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Scope of Solar Energy in Cold Arid Region of India at Leh Ladakh

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Abstract: Considering the fast depletion of fossil fuel, there is need for switching to renewable options for meeting the energy demands in future e.g. solar, wind, biomass etc. At present, 13% of the electricity production in our country is met through renewable sources, whereas globally it is about 22.8%. If we think about the availability of solar irradiation in India, it is abundantly available in cold arid regions at Leh-Ladakh. In spite of large availability of solar irradiation at Leh-Ladakh, e.g. 7-7.5 kWh m^{-2} day^{-1}, huge amount of diesel is still being used for meeting the daily energy demands of Leh-Ladakh. Solar energy has a great role to play for future energy security of Leh and Ladakh either through solar thermal or solar photovoltaic options. In this paper, different solar based technologies are discussed to use solar energy at domestic level, at farmers' field and even at industrial scale. Solar PV pumping system can easily be used for irrigation purpose and even to lift water against gravity at undulating terrains of Leh-Ladakh. Solar farming option can be utilized where both crop production and PV based electricity generation can be done on a single land use system. Solar air heating for buildings may provide congenial inside environment especially during winter months. Solar green house can be an effective way to produce vegetables even during harsh climatic conditions outside. Roof top PV system can share the electric energy consumptions in office buildings, hospitals, guest houses, hotels etc. Solar lanterns have the potential to replace conventionally used kerosene based lighting system. Other different solar technologies that have a potential in Leh-Ladakh are inclined solar dryer, solar PV winnower cum dryer, solar water heater etc. Utilization of above discussed solar based technologies may have improved the renewable energy scenario in Leh and Ladakh.

Key words: Renewable energy, Leh and Ladakh, solar thermal devices, solar PV technologies.

Considering the fast depletion of fossil fuel based energy, renewable energy is the most viable option for future energy security of world. At present, renewable energy share to world's global electricity production is about 22.8% (by the end of 2014), out of which 16.6% is contributed by hydropower, 3.1% by wind energy, 1.8% by biomass-power and 0.9% by solar PV (Renewable Energy Network for 21st Century, REN21). Cumulative renewable installed capacity in the world is 1712 GW including hydropower installation of 1055 GW. Annual growth rate of cumulative renewable energy installed capacity in 2014 was about 8%, whereas the annual capacity addition grew by 24% in 2014 as compared to 2013. India ranks 7th in the world in total renewable energy installed capacity while China tops the list followed by USA and Germany. In China, wind energy and hydropower installations are the major contributors to renewables whereas in USA, geothermal energy and in Germany, solar PV is the dominant contributor. India ranks 5th in the world in total wind energy installation after China, USA, Germany and Spain, whereas it is 10th in world among solar PV installation. Globally, 15% of the world population has no access of electricity. India today is home to one-sixth of the world's population, but accounts for only 6% of global energy use and one in five of the population-240 million people-still lacks access to electricity (World Energy Council, 2015). Therefore, much effort is needed in India to fulfill the future energy demand and specifically through renewable energy sources.

At present about 13% of energy generation in India is met through renewable sources e.g. wind, solar, biomass etc. whereas coal is till the main source contributing about 60% of total generation. During last few years, a great stride has been made to install solar PV plants, wind turbine, hydropower, biogas e.g. renewable installed cumulative capacity has been increased from 24914 MW in 2011-12 to 42752.21 by the end of 2015-16 with an

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Table 1. National solar mission targets

Application segment	Target for Phase I (2010-13)	Target for Phase II (2013-17)	Target for Phase III (2017-22)
Grid connected solar power generation	1,100 MW	4,000 MW	1,00,000 MW
Off-grid solar applications (includes solar PV pump)	200 MW	1,000 MW	2,000 MW
Solar thermal collectors	7 million sq. m	15 million sq. m.	20 million sq. m
Solar lighting systems	5 million	10 million	20 million

Source: Ministry of Renewable Energy Sources, Govt. of India.

annual growth rate of 17.8%. By the end of March 2016, wind energy installation shares the maximum 26769.05 MW (62%) whereas solar PV installation shares 6762.85 MW (15.8%). Rajasthan and Gujarat share ~58% of the total solar power installed capacity in the country, whereas these two states shares 29.2% of total wind installed capacity. Tamilnadu and Maharastra dominate the total wind installation in our country by sharing 52% of total installed capacity by the end of 2014-15. Under the national solar mission it is targeted to generate 1,00,000 MW of solar energy by the end of 2022 (Table 1).

