in the generation of wealth and a significant factor in ensuring economic and social development. In fact, it is one of the basic needs and a means to increase productivity, enhance employment opportunities, and thus improve the quality of life of the people. The importance of energy in economic development is recognized universally and the trends verify a strong relationship between the availability of energy and economic activity. The extraction, conversion, and utilization of fossils fuels coupled with an increasing population have led to serious environmental degradation. These issues are also global as climate change, loss of biodiversity, and ozone layer depletion cannot be addressed by countries in isolation. The growing evidence of such environmental problems is because of a combination of several factors, since the environmental impact of human activities has grown dramatically. The poor are disproportionately affected by the environmental degradation and lack of access to clean, affordable energy services. This is due to an increase in the world population, energy consumption, industrial activities, and so on. Hence, the environment problems can be solved only through long-term actions geared at sustainable development. In this respect, solar energy appears to be one of the most effective solutions.

Ecology and energy happen to be the twin concerns of development. In the recent years, serious environmental problems, mainly increase in the Earth's temperature because of the greenhouse gas emissions, have left their footprints on several areas. Apart from Antarctica, the hilly regions are facing the problem of glaciers melting and degradation of the natural water reservoirs. The ICIMOD (International Centre for Integrated Mountain Development) has observed that the impact of climate change is especially evident in the Himalayan region with the largest concentration of snow and ice outside the two poles. In addition, the warming in the Himalayan region has been much greater than the global average and the rising temperatures are leading to rapid melting of the glaciers. According to the IPCC (Intergovernmental Panel on Climate Change), Himalayan glaciers are shrinking at a faster rate than other glaciers elsewhere in the world.

Economic changes, energy demand, industrialization, population increase, and so on are threatening the ecology of the Himalayas. In recent years, deforestation in the foothills/ Middle Himalayas and overgrazing on the high pastures have all led to soil erosion and other environmental problems.

The state boundaries

Uttarakhand is located in the northern region of India. It was carved out of Himalayan and adjoining districts of Uttar Pradesh in year 2000, thus becoming the 27th state of the Republic of India. This state (Latitude 28° 53′ 24″ N to 31° 27′ 50″ N, Longitude 77° 34′ 27″ E to 81° 02′ 22″ E) is a part of the Western Himalayan ranges, starting from the Shivalik foothills to the Greater Himalayas, with Tibet as its north-eastern border (Figure 1). The state is bordering Himachal Pradesh in the North West and Uttar Pradesh in the South and has international borders with Nepal and China. It is subdivided in two regions Garhwal and Kumaon and comprises of 13 districts. As per the census of India 2001, there are 16 826 villages in the state. Indian National Parks in Uttarakhand include the Jim Corbett National Park (being the oldest national park of India) at Ramnagar in Nainital District, Valley of Flowers National Park, and Nanda Devi National Park in Chamoli District, which together are the UNESCO World Heritage Site.

Key land use attributes

As per the directorate of economics and statistics, the total area of Uttarakhand is 53 483 sq km (Hilly area 92.57%, Plains 7.43%); out of which 34 650 sq km is the forest area (Figure 2). The waste land availability in the state is 3836 sq km. Most of the northern parts of the state are a part of Greater Himalaya ranges, covered by the high Himalayan peaks and glaciers, while the lower foothills are densely forested. In this state, the famous peaks include Nanda Devi, Kedarnath, Trishul, Bandarpunch, and Mt Kamet, the major glaciers include Gangotri, Pindari, Milam, and Khatling. The state lies on the south slope of the Himalaya range, and the climate and vegetation vary greatly with elevation, from glaciers at the highest elevations to the tropical forests at the lower elevations. This state has twelve important ecological hotspots——Nanda Devi National Park, the Valley of Flowers, Gangotri, Govind and the Rajaji National Parks, Kedarnath, Mussoorie, Binsar, Sanadi, Govind, and the Ascod Sanctuaries. All these areas support many rare plants and animal communities. The Ganga, the Yamuna, Ramganga, and Sharda are the principal rivers of this region.

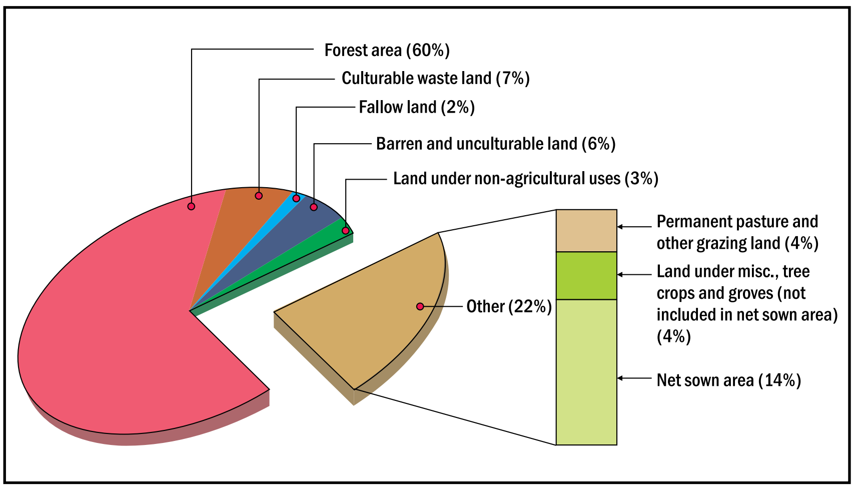


Figure 2 Land use pattern of Uttarakhand

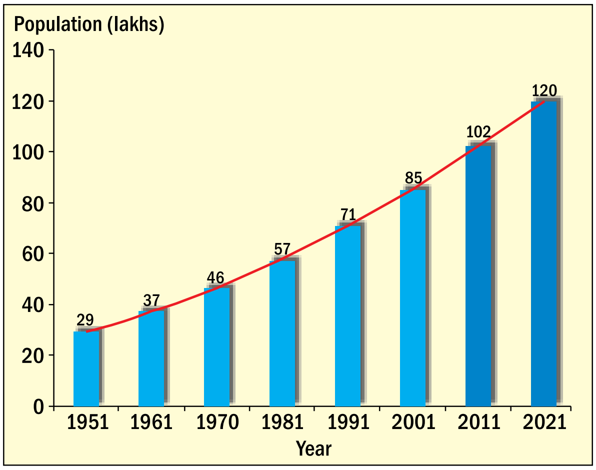


Figure 3 Population growth pattern of Uttarakhand

The habitation

As per the 2001 census, the total population of state is 8.45 million. On the basis of last 50 years population, it is projected that the population of the state will be 10.2 million by 2011 and touch 12.0 million by 2021 (Figure 3). The original inhabitants of Uttarakhand are either called Kumauni or Garhwali depending on their place of origin in either the Garhwal or Kumaon region.

Climatic variations

The climate in the northern part of Uttarakhand is typically Himalayan. This mountain range itself exerts an appreciable extent of influence on the monsoon and rainfall patterns. Within the Himalayas, climate differs depending on the altitude and the position. The climate of Uttarakhand is sharply demarcated in case of its two distinct divisions—the predominant hilly terrain and the smaller plain region. Climate ranges from subtropical in the southern foothills, averaging summer temperatures of about 30 °C and winter temperatures of about 18 °C. Warm temperate conditions prevail in the Middle Himalayan valleys, with summer temperatures usually hovering around the mark of 25 °C and accompanied by the cooler winters. Cool temperate conditions dominate the higher areas of the Middle Himalayas, where the summer temperatures are usually between 15–18 °C with winter temperatures dropping below the freezing point. At altitudes over 4 880 m, the climate is bitterly cold with temperatures consistently below the freezing point and the area is perennially shrouded in snow and ice.

Energy scenario of Uttarakhand

Cooking, lighting, heating, and so on are the most important energy use applications in the state. LPG and Kerosene are the fossil fuels, which are mainly used in the urban areas as well as the places well connected by the road. In the rural areas, wood, and biomass are being used for cooking and heating applications. As the state has a large forest cover, hence the availability of biomass is abundant for the rural households. The woody biomass still happens to be a main source for the thermal energy supply in the rural villages. Petrol and diesel are mainly used for the transportation and industrial sectors.

Understanding the electricity scenario

The state has an installed electricity generating capacity of about 1 760 MW (megawatt) including that contributed by the private sector. At the beginning of the year 2009, the total available capacity, including the central sector share was about 2 400 MW. The electricity generation in the state is mainly hydro power based. Against this installed generating capacity, the state was able to meet a peak demand of 1 150 MW with a deficit of 4.2% during the year 2007/08. During the same period, the deficit in the annual energy demand met was 2.9%. While considering the electricity data from CEA (Central Electricity Authority), it would appear that Uttarakhand's power requirement varies from about 19 MU/day during summer to about 23 MU/day during the winter season. Its own generation varies from about 12.5 MU/day during the summer to as low as 7 MU/day during the winter. The per capita electricity consumption

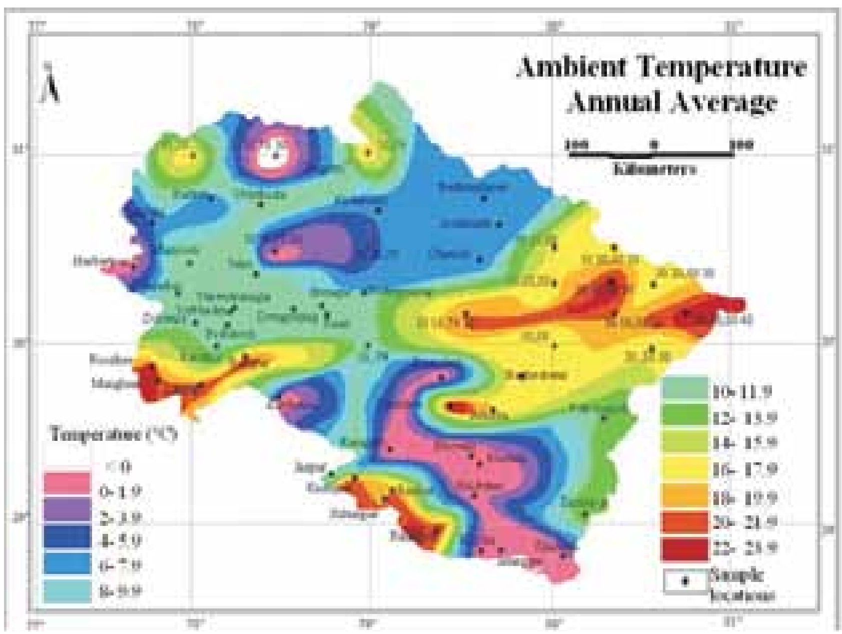


Figure 4 Annual average temperature map of Uttarakhand

546 villages in the state through the use of various non-conventional energy sources like solar, biomass, and so on. Pithoragarh district has the maximum number of un-electrified villages followed up by Bageshwer and Pauri districts.

Electrification of the pilgrimage centres

Uttarakhand, also known as the 'abode of the gods' (Devbhumi), has some of the holiest Hindu shrines, and for more than a thousand years, pilgrims have been visiting the region in the

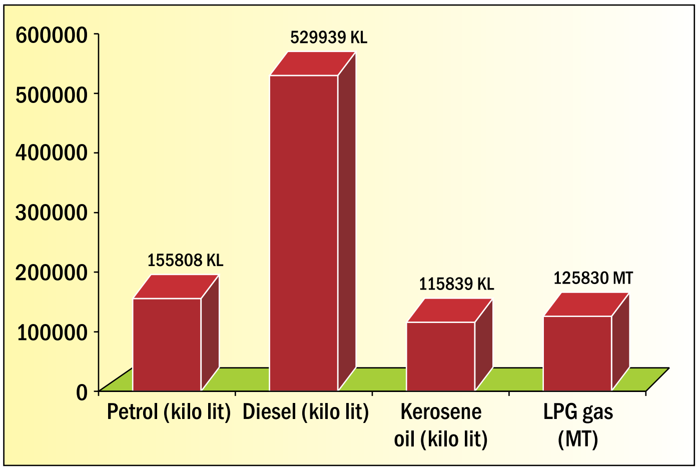


Figure 5 Energy supply scenario of Uttarakhand

of the state is about 706 kWh. On the basis of the last three years data, the electricity consumption of the state has been projected up to 2021. It has been observed that the annual electricity consumption of the state will increase by 52341 MU in 2021. The accompanying T&D (transmission and distribution) losses of about 30% have been reported. Most of the electricity consumption of the state is occurring in the industrial sector (48%) followed up by the residential (25%), and commercial sector (15%), and so on. The export of electricity to other states is the important source of income for this state.

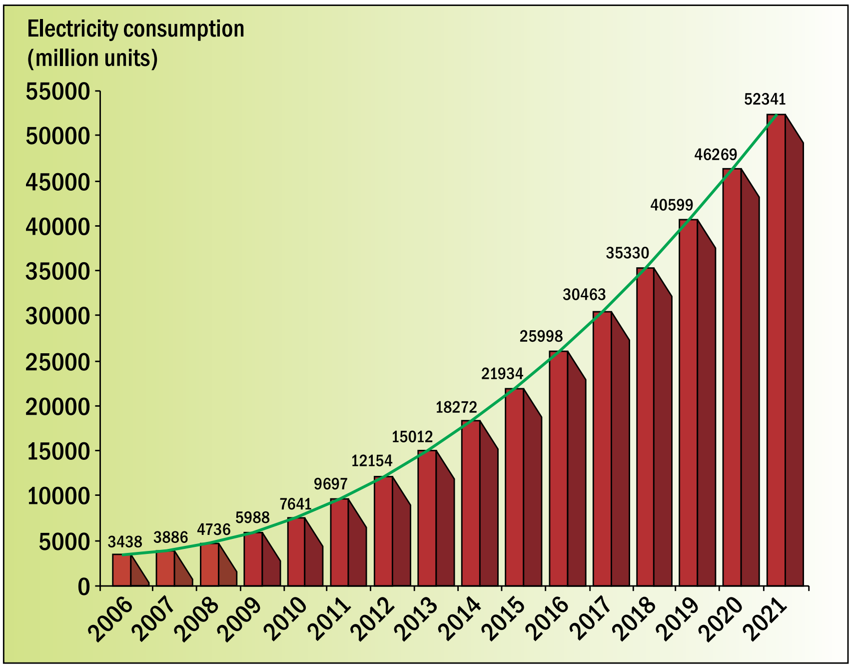


Figure 6 Electricity consumption pattern and projection of Uttarakhand

Rural electrification achievements

The lifestyle pattern of inhabitants in Uttarakhand is typically rural. Presently, 15 469 villages of the state are connected through grid. It is reported that 97% villages in Uttarakhand have been electrified covering 15 262 villages in 2008; with access to electricity provided to 14 726 villages as against a total of 15 761 revenue villages identified through census 2001. By the end of 2008, there were 499 villages still left to be electrified. UPCL (Uttarakhand Power Corporation Limited) and UREDA (Uttarakhand Renewable Energy Development Agency) are working towards electrification of these left over villages. Few such villages have also been identified under RGGVY (Rajiv Gandhi Gramin Vidyutikaran Yojna). Till now, UPCL has electrified 14 917 villages, while UREDA electrified

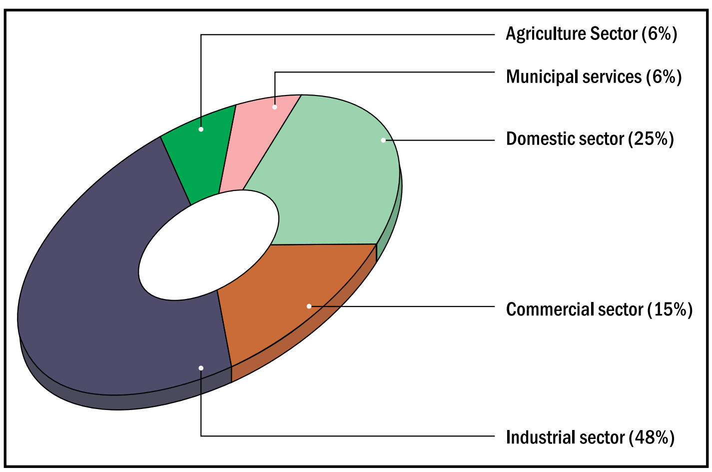


Figure 7 Electricity use pattern of Uttarakhand

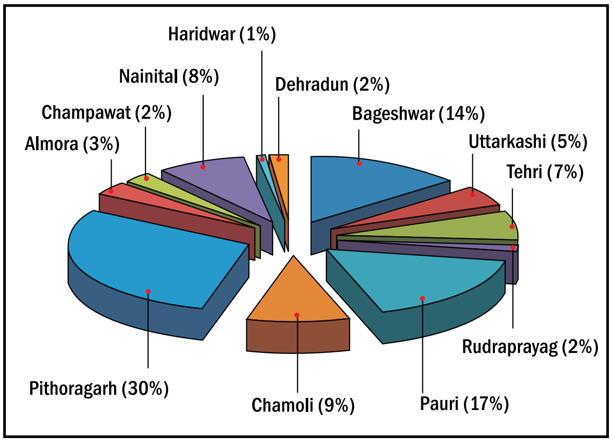


Figure 8 Status of un-electrified villages in Uttarakhand

hopes of salvation and purification from sin. Uttarakhand is also known as 'Kedarkhand' and comprises of a number of religious temples, pilgrims, tourist spots, bio-reserves, and international heritages, and so on. These are spread over the state and it is difficult to connect all such places with the grid. For example, Badrinath, Kedarnath, Gangotri, Yamunotri temples (most important temples of Panch Badri, Panck Kedar and panck prayag) remain accessible for only six months in a year. The state has a number of temples and shrines, many dedicated to the local deities or manifestations of 'Shiva' and 'Durga', references to many of which can be found in the Hindu scriptures and legends. A huge number of tourists reach these locations every year. However, ensuring a proper energy supply to these regions is still a big challenge. Specially, the Panch Kedar series has a very difficult terrain and rather very difficult to be served through the grid power. In Kedarnath, a 100 kW small hydro power system has been installed by MNRE, which supplies the electricity for street lighting and a few such related applications. Similarly within Tungnath, Madhyameshwer, Rudranath, Kalpeshwer, Hemkund, Roopkund, and Valley of flowers, a number of important places are not yet electrified. One of the most important problems to connect these places to the grid is in terms of their respective geographical outreach and snowy conditions prevailing during a good part of the year. It is equally true that a number of these places offer a significant potential for tourism; but energy supply at these places remains a major challenge. As such, the climate, topography, socio-cultural living pattern and energy use pattern of the Uttarakhand clearly indicate that the energy demand of the region is decentralized and oriented not mainly towards the electricity but may be favourably poised for the use of solar thermal energy as well. A large part of the state is alongside the international border. The defense establishments of the region also require a sustainable energy supply. Hence taking into account all these considerations, the role of solar energy utilization in the state might be an important option/aspect towards ensuring the much needed energy supply, energy security, besides environmental conservation, and an overall sustainability.

Solar energy availability in Uttarakhand

Uttarakhand possesses multiple micro-climatic zones. The hilly areas are close to 'cold and sunny' and 'cold and cloudy' climatic zones; while some locations like Dehradun lies under the semi-moderate climate conditions. In addition, the plain areas of the state like Haridwar and Kashipur lie in the composite climatic zone. Pantnagar is the hottest area in the summer with temperature zooming past 40 °C. The entire state receives good amount of solar radiation varying between 4–6 kWh/m^2/day. Using the satellite data of NASA (National Aeronautics and Space Administration) and measured data of IMD (Indian Meteorological Department), a solar radiation map has been plotted for the state, which shows the potential areas of solar radiation. It is observed that maximum locations of the state receive annual solar radiation from 1800 kWh/m^2 to 2200 kWh/m^2, the region has good sunshine for about 270–300 days.

Solar energy technologies at work

Solar energy can well be harnessed either by converting solar radiation into

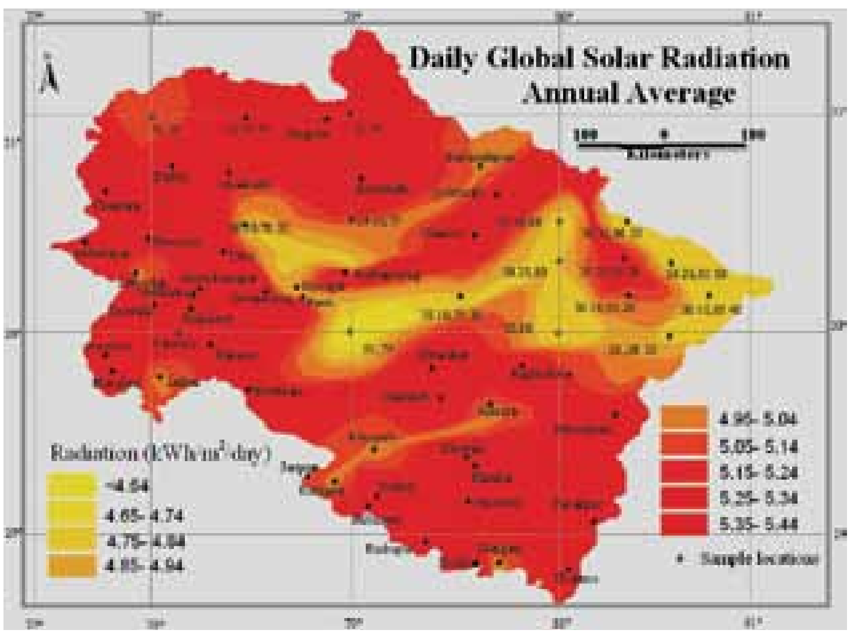


Figure 9 Solar Radiation map of Uttarakhand

heat through solar collectors or direct conversion into electricity using the solar PV (photovoltaic) cells. Presently, a number of solar energy technologies are commercially available for various kinds of end-use applications—cooking, water heating, drying, space heating, cooling and refrigeration, distillation, desalination, detoxification, industrial process heating, greenhouses, and also for electricity generation. Depending on the day to day living and energy use pattern of the Uttarakhand state, following few technologies have been identified especially for the hilly regions of this state.

Scope assessment of solar technologies for hilly regions of Uttarakhand

Solar energy technologies are very important for the hilly regions of Uttarakhand as the energy demand is of a distributed and decentralized nature here. At present, solar passive houses and solar PV based home-lighting systems, SK-14 type solar cookers, and ETC based solar water heaters are the most widely deployed solar energy technologies at Ladakh. Following few technologies for various domestic and commercial applications have been identified, where solar energy technologies could play an important role.

Solar home lighting systems

Solar HLS (home lighting system) is powered by solar cells, which convert the incident solar radiation directly to electricity. It is stored in the batteries for lighting as and when needed. These systems are useful in the non-electrified rural areas and function as a reliable emergency lighting system for various domestic, commercial, and industrial applications. HLS is a fixed installation designed specifically for the domestic use. It comprises of a PV Module, charge controller, battery, and lighting fixtures. The solar module is installed in the open on roof/terrace and exposed to sunlight with the charge controller and battery kept inside. Technically, the solar HLS is the best suited technology for the remote un-electrified villages/regions of the state.

Solar water pumps

Drinking water supply in the villages within the state is a big challenge. The state government has promoted the use of water pumps in various parts of the state. It has been observed that the groundwater is available at a depth of 150 ft and the solar powered water pumps can be used both for drinking water and irrigation needs. Such a system is generally a stand-alone system operating on the solar power generated during the day. DC surface centrifugal mono-block pump sets can be used for lifting water from bore /open well or a water reservoir for minor irrigation and drinking water purposes.

Solar water heaters

SWH (solar water heater) is the most commercialized solar energy technology worldwide, which can be used for the supply of hot water to meet a variety of domestic as well as industrial applications. It essentially consists of a collector to collect the available solar energy and an insulated storage tank to store the hot water. The solar energy incident on the absorber panel coated with selected coating transfers the heat to the riser pipes underneath the absorber panel. The water passing through the risers gets heated up and is delivered in the storage tank. The re-circulation of the same water through an absorber panel in the collector raises the temperature to 60 °C on a clear sunny day. Following few are the salient features of this technology.