At an annual rate of increase of 7%, power requirement in Ladakh is set to swell to 140.5 MW by 2025. Currently, 8000 litres of diesel are needed to generate sufficient power for a day's consumption in Ladakh, and all of this fuel if imported from outside. The Ladakh Renewable Energy Development Agency (LREDA) is the nodal agency for implementation in Ladakh of all non-conventional energy programs of the Ministry of New and Renewable Energy, Government of India (http://ladakhenergy.org/) and making constant efforts to improve the renewable energy utilization in Leh-Ladakh. Supplying power to isolated remote areas

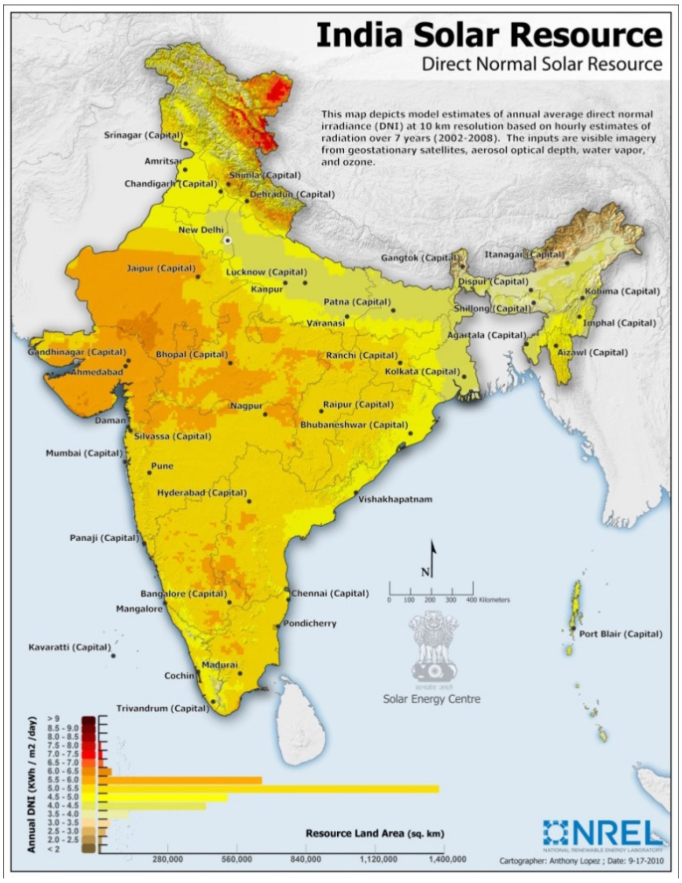

Fig. 1. Solar resource map of India.

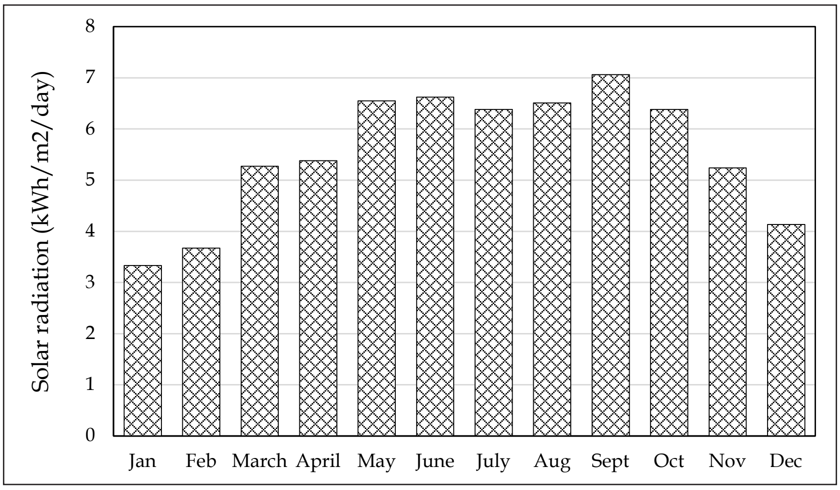

Fig. 2. Availability of solar radiation in Leh.

specifically during winter season is a formidable challenge, and it is virtually impossible to do so by the use of transmission lines from a centralised grid, which is neither a technically feasible nor an economically viable option. Solar energy is obviously the most potent form of renewable energy that Ladakh can tap for its needs. Micro hydel projects also hold a lot of promise for Ladakh. Another potential sources of renewable energy in Ladakh are geothermal energy and wind energy. Apart from relying on renewable energy for most of Ladakh's power needs, we also need to foster a culture of energy conservation in Ladakh. Under this strategy, energy efficient equipment should be used as often as possible. From incandescent lamps or CFL lamps, there is a need to shift towards energy efficient lamps like white light emitting diodes (LEDs).