- A 100 litres capacity SWH can replace an electric geyser for the residential use and thus save 1500 units of electricity annually.
- The use of 1000 SWHs of 100 litres capacity each can contribute to a peak load saving of 1 MW.
- A SWH of 100 litres capacity can prevent emission of 1.5 tonnes of CO_2 per year.
- Operating life is 15–20 years
- Approximate cost is Rs 15 000–20 000 for a 100 litres capacity system
- Payback period is 3–4 years, when the electricity use is replaced

The feasibility of solar energy system critically depends upon the user pattern of the system over the year. The hilly regions of the state require hot water almost throughout the year, for which their total dependence is currently on the biomass or fossil fuels. The technology could find enough space of diffusion in the region, as it is well promoted by MNRE through financial subsidies.

Solar cookers

Solar cookers are the best possible option for the replacement of biomass and LPG in the state. The dish type SK-14 dish solar cooker is usually used for faster outdoor cooking for about 10–15 persons with solar energy. A dish cooker (SK -14) with a dish diameter of 1.4 m is made of single reflector or by joining smaller pieces of reflector, fixed to a rigid frame, when exposed to the Sun in the normal direction, a point focus would be formed for cooking food. It consists of bright anodized aluminium sheets of 0.4 mm thick or 3 mm thick glass mirrors, bowl supporting frame, bowl stand, and manual tracking mechanism. Accessories like cap, hand gloves, goggles, manual and 5 litre capacity ISI marked pressure cooker are also supplied with the dish cooker. This cooker may be used for cooking food without any conventional fuel for large families or institutions, where food is cooked for 10–15 persons everyday. The solar steam cooking systems are based on the solar energy concentration technology. A number of solar concentrators are employed for tapping the solar energy for generating steam, which can be effectively used for large scale cooking in the community kitchens. Solar cookers might prove beneficial in the schools, as the state government is running 'Mid Day Meal' scheme.

Solar passive buildings

Passive solar buildings aim to maintain interior thermal comfort throughout the Sun's daily and annual cycles whilst reducing the requirement for active heating and cooling systems. Passive solar building design is an important part of the green building design, and does not include any active systems such as mechanical ventilation or photovoltaics. The scientific basis for passive solar building design has been developed from a combination of climatology, thermodynamics, and human thermal comfort. There are numerous technologies based on the solar passive architecture. Following technologies are most relevant for the cold hilly regions of the state

- Direct gain
- Trombe wall
- Attached greenhouse

Direct gain attempts to control the amount of direct solar radiation reaching the living space. Trombe wall is a sun-facing wall essentially built from a material that can act as a thermal mass (such as stone, metal, concrete, adobe or water tanks), combined with an air space, insulated glazing and vents to form a large solar thermal collector. In this type of arrangement, essentially heat is collected during the day, and it migrates by conduction through the wall and released for a night time use.

Solar greenhouses

All the greenhouses collect solar energy. Solar greenhouses are designed not only to collect solar energy during the sunny days but also to store heat for use at night or during the cloudy conditions. They can either stand-alone or be attached to the houses or barns. A solar greenhouse may be an underground pit, a shed-type structure, or a hoop house. Large-scale producers use free-standing solar greenhouses, while attached structures are primarily used by the home-scale growers. Passive solar greenhouses are often turn out to be good choices for the small growers, because these are a cost-effective way for the farmers to extend the growing season. In the colder climates or in areas with long periods of cloudy weather, solar heating may need to be supplemented with a gas or electric heating system so as to protect the plants against extreme cold.

Solar distillation

Solar still is a device to desalinate impure water like brackish or saline water. It a simple device to get potable/fresh distilled water from impure water, using solar energy as a fuel, for various applications in the domestic, industrial, and institutional sectors. Solar stills have got the following few major advantages over other conventional distillation/ water purification/demineralization systems

- Produce pure water
- No prime movers required
- No conventional energy required
- No skilled operator required
- Local manufacturing/repairing
- Low investment
- Can purify highly saline water (even sea water)

Especially in the remote hospitals, the solar distillation units might be very effective.

Solar dryers

Drying of agro produce is an excellent way to preserve food and solar food dryers are an appropriate food preservation technology for a sustainable world. The Himalayan region of India is a major source of medicinal plants and fruits, aromatic plants, herbs, flowers beside a number of cash crops. In the hilly regions of Uttarakhand, a number of varieties of agro-crops, fruits, vegetables, herbs, and typical cash crops are produced. Traditional technique of drying of these items involves open-air sun drying, which results in high stage deterioration and losses. Furthermore, open-air drying does not protect the raw-produce from a undesired conditions such as, contamination, dirt, debris, insects, and germs. Drying is an important step towards food and agro-produce processing, which includes cultivation and storage. As drying of such products contain a high amount of moisture, they need a typical solution and the food and agro-industries normally follow the electricity controlled drying technology, which consumes a huge amount of energy. Solar thermal energy used in the drying processes is fully suited to the needs for a sustainable development. As such, large scale implementation of solar drying technologies in the state especially in the rural areas could result in substantial energy savings, and thus narrow down the gap to achieve the planned target of a 'Herbal State'.

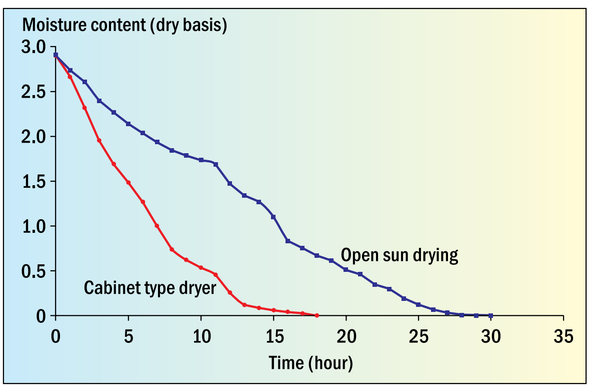


Figure 10 Solar Drying vs open sun drying

Larger scope for power generation

The climatic and solar radiation conditions are best suited for solar PV based electricity generation. SPV systems offer several advantages that make it suitable for rural electrification and decentralized energy supply. PV modules do not have any moving parts and operate silently without any hazardous emissions and are expected to have a long lifetime with little maintenance. The state has enough land availability, well established transmission and distribution system and other facilities required towards large scale solar power deployment. The power generation policies of the state could be oriented towards the possible realization of the targets of JNNSM (Jawaharlal Nehru National Solar Mission) under the larger ambit of National Action Plan of Climate Change, Government of India.

Present status of solar energy deployment at Uttarakhand

UREDA is the state nodal agency for the wholesome promotion of Renewable Energy Programme, Energy Conservation, and DDG projects under RGGVY and various other renewable energy programmes through an active involvement

Table 1 District wise availability of medicinal plants/produce in the hilly areas of Uttarakhand

Name of the District	Local name of the medicinal/herbal plants
Pauri	Awala, Bharmil, Banashpa, Bahara, Bheeal, Bharami, Cahnar, Chirata, Choru, Coranda, Ghantil, Giloie, Hearda, Hishar, Jawan, Kachnar. Kali-ghass, Karonda, Kingod, Kunja, Mint, Morada, Timaru
Chamoli	Ashawa ghanda , Atish, Awala, Baal chari, Baharmi, Baheara, Bajukijad, Bal charri, Ban haldi, Bandarmul, Basila, Bazardantti, Beal, Bhang, Bharami, Bhutakesh, Chippi, Chiraie, Chirata, Chitarak, Chouru, Dollu, Eshawa goal, Faran, Gadrain, Gamhar, Giloie, Hathjari, Heara, Jamboofaran, Jatamashi, Jiruna, Jiyapota, Kalazeera, Kalihari, Kapporhaldi, Katuki, Kirmadkijad, Kukrodha, Kunju, Kuut, Ladumfarin, Lasora, Makku, Malkagani, Mandtharai, Mashi, Mint, Mitha, Moria, Muskdana, Padal, Pashanbhad, Pipli, Prisnparani, Puranwa, Reahtta, Sahajan, Sajiwa, Salaparai, Samawa, Sanya, Sapiwa, Sarpgandha, Satawari, Silajeet, Silpahara, Sitaashok, Warmau, Waarun, Wigala, Wirhati
Rudraprayag	Archu, Atish, Awala, Ayar, Banashpa, Beahra, Beal, Brahami, Chandan, Chooru, Faran, Ghula-ghass, Gilaoie, Mishwa, Neem, Retha
Tehri	Atish, Awala, Beal, Bahara, Bhang, Burans, Chirata, Chouru, Coranda, Faran, Giloie, Heara, Hing, Hishar, Kadwi, Kingod, Kunja, Giloie, Makku, Mint, Moria, Silphara, Timaru
Uttarkashi	Atish, Awala, Beeal, Baheara, Bhang, Burans, Chiratya, Chorru, Coranda, Faran, Giloie, Heara, Hing, Hishar, Kadwi, Kingod, Kunja, Giloie, Makku, Silphara, Timaru
Almora	Awala, Ritha, Tejpat, Ashwa –Ghantha, Pashan –Bhead, Samawa, Kapor-Kachari, Zerinem, Lamon –Grass, Bhang
Bageshwer	Herde, Bahera, Kirmod, Simor, Guraza, Basil
Nainital	Awala, Harada, Ram-tulsi, Tajpat, Bharda, Ritha, Tamur, Padam, Harsingar
Champawat	Awala, Ganya, Ghudwaj, Jhula, Coliyas, Lapor Chari, Maas, Manijitha, Ritha, Satawar, Tajpat, Timur
Pithoragarh	Amla, Aniya, Atish, Badi elachi, Bahera, Ban andawa, Ban Haldi, Ban Kakadi, Ban Tulasi, Banashpa, Basil, Bazara Danti, Bhi Kafal, Dandas, Dhup Jad, Dhup Lakad, Dolu, Dolu beej, Dy Skoria, Dyas Koria, Eshb Gol, Gandasha, Gadari, Gadryani, Ghucchi, Ghud Wach, Gi Gada, Gin Jadi, Gin Zaru, Gola Tharia, Guraza, Hath Jadi, Herde, Indra Yani, Indra Yani beej, Jambu, Jata Mashi, Jhula, Kuut beej, Ka KoliCir, Kakda Sringi, Kala Chirita, Kala Zira, Kapal Ki chal, Kapoor-achrr, Kirmod, Kuppor Kachari, Kutakibeej, Ktaki, Lah Su Nia, Maha Meada, Manari, Mar Pati, Mi Rak, Mitha, Mor, Mos-Grass, Near Pati, Pashan Bhad, Pathar Loong, , Prunia, Ratan Joot, Ridhhi Wardhi, Ritha beej, Roots and ofchestnut, Ritha phal, Salammesri, Samawa, Samawa , Gaath, Samawa Panchang, Simor, Som Tala, Stu Wa, Teaj pat beej, Teaj Pat, Talish Patra, Tatari, Thoyia, Timur chaal, Timur beej, Wach

of local panchayat, NGOs, and District administration. It is continuously working on the smooth implementation of various solar energy based projects and has achieved satisfactory targets so far. By the end of 2008, UREDA had implemented 4000 SWH systems, more than 200 SK-14 solar cookers, 2700 domestic solar lights over the entire state. Recently, UREDA has implemented some solar drying systems for the demonstration purpose. The agency is also distributing SK-14 solar cookers to the schools. In addition, UREDA has electrified 546 villages in the state, and is also working towards the deployment other renewable energy technologies mainly biomass gasifier and small hydro power systems in the state.

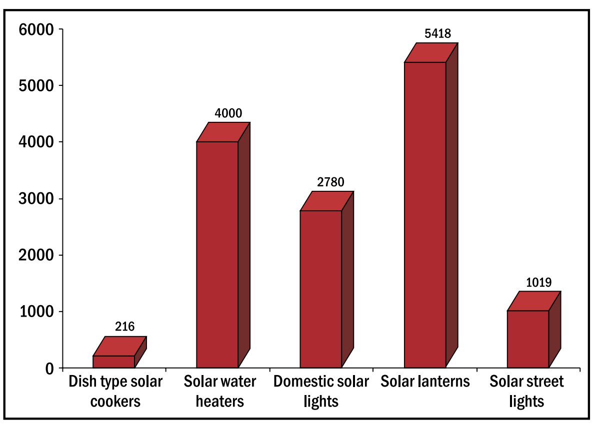


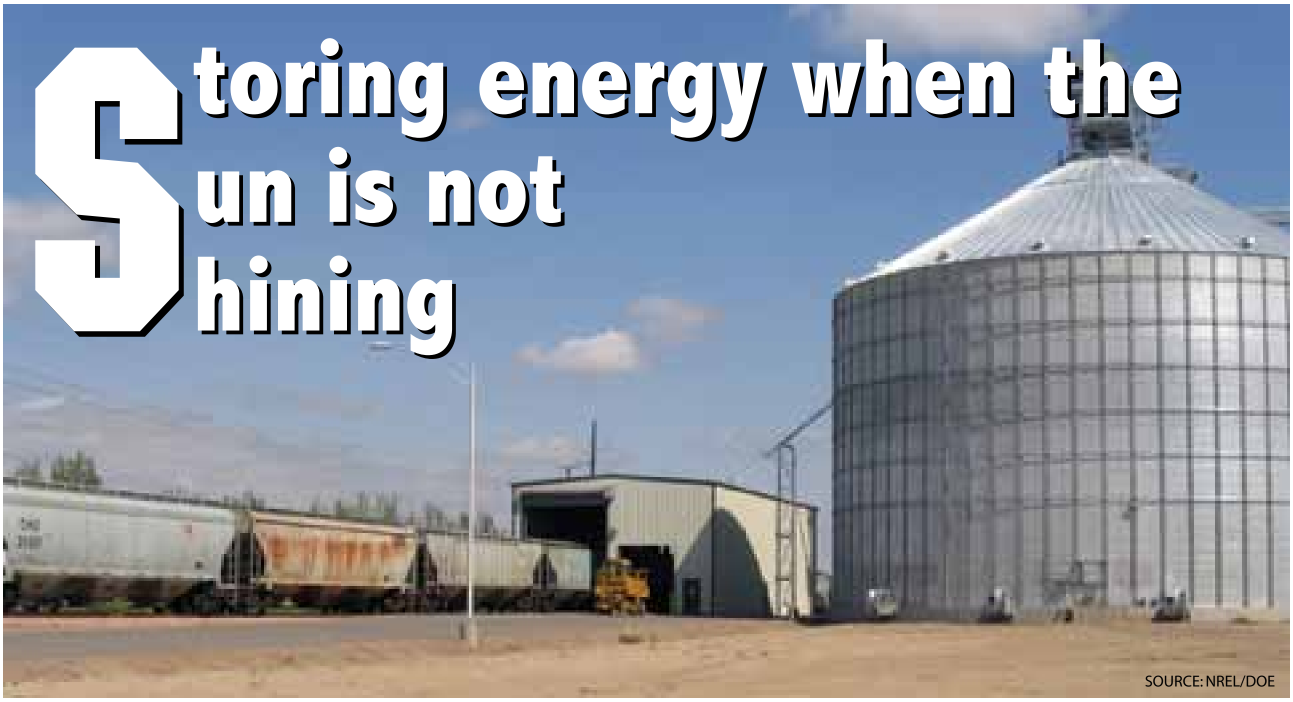
Figure 11 Solar energy system implemented by UREDA

UREDA with the financial support of MNRE has established state level and district level energy parks as per the renewable energy policy of the Government of India for proper harnessing and awareness generation amongst the potential end-users. It has set up a state level energy park spread over 2.3 acres of land at Patel Nagar (industrial area) to generate requisite awareness about the immense benefits of various renewable energy based systems amongst the public at large. That is not all, as the two quite popular tourist destinations – Haridwar and Dehradun – have been designated as the solar cities by the MNRE. The underlying consideration is to reduce their energy consumption by 10% by 2018 through the adoption of energy efficiency measures in various sectors like domestic, commercial, municipal services, and industrial along with renewable energy utilization.

The sunny way forward

The unique position of Uttarakhand as a state with hilly terrain, snow clad mountains, glacier fed rivers, and large forest cover provides it with both opportunities and challenges. While it may appear that there is a huge potential for exploiting its natural resources for net revenue earning, there are also credible risks of upsetting the delicate and complex balance of ecologically sensitive sub-systems of the nature. The solar radiation pattern, climate, and energy use pattern of the hilly regions of Uttarakhand point towards a large potential of solar energy utilization in the state. The state has been declared as an 'Energy State' by the Government of Uttarakhand and number of efforts has already been made in this direction. As such, trapping the large potential of solar energy in the state might be a sound move towards achieving the distinct tag of a 'Clean Energy State'.

Storing energy when the Sun is not Shining



SOURCE: NREL/DOE

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Background

TES (thermal energy storage) has a key role in energy conservation for many processes, such as waste heat recovery, load levelling at power plants, and renewable energy sources. This article describes TES, its various forms with the TES materials for different applications that will ultimately help to find the suitable TES technology for energy-efficient and environment-friendly applications.

Energy storage is a big challenge for the renewable energy sources, which produces electricity intermittently. If, renewable energy is to significantly displace fossil fuels, new methods of energy storage need to be developed. For example, solar energy is available only during the day time hence, its application requires efficient TES so that the excess heat collected during the sunshine hours may be stored for later use during off-sunshine hours. Similar problems arise for the waste heat recovery systems, where the waste heat availability and utilization periods are different. It is a fact that there is always some variation in the demand and supply of the electrical energy and in its consumption for heating and cooling. TES can be applied for heating and cooling application to reduce the peak load of electricity. However, the predominant benefit of thermal storage will be in its ability to produce more kWh from a fewer kW of operating capacity.

Choice for the selection of energy storage technology depends on the type of energy source, its availability, cost, and duration of the storage required. A decisive criterion of a heat storage medium is its price and the costs that arise upon its utilization. Long life and a high cycling stability are the pre-requisites for economic application, which is at a price competitive with the existing storage facilities. High thermal diffusivity of the heat storage material provides a quick response to temperature differences, that is quick charging and discharging; high heat diffusivity yields a high amount of heat being stored.

Transferring the heat

Heat transfer processes have to be effective, the heat may be either transferred directly to the storage material as, for example, in a dry pebble bed with air flow, or a heat exchanger may be required as in a solar domestic hot water store, where the water-antifreeze mixture flowing through a solar collector has to be separated from the hot water for consumption. Other aspects of selecting a heat storage material may be operational advantages in energy supply systems or a larger flexibility in application.

In general, following characteristics should be met by any type of heat storage media.

1) High heat storage capacity
2) High heat transfer
3) Adequate thermal diffusivity
4) Ability to undergo charging – discharging cycles without any changes in thermo physical, chemical, and kinetic properties
5) Long service life, non-corrosive, non-toxic, nonflammable
6) Easy availability in the local market, simple in handling, and storable in simple containment
7) Inexpensiveness

The thermal storage technologies can be divided mainly into three categories depending upon the nature of heat storage

1) Sensible heat storage
2) Latent heat storage
3) Thermo-chemical heat storage

SHS (sensible heat storage)

It is conceptually the simplest form of storing thermal energy. In SHS, the temperature of the storage material varies with the amount of energy stored. In SHS, thermal energy is stored by raising the temperature of a solid or liquid. SHS system utilizes the heat capacity and the change in temperature of the material during the process of charging and discharging. The amount of stored heat depends on the specific heat of medium, the temperature change, and the amount of storage material used.

Based on the state of the SHS medium, they can be classified as solid, liquid, or gaseous heat storage materials. A comprehensive list of such type of heat storage media is given with their thermo-physical properties in the following table1 .

Table 1 Sensible heat storage materials

Phase	Medium	Density (kg/m³)	Heat capacity (J/kg K)	Thermal conductivity (W/m °C)
Solid	Aluminium	2707	896	204 at 20 °C
	Brick	1698	840	0.69 at 20 °C
	Concrete	2240	1130	0.9 - 1.3
	Pure iron	7897	452	73.0 at 20 °C
	Copper	8954	383	385 at 20 °C
	Stone, sand stone	2200	710	1.83
	Lead	11 340	131	35.25
	Graphite	2200	609	155
	Soil, Clay	1450	880	1.28
Liquid	Oil	750–970	1465–2400	0.106–0.168 °C
	Molten salts	510–960	1300–4190	38.1–67.5
	Organic fluids	7.4–831	2200–3000	0.117–0.169
	Water	1000	4190	0.63 at 38 °C
	Water-Ethylene glycol 50/50	1050	3470	0.401
	Ethylene glycol	1116	2382	0.249 at 20 °C
	Paraffin, liquid	900	2130	0.26
	Oil	750–970	1465–2400	0.106–0.168 °C
Gaseous	Air	1.205	1005	0.026
	Hydrogen	0.075	1436	0.202
	Water vapour	0.589	2135	0.029

Watering the thermal storage

Solid materials are usually chemically inert and, in the form of rocks and pebbles, abundant and cheap. But they have the disadvantage of large pressure drop in the fluid flow and large storage volume. For solid materials, SHS have to be combined with fluid heat carriers, so the properties of the solids have to be taken into account, which affect the following few parameters.

- Fluid flow and heat transfer—particle and container size
- Mechanical durability against abrasion
- Thermal cycling
- Hygroscope

The most widely used liquid for thermal storage is water. It is abundant and inexpensive and has relatively high heat diffusivity. It can be easily stored in all kinds of containers and the control of water flow systems is highly flexible and is often state-of-art mechanism. Another advantage with the water storage system is that it can be used without heat exchangers, easy to handle, non-toxic, non-combustible, and easily mixable with additives (anti-freeze, anti-corrosive). Other liquids such as oils, molten salts, and metals (Na) are used for high-temperature storage as their vapour pressures are low. However, freezing points of such materials have to be taken into consideration. Oils and paraffin may be used as a Heat Transfer Fluid in combination with solids.

Gases have extremely low heat diffusivities and are particularly unsuitable for storing heat. Moreover, their volumetric specific heat capacity is extremely low (1 kJ/m³/K), while that of solids or liquids is between 1000 and 4200 kJ/m³/K (water Cp = 4200 kJ/m³/K). Gases are, however, highly important heat carriers, especially at very high temperatures. Air and flue-gases are the heat carriers in power regenerators. Air is used as a quick responding carrier with little thermal inertia in air heating systems with pebble-bed storage. Hydrogen is stored in metal hydrides either as a later fuel or as a reactant for the chemical heat storage. Gases require large volumes or pressure vessels for storage.

There is one more category in the sensible heat storage material—High Temperature Sensible Heat Storage. The ability to store high temperature thermal energy is basically limited by the availability of heat transfer fluids. Molten salts and liquid metals are commonly used for thermal power plants. Most organic heat-transfer fluids tend to thermally decompose at or above 400 °C.

Salty storage mediums

A basic problem afflicting storage concepts using molten salts and metals is solidification at low temperatures. Thus, unless auxiliary heat is provided, shut-down of the solar energy system can be complicated by the solidification of the heat transfer fluids. This can result in an increased system complexity and cost if, extensive heat tracing is required. The use of water or steam as a storage fluid in a solar thermal electric system using a steam driven power generation unit would permit elimination of the expense of an oil water steam generator. However, although these advantages are significant, yet they are usually overwhelmed by the expense of the pressurized storage tank needed.

Heat storage—the inside view

Another form of heat storage namely, LHS (latent heat storage) is based on the heat absorption or release, when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice-versa.

LHS systems have certain benefits when compared to SHS systems. The most important is the higher energy density per unit mass and per unit volume. LHS is much more attractive than SHS because of its smaller temperature swing. However, many practical problems are often encountered with LHS due to low thermal conductivity, variation in thermo-physical properties under extended cycles, phase segression, sub-cooling, incongruent melting, volume change, and high cost. These have to be technically resolved, before it can be widely used.

LHS materials are more commonly known as PCM (physical change materials). It is a relatively new area of research. The first and most common application of PCM is their use for heating and cooling in buildings. Although research in LHS for solar heating systems continues, yet it is increasingly being considered for waste heat recovery and load levelling for power generation.