Availability of Solar Irradiance in India

The arid and semi-arid part of the country receives much more radiation as compared to the rest of the country. The average irradiance on horizontal surface in India is 5.6 kWh m^{-2} day^{-1} and at Jodhpur 6.11 kWh m^{-2} day^{-1}. The solar resource map of India shows that western India receives maximum amount of solar irradiation whereas major portion of India (~140 million ha) is receiving solar irradiation of 5-5.5 kWh m^{-2} day^{-1} (Fig. 1). The solar resource map along with grid wise solar radiation data can also be downloaded from http://mnre.gov.in/sec/solar-assmnt.htm. The cold arid region of the country located at Leh and Ladakh receives highest amount of radiation, which is about 7-7.5 kWh m^{-2} day^{-1}. At Jodhpur, maximum amount of radiation is received during the month of April (7.17 kWh m^{-2} day^{-1}), whereas

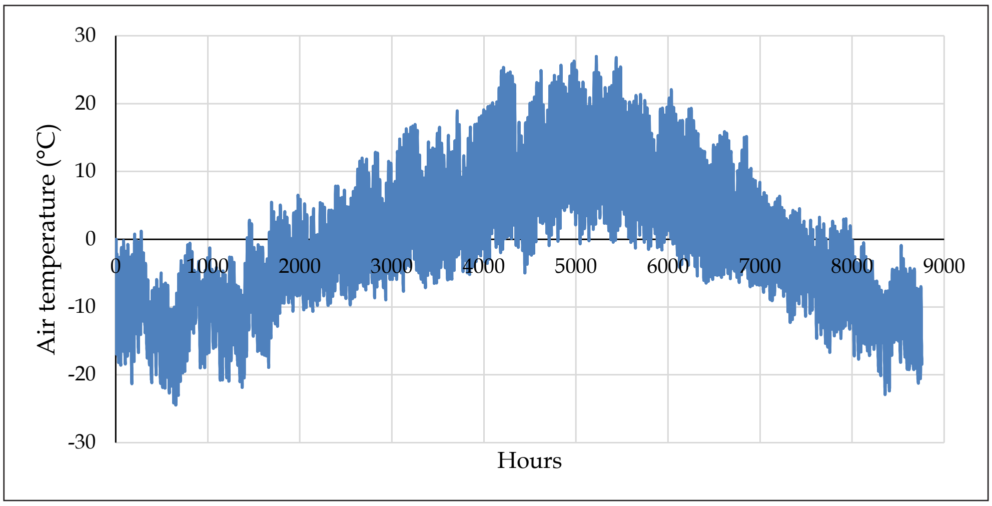

Fig. 3. Average hourly variation of temperature in a year at Leh.

the minimum amount of radiation is received during the month of December (5.12 kWh m^{-2} day^{-1}). In total, 6390 kWh of solar energy is available during a year at Jodhpur. Moreover, most of the days in a year at Jodhpur are cloud free which has been measured and reported in several literatures as 300 days clear sunny days in a year. Available solar irradiation and utilizable energy for any location in India can also be viewed from http://pvwatts.nrel.gov/ or http://mnre.gov.in/sec/solar-assmnt.htm.

Availability of Solar Energy in Leh

Solar radiation available in Leh is plenty. Average annual solar radiation is about 5.54 kWh m^{-2} day^{-1}, however the maximum amount of radiation is received during the month of September. Average monthly variation of solar radiation in Leh is presented in Fig. 2. Average solar radiation on a tilted surface with a tilting angle of 35° is about 6.36 kWh m^{-2} day^{-1}.

Ambient temperature in Leh remains sub-zero for most period in a year and reaches to a low of about -28°C during January-February. Average hourly variation of temperature in Leh is presented in Fig. 3.