LHS can be accomplished through solid-liquid, liquid–gas, solid–gas, and solid-solid phase transformations, but the only two of some practical interest are the solid-liquid and solid–solid. Solid–gas and liquid–gas transition. These have higher latent heat of fusion, but their large volume changes on phase transition are associated with the containment problems and rule out their potential utility in thermal storage systems. Large changes in volume make the system complex and impractical. In solid-solid transitions, heat is stored when the material is transformed from one crystalline form to another. This transition generally has smaller latent heat and volume changes than solid-liquid transition. Solid–solid PCMs offer the advantages of less rigorous container requirements and better design flexibility. Trombe Wall with LHS materials could provide better performance than a plain concrete Trombe Wall. Solid-liquid transformations have comparatively smaller latent heat than liquid-gas. However, these transformations involve only a small change in volume (<10 %). Solid–liquid transition has proved to be economically attractive for use in TES systems.

As the source temperature rises, the chemical bonds within the PCM break up as the material changes phase—from solid to liquid (as is the case for solid–liquid PCMs which are of particular interest here). The phase change is a heat-seeking (endothermic) process and therefore, the PCM absorbs heat. Upon storing heat in the storage material, the material begins to melt when the phase change temperature is reached. The temperature then stays constant until the melting process is finished. The heat stored during the phase change process (melting process) of the material is called latent heat. LHS has two main advantages, first, it is possible to store large amounts of heat with only small temperature changes, and therefore, to have a high storage density, second, because the change of phase at a constant temperature takes some time to complete, it becomes possible to smoothen out the temperature variations. The comparison between latent and SHS shows that using LHS typically 5–10 times higher storage densities can be reached. PCM storage volume is two times smaller than that of water. LHS can be used in a wide temperature range. A large number of PCMs are known to melt with a heat of fusion in any required range. The PCM to be used in the design of thermal storage systems should accomplish desirable thermo physical, kinetics, and chemical properties.

Changing phase unlike the conventional phase

There are a number of PCMs (organic, inorganic, and eutectic), which can be identified as PCM from the consideration of melting temperature and latent heat from the fusion. However, except for the melting point in the operating range, majority of PCMs do not satisfy the criteria required for an adequate storage media. Table 2 gives a comprehensive overview of organic and inorganic types of PCMs.

As no single material can have all the required properties for an ideal thermal storage media, one has to use the available materials and try to make up for the poor physical property by an

Table 2 List of PCMs

	Material	Melting Point (^0C)	Latent Heat (kJ/kg)
Organic	Formic acid	7.8	247
	Acetic acid	16.7	273
	Phenol	41.0	120
Inorganic	H_2O	0.0	333
	D_2O	3.7	318
	H_2SO_4	10.4	100
	NaCl	802	492

adequate system design. For example metallic fins can be used to increase the thermal conductivity of PCMs, super cooling may be suppressed by introducing a nucleating agent in the storage material, and incongruent melting can be inhibited by use of suitable thickness. Further PCMs can be subgroup as paraffins, non paraffins, salt hydrates, eutectics, cross-linked polyethylene, and poly-alcohols. In this article, no detailed properties of each of these sub groups are presented. Salt hydrates are the oldest and the most studied amongst heat storage PCMs. They essentially consist of salt and water, which combine in a crystalline matrix when the material solidifies.

Phase change slurries

PCS (phase change slurries) are fluids with dispersed particles, which show a phase change at the melting temperature of the dispersed phase. These fluids can be designed to optimally fulfil particular objectives. In refrigeration and air conditioning, this can result in an enhanced thermal conductivity of a fluid, a higher heat transfer characteristics, a higher thermal energy storage capacity, temperature stabilization, less pressure drop, and so on. The use of PCMs in a dispersed phase in a continuous carrier fluid leads by its phase change and latent heat to very high energy densities, whereby the pumpability of the fluid still remains. Ice slurry is the best-known PCS, but restricted to temperatures below zero degree Celsius. To overcome this restriction, at present, other types of PCS are developed—micro-encapsulated PCS, clathrates, shape-stabilized paraffins, and so on. Nanofluids, that are fluids with dispersed metallic particles on a nano scale, also show enhanced heat transport properties. An advantage is that the small particles as a result of Brownian motion do not lead to a stratification, which is induced by the buoyancy force. Temperature stabilization, high thermal conductivity, latent heat storage, thermal radiation, heat convection, low pressure drop, convective mass transport, turbulent mixing, sensible heat storage are few of the desirable properties. PCS satisfies the important properties of temperature stabilization, heat convection, latent heat storage, convective mass transfer, and sensible heat storage simultaneously. Table 3 gives the advantages, disadvantages, and applications of different PCS.

Ice slurry consists of solid ice particles in a fluid forming a suspension with two phases. Ice slurries have the advantage of having high cooling capacity, lower energy demand for the pumping. High heat transfer rates are possible because the fine ice particles are dispersed in the fluid. They have the disadvantage of having the additional pump for the ice slurries, and hence additional energy cost too. Other disadvantage is of being used only at close to 0 °C temperature. Ice slurries have the application in the food industries like dairies, breweries and so on. Also, hey have an additional benefit of being environment friendly as compared to CFCs used in air conditioning and refrigeration industries.

Table 3 Advantages, disadvantages, and applications of PCS

Suspension	Advantage	Disadvantage	Application
Ice slurry	Environmentally friendly	Ice generators expensive, mixing in the storage tanks leads to additional energy demand	Refrigeration process technique, chemical industry, plastic extrusion, and so on
Clathrate slurry	High enthalpy density	Guest molecules are freon gases, but new developments with propane, butane, ans so on are possible	Air conditioning, Solar thermal engineering
Micro-emulsion Slurry	With good surfactants no sedimentation	Time behaviour by alteration of particle size distribution	Air conditioning, Solar thermal applications
Shape-stabilized PCM slurry	High heat transfer rate	Destruction of plastic structures	Air conditioning, hot water supply, solar engineering
Micro-encapsulated PCM slurries	Large range of melting temperatures; High thermal cycling resistance	Destruction of capsules possible Sedimentation Creation of skin layers in open systems	Air conditioning, solar thermal heating, cooling of electronic devices
Nano-particle PCM slurry	No particle stratification	Eventually small clustering effect	Models have to be investigated

Thermo-chemical energy storage for better gains

Third group in the thermal energy storage, thermo chemical energy storage systems, utilize the heat of chemical reaction for energy storage. Thermal energy can be stored for an infinite period of time without insulation in chemical potential form. This may involve a reversible chemical reaction, absorption, or a hydration process. Reactions absorb energy when proceeding in one direction and release it, when proceeding in the reverse direction. Every reaction has a characteristic 'turning temperature', which marks the point at which it will change from naturally tending to favour reaction in one direction to favouring reaction in the reverse direction. Finally, chemical mixtures which would otherwise react can often be rendered inactive by, for example, separating the components or cooling them down. This paves the way to what is required for a thermo chemical energy storage system.

The heat stored and released is equivalent to the heat (enthalpy) of reaction. The enthalpy of reaction is much larger than the enthalpy of transition (in LHS) or the sensible heat stored over a reasonable temperature span. Materials for the storage of chemical heat, their temperature of reaction, and heat of reaction are given in the table 4. The reversible reactions suitable for heat storage can be classified into thermal dissociation reactions and catalytic reactions.

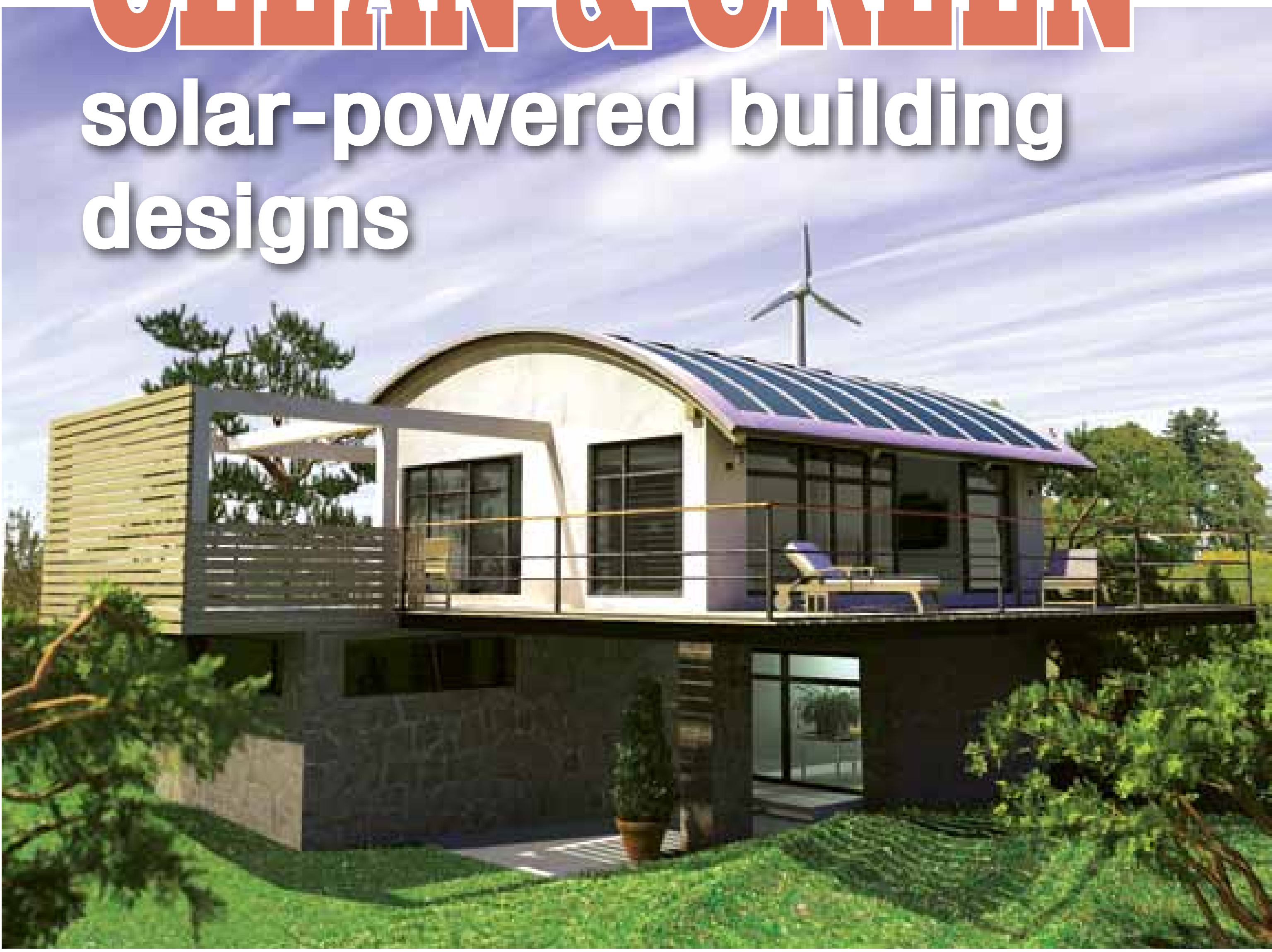
Teaming up the storage

A brief overview of the TES technology for various purposes, list of the various PCMs with available thermo physical properties, recent innovations on PCM applications were included in this article for generating some awareness about new energy storage applications. Study on thermo-chemical energy storage for solar thermal power plants, combination of sensible and latent heat storage, phase change slurries, for various uses were also discussed. In short, a number of heat storage materials are available, but it is very difficult to find a suitable TES material for a specific application. A complete thought process is required before making such a selection. It will not only reduce the cost of the system, but will also help in reducing the overall dimension of the system.

Table 4 Temperature and heat of reaction of materials for chemical storage

Material	Temperature (°C) of reaction at 1 bar	Enthalpy (J/g) of reaction (Gas)	Enthalpy (J/g) of reaction (Compound)	Enthalpy (J/cc) of reaction (Compound)
Hydroxides	270–650	4235–7383	771–1414	3134–3470
Ammoniated salts	40–340	2733–3201	~745	~410
Carbonates	400–860	2474–3520	1296–1546	3836–4189
Metal Hydrates	−10–330	14 040–38 520	134–2922	744–4237

CLEAN & GREEN
solar-powered building designs



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Introduction

Developing countries are focusing on policies to reduce GHG (greenhouse gas) emission growth and trying to initiate low-carbon development. Under the current global-warming framework prepared by UNFCCC (The United Nations Framework Convention on Climate Change) at the Copenhagen summit, only industrialized nations would be required to 'cap', and then reduce their GHG emissions. Although, India is not formulating a binding emissions cap, scientists and government officials have been updating the nation's GHG inventories and quantifying potential reductions. Preliminary results from one such analysis suggest that by 2020, the nation could cut its projected emissions by 20%–25%. Also, the government is discussing deeper cuts, all contingent on the international aid/technologies available for the deployment of resources from the developed countries. India's Environment Minister, Jairam Ramesh, says the negotiations are likely to go nowhere unless wealthy nations embrace more ambitious emissions reductions besides promising more money to help the developing countries cope with the perils of climate change. He says that the negotiators should focus on a few key issues, including deforestation, adaptation money for the least developed nations, and CDM (Clean Development Mechanism). It allows the rich countries to offset their emissions by paying for clean-energy use and other 'green' projects in the developing world.

The school programme: a case study

The best example is that of green building integrated in school environs to quantify its greenhouse gas reductions and efficiency gains. Most schools rely on standardized emissions inventories, such as the Campus Carbon Calculator provided by Clean Air–Cool Planet, a non-profit group based in Portsmouth, New Hampshire. In some cases, institutions have their own environmental engineers or energy analysts, who keep track of carbon accounting, with others engaging students through their coursework. In addition, the Association for the Advancement of Sustainability in Higher Education, based in Lexington, Kentucky, has developed a system to help schools track their progress over a period of time. Since February 2008, some 70 schools had piloted the system near New Hampshire.

Major programmes

In August 2009, USAID (US agency for International Development) announced an outlay of $2.4 billion in matching funds to support the production capacity for advanced batteries and drive systems for electric vehicles. Similar announcements support an increase in the utilization of bio-fuels, solar power, and wind power. MNRE (Ministry of New and Renewable Energy) had announced the Jawaharlal Nehru National Solar Mission targetting 20 GW of solar power generation and utilization by 2020. Solar Mission will target research and development projects on harnessing, storage, and use of solar power in an efficient manner.

Technology option for better gains

Researchers are exploring more exotic chemical compositions and materials engineered to have nanostructures for the following.

- Decrease thermal conductivity
- Slow the flow of heat
- Easy capture of the available energy

Any heat that flows all the way through the material is lost. BIPV (building integrated photovoltaics) systems with photovoltaic materials – transparent, semitransparent or opaque – are used to replace the conventional building materials in parts of the building envelope such as the roof, skylights, or facades. The individual components depend upon the building geography and use of the energy. The innovative design for the individual house is being incorporated preferably during the construction of buildings as a principal or ancillary source of electrical power. PV is a truly elegant means of producing electricity on site, directly from the sun, without concern for energy supply or any environmental harm.

Historical development of BIPV—India

India has a history of rich heritage of architectural delight. There are monuments with enriched features in exploiting environment concerns in their design and material used for construction. Some of these monuments are very much comparable with the concept of zero-energy building. The scientific basis plays an important role for design of building and the material with minimum energy requirement during construction. These also consume less energy for a sustainable existence. The concept of BIPV is slowly but surely taking shape in the country.

BIPV buildings in India

India's first green housing project facilitated with building-integrated solar power has been recently developed in Kolkata. Both environmentally and economically attractive, this project acts as a trailblazer for a rapidly developing country but faced with energy shortages.

ITC green centre at Gurgaon resulted from consultations with the CII (Confederation of Indian Industry), TERI (The Energy and Resources Institute), Shriram Test Centre, USGBC (United States Green Building Council), Architects, Engineering Consultants, and

Independent Commissioning Agency. The building envelopes energy, indoor air quality and water efficiency. Materials and sustainability measures were evaluated on the basis of the simulation studies and optimized. The energy efficiency of the building was achieved by saving and effective use in office capacity for the following.

- Sustainable site
- Water efficiency
- Energy and atmosphere
- Materials and resource
- Indoor environmental quality
- Innovation and design process

BIPV: the concept

Given that India is a tropical country, BIPV systems may well turn out to be a favourite option. In the conventional building design, photovoltaic materials are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. The transparent and opaque photovoltaic modules are integrated with other façades for the sunlight, air, and colourful aesthetic look of the building. These are being increasingly incorporated into new buildings, although existing buildings may be retrofitted with BIPV modules as well. The principle advantage of BIPV design over the more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour. In addition, since BIPV is an integral part of the design, these generally blend better. Such advantages make BIPV as one in the fastest growing segments of the photovoltaic industry.

The incoming radiation

The sun's energy reaches the earth in the form of heat and light. Other aspects of solar radiation are less easily perceived and their detection often requires the use of sophisticated equipment. The solar radiation travels through space in waves, and it is the length of these waves (the shortest is less than a millionth of an inch, the longest more than a thousand yards), by which all the incoming solar radiation is classified. The aggregate of all radiation aspects of the sun is called the solar spectrum.

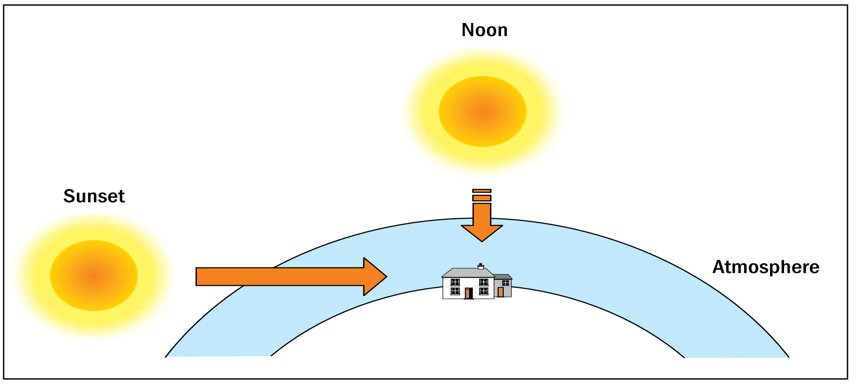

Figure 1 Some wavelengths of radiation absorb by the atmosphere through which it passes.

Because of the earth's tilt and rotation, the distance that solar radiation travels varies. It depends on the time of the day and month.

Formation of a BIPV system

A comprehensive system to meet the energy requirement in the form of light, heat, electrical energy has PV modules, which might be thin-film or crystalline, transparent, semi-transparent, or opaque. In addition, it has a charge controller, to regulate the power into and out of the battery storage bank (in stand-alone systems), utility-interactive power storage system, generally comprising of the utility grid in utility-interactive systems. There may be a number of batteries in the stand-alone systems besides power conversion equipment, backup power supplies, and appropriate support and mounting hardware, wiring, and safety disconnects. (Figure 2)

BIPV systems can either be interfaced with the available utility grid or may be designed as stand-alone, off-grid systems. The benefits of power production at the point of use include the following.

- Reducing the losses associated with transmission and distribution (known as grid support)
- Reducing the electricity bills of the consumers by matching peak production with periods of peak demand.

Moreover, buildings that produce power using the renewable energy sources reduce the demand on traditional utility generators.

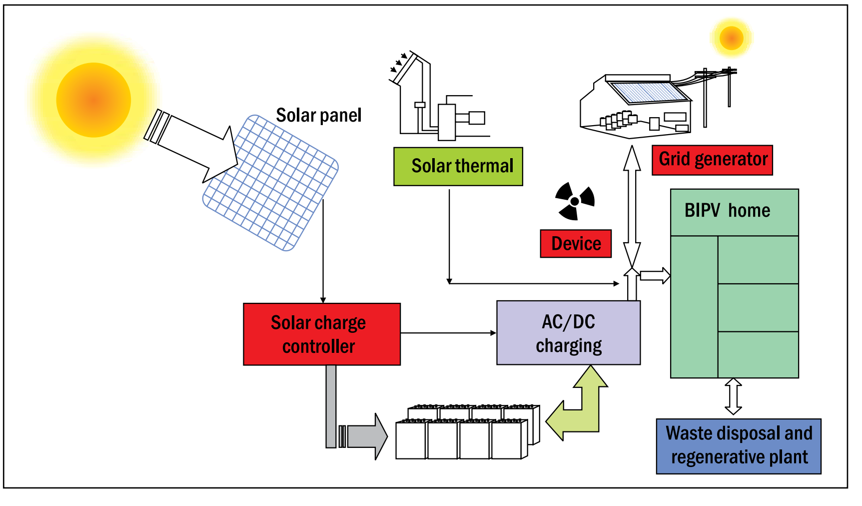

Figure 2 BIPV system diagram

Design considerations

The most attractive building design incorporating BIPV system uses environment-friendly and energy-efficient equipment. The equipment should be viewed in terms of life-cycle cost, and not just the initial cost, because the overall cost may be reduced by the avoided cost of the building materials and labour that they replace. Other design considerations for BIPV systems usually include the following.

- Use of building
- Electrical loads and peak load
- Location and orientation
- Applicable building and safety codes
- Available information resources to know the relevant utility issues and costs

The designer includes some important steps of the following type in designing a BIPV system.

1. Energy assessment: The energy assessment of the buildings help to enhance comfort and save money, while also enabling a given BIPV system to provide a greater percentage contribution to the load.
2. Utility-interactive PV system: The vast majority of BIPV systems will be tied to a utility grid, using the grid as storage and backup. The systems should be sized to meet the goals of the owner—typically defined by budget or space constraints; and, the inverter must be chosen with an understanding of the requirements of the utility.
3. Shift the peak: If the peak building loads do not match the peak power output of the PV array, it may be economically appropriate to incorporate batteries into certain grid-tied systems so as to offset the most expensive power demand periods. This system could also act as an UPS (uninterrupted power system).
4. Thermal heat transfer: The thermal heat, with air or water as carrier may be effectively utilized to provide adequate ventilation for the solar panels.
5. Local climate: Specific design for specific climate and environment conditions will help in a proper selection of the solar panel. Cold, clear days will increase power production, while hot, overcast days will reduce the array output.
6. Day lighting: Consider integrating day lighting and photovoltaic collection using semi-transparent thin-film modules, or crystalline modules with custom-spaced cells between the two layers of glass. Designers may use PV to create unique day lighting features in façade, roofing, or skylight PV systems. The BIPV elements can also help to reduce unwanted cooling load and glare normally associated with large expanses of architectural glazing.
7. Array design: Arrays design for potential snow- and wind-loading conditions. Surfaces reflecting light onto the array may increase the array output. Properly angled arrays will shed snow loads relatively quickly and arrays in dry, dusty environments or environments with heavy industrial or traffic (auto, airline) pollution will require washing to limit efficiency losses.
8. Traditional design and material: BIPV systems can be designed to blend well with the traditional building materials and designs, or they may be used to create a high-technology, future-oriented appearance. Semi-transparent arrays of spaced crystalline cells can provide diffuse, interior natural lighting. High profile systems can also signal a desire on the part of the owner to provide an environmentally conscious work environment.

BIPV design and construction parameters

Solar glazing and laminate

In photovoltaic applications, usually low iron-tempered glass is used. Glazing can be made as simple glass/glass laminate or as complex isolation glass/glass laminate. Special laminates with coloured back sides have also been produced. Due to the safety requirements for lamination, usually PVB foil instead of EVA foil is used especially for laminates used in case of transparent roofs. Laminate can consist of mono-crystalline cells, thin-film cells, or transparent cells.

In BIPV applications, different types of modules (depends on application) can be used—classic (framed) modules, flexible crystalline or thin-film on metal substrate, roof-tiles with solar cells, opaque, semitransparent and transparent mono-crystalline modules, modules with coloured solar cells, semi-transparent micro perforated amorphous, and so on.

Upon the customer's request, almost all the module (mechanical and electrical) parameters can be customized. Customization includes module shapes, cell type and colour, cell transparency, laminate construction, laminate/module size, heat/noise isolation properties, module voltage, and peak power, and so on. Limitation during production represents usually only laminator. Largest laminators allow production of laminates up to five sq m of area in one piece.