Basics of Solar Energy Utilization

Technologically solar energy can be harnessed either in the form of thermal energy by using flat plate collectors and concentrators, or by generating electricity using photovoltaic cells. A schematic diagram on different solar technologies is presented in Fig. 4. Work on the utilization of immense, non-pollutant and inexhaustible solar energy has been carried out at CAZRI, Jodhpur for various domestic, industrial and agricultural applications in order to supplement the energy demand. This includes the development of solar still, solar dryer, solar cookers, solar water heaters, solar candle device, solar polish making machine etc. In addition, work on the development of solar PV based systems like solar insecticide sprayer, solar PV duster, PV pump operated drip irrigation system for growing orchards, PV winnower, PV dryer has been contemplated.

Solar PV technologies consist of semiconductor or other molecular devices called photovoltaic or solar cells that convert sunlight into direct current (DC) electricity. PV modules consist of multiple cells assembled on a common platform, connected in series

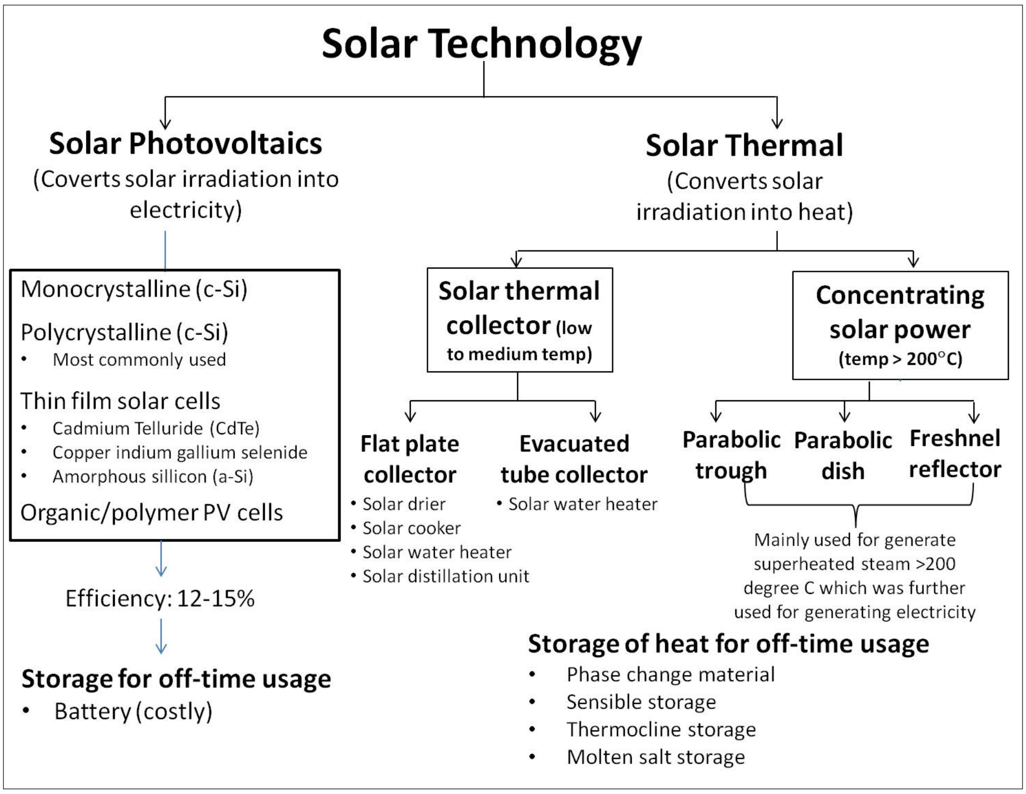

Fig. 4. Different type of solar technologies.

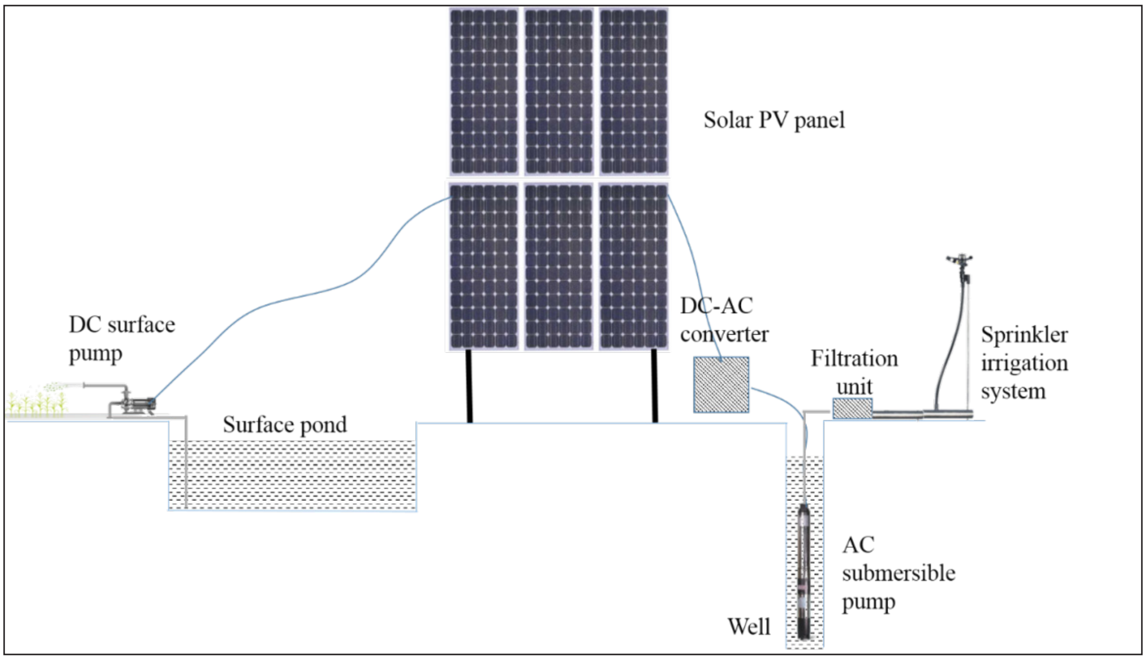

Fig. 5. Schematic diagram of a solar PV pumping system.

and sealed in an environmentally protective laminate. If the power provided by one PV module is not enough, then multiple modules are linked together to form an array to supply power ranging from a few watts to many megawatts. In addition to the modules, other components (for example, inverters, batteries, charge controllers, wiring and mounting structure) may be required to form a complete PV system.

Solar thermal technologies heat water or air, and other possible working fluids, for non-electricity uses of energy. Solar water heaters can displace conventional electrical water heaters in homes and in commercial establishments. Hot-air-based thermal collectors can displace fossil fuel use in cooking, agricultural drying and more generally in industrial heat processing. In India, solar water heaters have been commercialized and are an economically viable option for many regions. Other applications are still in nascent stages.

Apart from these two major solar technologies, concentrated solar thermal power (CSP) technologies can also be utilized which first convert solar energy into heat energy and then into electrical energy. Most CSP technology options, namely, the parabolic trough, Fresnel mirror system and central tower, are meant for utility-scale use. Further, with thermal storage, these three CSP technologies can provide electricity several hours after sunset. However, a less proven CSP option, the Stirling engine system, can be used in 10 to 25 kW decentralised applications, and can also be easily aggregated for utility-scale plants. Unlike other CSP technologies, this requires little water, but it also lacks inherent storage of thermal energy.

Future Scope of Solar Energy in Leh

In the following sections, future scope of solar energy applications in Leh is discussed covering solar PV technology and solar thermal technology.

Solar PV pumping system

Irrigating crops at right time with right quantity is highly essential for sustainable food production, however is highly energy intensive. Electrified pumps or diesel operated pumps are mostly used for this purpose throughout the country, however, may be replaced with solar photovoltaic pumps to enhance the energy productivity. A solar PV system is mainly composed of i) PV panels (ii) mounting structure (iii) pump unit (AC/DC) and (iv) tracking system (Fig. 5). Sizing of PV panel depends on the capacity of pump to draw water. If the suction head is about 4-5 m, which is applicable in case of a surface water reservoir, 1 hp capacity pump is sufficient which require about 900 W_p panel in case of DC pump and 1400 W_p panel in case of AC surface pump.