Façade integrated modules

Most commonly realized type is the 'curtain wall', or facade mounted modules. 'Cold' and 'warm' photovoltaic facades are possible. In the BIPV facades, different types of modules can be used: classic modules, transparent or semitransparent modules (crystalline or micro perforated amorphous modules). 'Shadow-Voltaic' system is also very often part of a BIPV facade. Modules can be fixed or mounted on the tracking structures (Figure 3).

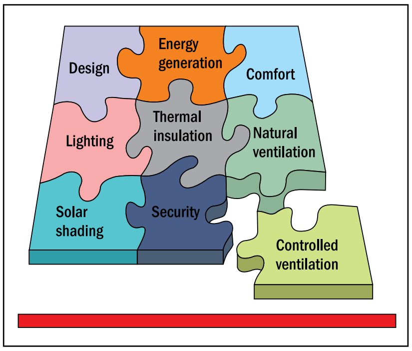

Figure 3 Façade design

Roof integrated modules

The roof-integrated modules are usually laminated without frame such as solar roof tiles or shingles. For details, please go through the solar roof-tiles section. As roof integrated modules, other module types can also be used—flexible modules, transparent or semitransparent modules, thin film modules, and so on.

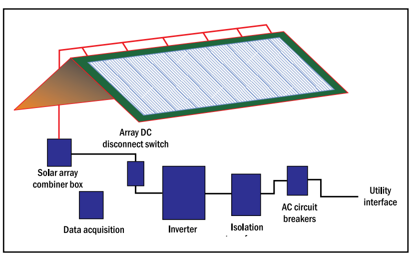

Figure 4 Rooftop BIPV

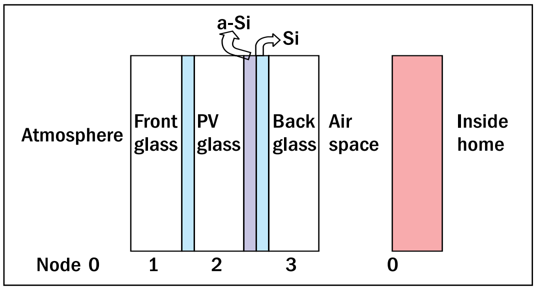

Figure 5 Cross-section of vertical BIPV façade

Energy (heat) transfer modelling of a BIPV façade

The following equations describe heat transfer in the modelled vertical façade system, with heat-transfer rates denoted by 'q'. Heat-transfer rate subscripts indicate the source and target nodes (Figure 5), respectively, and the chosen sign convention is q > 0 for heat transfer to the node and q50 for transfer away from the node. At node 1, heat is transferred between the environment and the glass via radiation and convection

$$q_{01} = [€_g \sigma\{T^4_{sky} - T^4_1\} + \{T_{amb} - T_1\} h_w]A \quad (i)$$

heat is transferred between the PV module and the glass by conduction.

$$q_{12} = (T_{mod} - T_1) \frac{kg}{Lg} A \quad (ii)$$

Where

$€_g$ is emissivity of the glass

σ is the Stefan–Boltzmann constant,

T_{amb} is the ambient temperature,

T_{sky} is the sky temperature calculated as $T_{amb} - 6$ K,

$T_{1,2,3}$ is the temperature at node 1,2,3

a is the PV module area.

hw is average wind convection coefficient

k_g the thermal conductivity of the glass–silicon assembly

L_g is the glass thickness.

At node 2, the heat-transfer fluxes are conduction from the back glasses

$$q_{23} = (T_3 - T_{mod}) \frac{kg}{Lg} A \quad (iii)$$

The solar energy flux, which is absorbed by the PV module but not converted to electricity

$$q_{02} = Ga(1 - \eta) A \quad (iv)$$

G is solar radiation

a is fraction of solar energy absorbed

η is the electrical efficiency of the module.

At Node 3 is affected by convection from the module and radiative and convective heat transfer to/from the airspace.

$$q_{34} = \left[\sigma(T^4_{amb} - T^4_3) \frac{1}{\frac{1}{€_g} + \frac{1}{€_1} - 1} + (T_{air} - T_3) h_{air} \right] A \quad (v)$$

€1 is the emissivity of insulator

T_{air} is the temperature in the airspace

At node 4, heat conduction through the back insulation and ventilation heat loss

$$q_{40} = (T_{amb} - T_{air}) \left[\frac{k_i}{L_i} A + \rho_{air} C_{air} V_{air}\right] \quad (vi)$$

k_i is the thermal conductivity of the insulation

L_i is the insulator thickness.

Capacitive heat sink component due to its thermal mass is considered negligible in comparison to other component.

Performance of BIPV Integration

For a power analysis study on the mechanically ventilated PV system is designed in two parts along a central glassed-in strip of the existing façade. For example, consider PV panels mounted on a steel/aluminum supporting structure covering a total area of 150 m². The experimental PV installation will be raised on the South West façade of the building with a complex measurement of key parameters.

- Number of modules — 176
- Capacity of individual C-Si module — 105 Wp
- Number of PV arrays — 3
- Total area of PV arrays — 150 m²
- Total output power — 18.5 kWp
- Number of sensors — 50

The approximate cost of crystalline silicon solar panels is Rs 0.3 million ($4000) for covering area of 150 m².

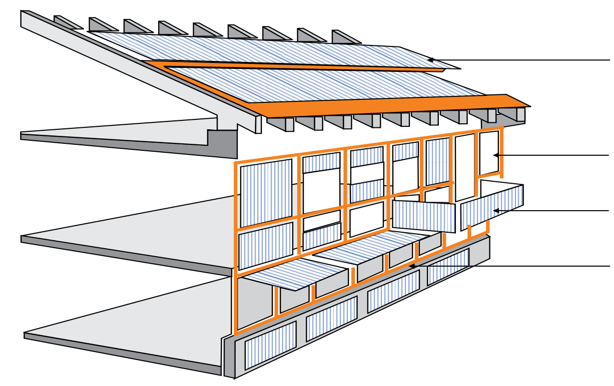

Figure 6 Integrated BIPV

These CE mark requirements are driven from the following

- EU directive for such a building
- CEN standard
- IEC standard
- CENELEC norms
- Existing PV Standard NVN 7205
- European Building Code for BIPV (Glass product)
  - DIN 1286-1 & 2
  - DIN EN ISO 12543-2

Building code and legal framework

The European Union has already adopted BIPV system for commercial and residential buildings. The legal authority is working to develop reliable and quality calibration procedures for standard and innovative types of PV modules. The underlying objective is also to harmonize measurements and evaluation techniques for the entire BIPV systems. According to CPD (Construction Products Directive), the parameters of BIPV system merit the following considerations.

1 Mechanical resistance and stability
2 Safety in case of fire
3 Hygiene, health, and the environment
4 Safety in use
5 Protection against noise
6 Energy, economy, and heat retention

Developing CE mark requirements for BIPV

cl 6.1.1 State-of-the-art and best practices
cl 6.1.2 Regulation and building code for BIPV in Europe.
cl 6.1.3 Report on the requirement of BIPV products, test procedures, and PV codes
cl 6.2.1 Inventory of requirements as the test procedures to be used for CE mark

Future expansion

The country's leading developers, such as DLF, ITC, Siddha group, and MRMGF have already shown considerable interest in setting up mega-scale projects using roof-integrated solar PV as an integral component. The BIPV homes are energy efficient with better aesthetic and environment considerations, but have higher initial capital cost. However, the LCC (life cycle cost) analysis makes this type of technology use for homes ideal for a sustainable living. The BIPV design has raised many issues related to safety and the Indian standard for construction of homes incorporating the BIPV features is in progress.

ANNOUNCEMENT

The Solar Quarterly editorial team invites articles and research papers from professionals, researchers, academicians, and others on solar energy and issues related to solar as a form of renewable energy.

Send in your contribution to:
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HOT SUN

COOLING THE AIR

ASHEESH JHA, Head, Sales and Marketing, MAMATA Energy India

Background

India's total installed power generation capacity, as on 1 January 2010, was approximately 156 783.98 MW, of which 52.36% is coal based, 23.52% hydro, 9.83% renewable and the balance is oil, gas, and nuclear based. The per capita power consumption is 632 KWh/year as against the world average of 2516 KWh/year. Power shortages are estimated at about 11% of total energy demand and 15% of peak energy requirements. These are likely to increase in the coming years. Solar thermal technologies have a special relevance in India in view of high availability of solar energy. The average radiation is 4.0–7.0 kwh/m^2/day, with on an average 250–300 clear sunny days in a year.

There is immense potential especially in the industrial sector to meet thermal energy demands, and thus it makes sense to use solar thermal energy. It is in tune with a very well recognized rationale of 'energy saved is energy generated'.

The logical sense in pursuing solar

I want to raise a question, why in India we have massive electrical power cuts, especially in summer? The answer is not hard to find, as during the summer months, our air conditioning load increases a lot. This is exactly where a technology innovation can play a big role. We have higher heat load because of sunshine, and we can use this very radiation from sun for cooling through a process better known as 'liquid vapour absorption'.

The underlying technology

Vapour absorption is one of the oldest known technologies used by mankind for cooling. Solar thermal technologies originated by using flat plate collectors, but these are not the efficient collectors. They need frequent cleaning of the aperture area as well copper tubes for removal of scales. So to overcome this problem, the next development was a full use of glass tubes, where absorbing efficiency no doubt increased, but the big problem of deposition and cleaning of scales still existed. Hence, to overcome all these problems, the ETHP (third generation solar collectors) were invented. These collectors have absorbing efficiency as high as 75% and no water is in touch with the solar tube. Solar concentrators can generate low pressure steam. Using these ETHP or solar concentrators, we can use solar air-conditioning for about 10–12 hrs a day.

The design innovation at Mamata Energy

Mamata Energy make ETHP tubes, and they are designed to absorb UV and IR rays, which makes them very effective under low ambient temperature condition. Further, in summer, these tubes can reach to a stagnation temperature of 240 °C. This system needs almost no maintenance, as 'circulating water is not in touch' with the tubes. Thus, it can be maintained during the operational hours without any leakage of water. With these distinctive advantages, they are suitable to use for the following few end-use applications.

- Water heating
- Process heating
- Hot air drying
- Air conditioning

Using this revolutionary third generation ETHP technology, MAMATA energy is the first company in India to install solar thermal air conditioning, of 25 TR at their facility in Santej, located few kilometres away from Ahmedabad. They are heating 18000 lit/hr of water up to 90–99 °C, which is being used to fire a single stage hot water fired VAM (Vapour Absorption Machine). It has been running successfully since January 2006.

Global perspective

These ETHPs were originally invented in Germany and are already being used in the European countries, where ambient temperature is usually very low. However, this technology is still in the pilot project stage in India.

Potential for using solar thermal air conditioning in India

It was a dream to run central air conditioning on solar energy. And this dream came true a few years back, when MAMATA Energy Pvt Ltd. installed India's first solar thermal air conditioning system. It was mainly possible because the company has funded research and networked across the world, to develop this technology for commercial use. A study shows that, air-conditioning accounts for approximately 60% of electric consumption. Using vapour absorption technology for space air conditioning is a well known technology used in the developed world. However, for a country like India, it was never a viable proposition until the ETHP was made available by MAMATA Energy.

Operational performance

MAMATA Energy's evacuated tube heat pipes, offer better performance than the flat plate collector, as demonstrated by a graphical relationship between the respective efficiency of ETP and flat Plate collectors in various temperature ranges. Using solar thermal power for AC of 25 TR capacity using evacuated tube heat pipe solar collectors and single effect hot water fired vapour absorption technology; the consumption level comes to only 5.69kW/hr. In India alone, we have a potential requirement of 45 00 000 TR of air conditioning, which can be met by using about 5400 MW/hr of electricity. If, only 10% of this requirement can be taken care of by solar thermal mode of air conditioning, we can save 540 MW/ Hr. It may also mean a reduction of nearly 1 billion tonnes of CO_2 injected every year into the atmosphere.