Functionality and suitability of solar PV pumping system has been studied quite long ago by Pande et al. (2003) in pomegranate orchard and recently being tested at different scale of operations by Santra et al. (2014). Therefore, the solar pumps has huge potential in hilly undulating terrain of Leh for lifting the irrigation water from Indus river tributaries and even to distribute drinking water to far flung areas. Size of the solar pumps depends on the suction head or gravity head; more is the delivery head larger will be the PV panel size and thus involves higher cost. Generally, 3 HP pumping systems are able to pump water with a total delivery head of about 75 m. The mounting structure for erecting the panels with an angle from horizontal surface, which is generally equal to the latitude of any place require strong mounting structure to withstand the wind forces. The pumps to be used in a solar pumping system may be either DC or AC type and surface or submersible type as per situation. As the PV panels generates DC current, additional DC-AC inverter system is required for AC pumping system. To track the panel perpendicular to the sun, tracking system may be required for better performance of the system. Two types of tracking system are available: i) one axis tracking which tracks the solar panel as per azimuthal rotation of sun from east to west and ii) in additional to azimuthal rotation PV panels can be tracked as per zenith angle of sun using a two axis tracking system. Both manual and auto tracking system are available in market however in case of auto tracking system there will be an additional cost of tracker. Cost of available solar PV pumping system in market with 3 hp capacity pump is about Rs. 3.5-4.00 lakhs with additional cost of Rs. 14,000/- for auto tracker and about Rs. 8,000/- for providing lighting systems.

Solar farming

Installation of solar power plants for electricity generation require about 2 ha MW^{-1}, however due to ever increasing pressure on land requirements, there is a need for their optimum and judicious use by integrating the cropping practices with the erection of PV arrays. Moreover, the problems of dust deposition on solar panels require regular washing with water, which is again a scarce resource in arid region. In addition, extending electric grids in isolated hamlets and farm fields is not economical and poses practical problems. In view of these problems, the concept of integrating solar power generation and agricultural farming for both grid connected and off-grid electricity generation may be introduced. In this system it is proposed to either ascertain a portion of land for erection of PV modules in a farmer's field or introducing crop cultivation in the same piece of land where PV panels are erected for electricity generation

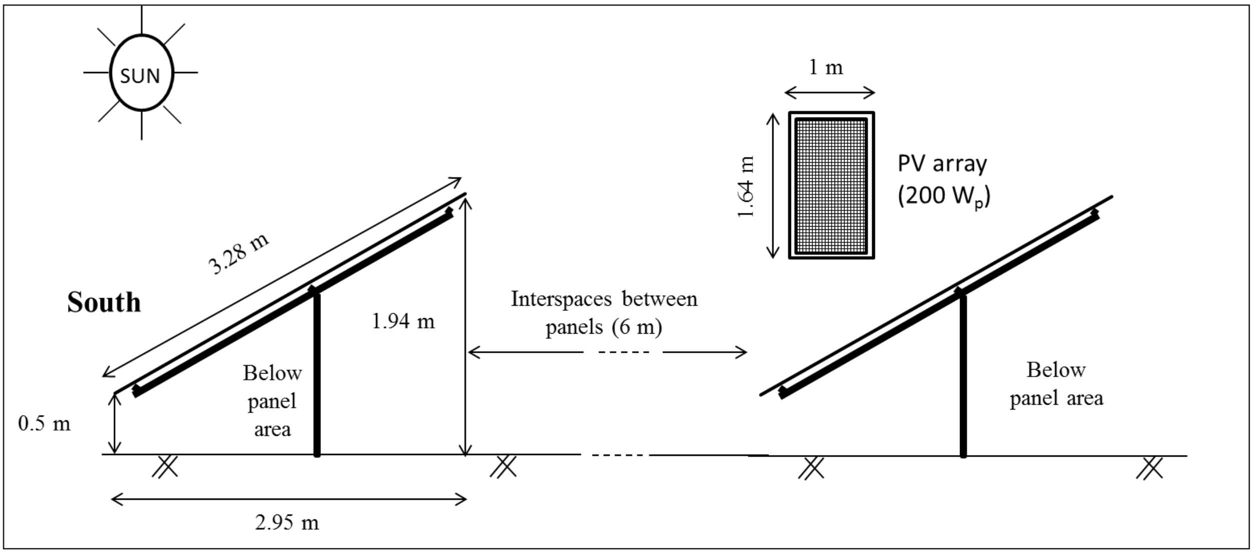

Fig. 6. Schematic design of solar farming system.

purpose (Fig. 6). By adopting such system, the risk of loss due to crop failure during aberrant weather events may be marginalised in farm scale and may prove to be an effective drought proofing strategy.

Solar air heater for buildings

In the cold arid region at Ladakh during winter, when the region faces sub-zero temperatures, traditional and conventional indoor heating methods are adopted. People in residential buildings generally use crude heating devices such as *bukharis* (wood-burning stove), kerosene/wood stoves, and sometimes LPG to keep their homes warm during the harsh winter, when temperatures drop to as low as -28°C. Solar thermal systems offer a great potential for room heating in this cold arid region because availability of solar radiation in Ladakh is among the highest in the country. Use of solar thermal based room heating system will reduce dependency on conventional fuels for heating, efficiency of which may be increased by integrating it with a thermal energy storage and insulation of the houses.