The green edge

Solar thermal air conditioning as a product application goes hand in hand with the major objectives of green building projects as per LEEDS (leadership in energy and environment system). In context to the green building projects, if, we want to achieve platinum rating, it is must to use renewable energy at site. It can replace the conventional air conditioning system, and hybrid solar thermal air conditioning caters to the need of air conditioning round the clock. The additional gain accrues under the ambit of clean development mechanism.

Summing up the advantages

- Installations of this nature can be registered for earning the carbon credits
- Corporate entities can gain an added visibility along with other benefits of using renewable energy
- Power consumed by STAC is equivalent to one-fifth of the conventional energy normally consumed for the air conditioning
- It can be used for space heating during winter without incurring any additional cost.

TAKING FORWARD THE GLOBAL SOLAR WATER HEATING PROJECT

Ajit K Gupta has been associated with the renewable energy sector for three and a half decades. He has played a key role in the development and deployment of renewables including solar, wind, biomass and small hydro. He has also been an important figure where policies, regulatory, legislative aspects, and institutional developments are concerned. He started and was responsible for the development of programmes on grid power generation; remote village electrification; and, urban, industrial, and commercial applications of renewables. Gupta has served as Director of the Solar Energy Centre and was also the first Executive Director of the Centre for Wind Energy Technology. He joined the Government in the Department of Science and Technology in 1973. He retired as Adviser, MNRE (Ministry of New and Renewable Energy), Government of India, in September 2008. Since December 2008, he has been heading the Project Management Unit of the UNDP/GEF Global Solar Water Heating Project as the National Project Manager in the MNRE.

In an interview with Arani Sinha, Ajit K Gupta talks about the 'Global Solar Water Heating Project' and the future of renewable energy in India

Q. You have been associated with the India's RE (Renewable Energy) programme since its early days. In what ways would you like to remember such a long and valued association with the programme?

I consider myself fortunate to be associated with the sector since its inception in the mid 1970s. I have seen it grow from a small division in DST (Department of Science and Technology) to a full fledged ministry. I have enjoyed my journey for the last 35 years, and I am happy to have contributed in the development of various technical and field applications. Of all the achievements, I would single out the contribution in developing the wind power technology, in India, as very important.

Q. The wind energy programme in the country has marched from strength to strength since its commercial inception. When do you see the solar energy programme going along the same path?

We initiated wind energy programme in the early 1980s. The strategy and approach had four points. Firstly, we established a strong wind resource assessment base across the potential regions. Secondly, we demonstrated by showcasing the best technologies from across the world, in this field. Thirdly, we involved the utilities from the beginning. Since, we would be feeding the electricity into the grids, which strictly falls into their domain, their participation from the beginning was important. Fourthly, we involved

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the private sector from the beginning so that they too were able to get a feel of the technology and its application. This along with quality backup and guidelines for project development have helped the development of this sector in India. A similar approach is necessary for solar power generation so that it leads to rapid development of the sector in the coming years.

Q. How would you look at the just announced draft guidelines concerning the selection of solar grid connected projects under Phase-I of the Jawaharlal Nehru National Solar Mission?

The government is taking action along several fronts to meet the goals set under the Solar Mission. The mission calls for the installation of 1000 megawatt of solar power in Phase-1 by 2013, both solar thermal and solar photovoltaic. For Phase-1 NTPC's NVVN (Vidyut Vyapar Nigam) has been designated as the nodal agency.

However, there are certain aspects that would need to be considered as we move along. First is the total lack of experience of the country in connected solar projects. From practically nil capacity, we have to move on to 1000 megawatts in the next three years. The schedule is extremely tight, and solar thermal power projects have long gestation period. However, the roles of the states are not very clear in this central government project. For each project the developers will need to procure land, need access to water, and will need power evacuation facilities for which they will need Power Purchase Agreements. All this is in the domain of the state. Therefore, the states will have to be involved if this approach is to succeed. We will have to wait for the guidelines and proposals to be finalized.

My view is that instead of the developers trying to develop individual projects, if we can have solar parks with basic facilities where private developers can come and install their projects, development would be much faster.

Q. Could you kindly enunciate the key issues and challenges still daunting the solar grid power generation?

Barriers that one might face in the development of this sector are related to the intermittency of the resource, inadequate resource assessment, nascent storage technologies, high capital cost, and low capacity utilization, which affects the viability of these projects in the immediate term. Resource assessment, R&D, and technology development are critical for achieving the goals of the Solar Mission.

As far as local manufacturing capacities are concerned, we do have some degree of capacity and capability in solar PV, but we do not have any indigenous production base for solar thermal projects. Thus, we need to evolve a special incentive package for solar thermal manufacturers.

Q. Solar water heating should be perceived as a preferred product choice when pitched against electric geysers. Then what is still stopping its fast pace market penetration?

Amongst the commonly cited barriers for the penetration of solar water heating, I would like to refer to two main problems. Firstly, the lack of adequate awareness, and secondly, adequate quality that will install confidence amongst users. Under the UNDP Project we seek to address these issues and take necessary steps to rectify these problems. Affordability in my view is not a critical factor. Conducive policies by municipal authorities and utilities can help in the promotion of solar water heaters.

Q. Could you tell us about the specific charter in your newly assumed role

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under a UNDP/GEF Supported Global Solar Water Heating Project.

I retired from the Ministry of New and Renewable Energy in September 2008 and got the opportunity to continue working in this sector in the UNDP/GEF project. I am currently the national project manager. Water heating has not been able to attain its niche amongst other renewable technologies. We have not yet been able to tap its full potential. Of the total 40–50 million sq m of solar water heated area we have only been able to install about three million sq m over the last three decades.

The project aims at accelerating the whole process by focusing on key aspects that will help us to tap the vast potential, particularly in the rapidly growing residential segment. We will be focusing on raising awareness, reformed policy and regulatory framework, consolidation of the supply chain, capacity building and training, and above all quality issues for which the image of the sector has suffered. I endeavour to work on all these aspects such that this technology helps us in saving peaking power.

Q. Rural adoption of solar energy products like the solar lanterns and home lighting systems are witnessing an increasing support from the women folk across the country. Is this a strong case for gender equity taking place in the RE sector?

Certainly, to the extent that lighting in any form can bring about women empowerment in our villages. The women have some spare time in the evening and night when they do not have access to electricity. They are mostly engaged in household chores during day time. Access to solar lanterns and lighting allows them to engage in increasing their livelihood activities and generate some additional income. Thus, it opens up avenues for productive work for the women that empowers them as well as provides some extra income to the family.

Other forms of renewable energy sources too have helped in such empowerment. This includes development and utilization of improved cooking stoves or construction of family based bio-gas plants. It relieves them from the drudgery of smoking hulas and the hard work of collecting firewood.

Q. Finally, do you have any special message for the curious readers of, The Solar Quarterly magazine?

I have always said that RE will have a place in our country where we have a deficit of power. Renewables can not only provide access to energy to our rural areas, but it can also help build our grid capacities and substitute fossil fuels for power generation and the transportation sector. Thus, it is very important for bringing about energy securities in our country. It is green and environment friendly, do not need to worry about emissions as by their very nature they promote low carbon growth.

The time has come for mainstreaming of trenewable energy in various development sectors, to take the economy towards a sustainable growth and development path. India, now has considerable experience in the development and application of different RE technologies.

UNDP/GEF Global Solar Water Heating Project

The objective of the 'Global Solar Water Heating Project' implemented by the Ministry of New and Renewable Energy under the UNDP's (United Nations Development Porgramme) India country programme is to accelerate and sustain the solar water heating market growth in India, and to use the experiences and lessons learned in promoting a similar growth in other countries participating in the global project; to establish a supportive policy and regulatory environment; to build the market demand; and to strengthen the supply chain. The Project commenced in November 2008 and will run up to December 2012. The expected outcomes of the project are the following

- Enable policy framework
- Enhance awareness
- Attract financing mechanism
- Quality and enhanced supply chain capacity
- Lessons learned, replication, and sustainability

MOVING TOWARDS GRID PARITY

Dr Parmod Deo is the longest serving electricity regulator in India. On 9 June 2008, he took over as the Chairman of the Central Electricity Regulatory Commission. Dr Deo has 20 years of experience in policy, regulatory, and project management aspects of the energy sector. In 2005, the World Energy Association awarded him with the World Wind Energy Award, for his outstanding achievement in dissemination of wind energy. He is also the receipt of the Distinguished Personality- Energy Management Award, 2006, and the Wartsila Mantosh Sondhi Award, 2009 for his contribution in the power sector. In an interview with Arani Sinha, Dr Deo talks about the role of CERC in moving towards grid parity and enhancing the role of renewable energy in the country.

Q. You have enjoyed an illustrious career as the longest serving electricity regulator in the country so far. What further achievements of yours are in the offing that could have far reaching impact on the country wide development of RE (renewable energy) programmes?

As a regulator, I would definitely like to bring down the cost of electricity in the country. Also, we need to develop a national market for electricity, so that regions having electricity shortage can meet their demand by purchasing from this market.

Coming specifically to renewable energy, you need grid parity. There are many externalities in conventional power. The challenge is to capture these externalities. The cost of mining fuels, transportation, and so on raises the cost of power production, and you simply cannot change that. RE can solve some of these issues. It has to become part of our national power planning. This will boost our energy security by lowering our dependency on oil and coal import while at the same time lowering the production costs.

However, one has to balance the equation to encourage development of RE projects. The best way is to give preferential tariff to the RE developers so that the investors feel comfortable. This approach has been accepted by the National Approach Plan on Climate Change, keeping a specific target of 5% energy from RE sources. Once we reach parity, no more support will be required for RE energy.

For wind power, there is an idea to bring in generation-based incentives. It is observed that many setup wind projects for tax considerations and are not much bothered about operational efficiency. What we are saying is that, if CERC guidelines are followed then generation-based incentives will not be needed.

Q. Do you see any specific merits in having changed from a capital cost based solar promotion scheme to a generation based incentive scheme?

We have not really changed. In determining tariff rates for solar, we have gone by cost plus formula. What we are saying is that given cost plus returns, if your efficiency, and hence production levels are higher, you will be rewarded for that. Our capital cost benchmarking has been done with a certain assumed efficiency level. If one is receiving other benefits like accelerated depreciation benefit, it has to be factored in so as to ensure a level playing field.

For wind power, there is an idea to bring in generation-based incentives. It is observed that many setup wind projects for tax considerations and are not much bothered about operational efficiency. What we are saying is that, if CERC guidelines are followed then generation-based incentives will not be needed. If it is given, then it has to be deducted.

Q. CERC is always perceived as the guiding force of RE regulation. What other steps or role should CERC play in order to exert a still bigger influence on the overall RE scenario in the country?

Earlier, CERC had no role to play in the RE sector. It set tariffs for central generating stations or interstate. In the National Tariff Policy of 2005, the law said that the Central Commission will frame regulations for generation and transmission tariff, which will form the guidelines for state regulating commissions. Thus, CERC played a very general role. However, the tariff policy clearly said that where it is not possible to have a competitive bidding, especially for non-conventional energy sources, CERC will come out with guidelines. We have used this opportunity to come out with the guidelines, which will hopefully be followed by state regulatory commissions and will determine tariffs. Otherwise, there was a great variance in the tariff rates set by different state commissions.

Q. Are you generally satisfied with the role being played by the state electricity regulation commissions in furthering the cause of RE programmes moreso based on solar energy?

It is just the beginning for solar energy in India. Under Phase-1 of the National Solar Mission, there is little role for the state electricity regulators. Power generated by the power plants being setup under the current programme will be purchased by the National Thermal Power Corporation. In case of rooftops units, the tariff will be determined by state regulators. We are coming out with guidelines for such smaller systems as the tariff has to be much higher.

Q. According to some, the solar industry in India has come of age, while others still perceive that it has a long way to go before making any noticeable impact on the national electricity scene. What is your expert view on this matter?

The whole idea behind the Solar Mission is to create sufficient market for peers, which includes the manufacturers. There is already a strong lobby with export capacity. Thus, one demand is to have indigenous content in all solar plants which are to be setup. The draft guidelines currently open for discussion also includes that all the modules will be procured in India. While for solar thermals; the content will be 30%.

However, there is another lobby which says that for efficient technology, such restrictions should not be there. Moreover, if you look for funding from abroad, these procurement conditions will act as a barrier.