In the system, the heat needed to warm up the buildings is collected by a solar air heater on the roof of a house. The system heats up air during sunshine hours and the heated air is circulated inside the building through highly efficient fans powered by solar photovoltaic panels of 60 W each. The hot air circulated is used to heat up the pebble bed thermal energy storage under the floor of the building. This serves not only as a heat storage system, but also as an underfloor heating system and heats the room directly. In extreme cold weather, the heated air can directly be circulated through the indoor and gives a warm effect instantaneously. To save the energy generated from the sun, the house is insulated for protection against external weather. The system can meet up to 97 per cent of the average yearly heating demand at a room temperature of 15°C. Details of such air heating system may be found in Shukla (2014).

Solar green house

In cold arid region of Ladakh, it is very difficult to grow crops in open fields specifically during winter season when air temperature is sub-zero and snowfall occurs frequently. It is perceived that the greenhouse technology with controlled environment facilities may provide the required ambient temperature and other conditions suitable for crop production in Ladakh region (Triquet *et al.*, 2009; Murkute and Singh, 2015). Practically, the technology should help maintain a temperature of about 20°C (±5°C) inside a structure when the outside temperature is about –40°C. Since there is ample sunshine (3-7 kWh/m^2/day) in the region for 300 days in a year, harnessing this nonconventional resource, i.e. solar thermal energy for heating would be cost effective and eco-friendly. Polyhouse made of white transparent polythene generally makes the inside temperature warmer than outside, but when the outside temperature is below freezing then it is very difficult to maintain congenial environment for crop growth. Under such situation, heating inside the protected structure is required. It may be achieved by circulating the cold air through earth tube heat exchanger, which are generally placed underneath the soil profile at a depth 1-2 m, which generally remains warmer even during cold seasons. Forced circulation of air may be

Fig. 7. PV winnower cum dryer.

achieved through a solar PV operated DC fan. Otherwise, air may be heated using evacuated solar tube heating system, which may be further circulated inside the protected structure to maintain congenial environment. Suitable phase change material may also be used as heat storage material inside the structure to maintain suitable environment.

Roof top PV system

Roofs of building specifically the office buildings, hospitals, guest houses, hotels etc can be utilized to generate electric energy for their own use. In this system, PV panels are installed on the roof of a building with a tilting of about 35° facing towards south and are connected to a DC-AC inverter to supply electricity to the electric loads of a building. A battery back can also made to store the energy for off-time usage or even during periods in a day when sufficient sun radiation is not available as per attached load. An initial analysis has shown that a 4 kW roof top system can generate 6660 kWh electricity in a year at Leh (34.15° N and 77.55 E) (http://pvwatts.nrel.gov/)

Solar lighting system

Solar lighting system or solar lantern is a stand-alone portable system consisting of CFL/LED light, battery, electronic system and a solar PV panel. Whenever the system is exposed to open sun radiation, it generates electric energy for lighting or to store the energy in battery. Generally, 8-12 Wp capacity PV panel is used with 12 V, 7 AH battery storage in a solar lighting system. The system is very effective in remote areas, where electric supply for lighting or even other energy sources for lighting is scarce.

PV winnower cum dryer

The PV winnower cum dryer (Fig. 7) can be used for winnowing threshed materials in the absence of erratic and unreliable natural winds and also for dehydrating fruit and vegetables more effectively and efficiently (Pande, 2009).

The system comprises PV module and compatible especially designed winnower with dc motor - fan assembly. 35 to 50 kg grain could be separated with in 1 to 1.5 hours from threshed materials of pearl millet, mustard grain and cluster bean. The same fan of winnower is used in a dryer to use the system for dehydrating fruit and vegetables under forced circulation of air. Drying of mint, spinach, onion, mushroom, ber etc. can be accomplished with retention of colour and aroma.

Inclined solar dryer

Solar dryer is a convenient device to dehydrate vegetables and fruits faster and efficiently under control conditions while eliminating the problems of open courtyard drying like dust contamination, insect infestation and spoilage due to rains. Among solar dryers like forced, natural, tilted and domestic type. CAZRI designed solar dryers, a low cost tilted

Fig. 8. Inclined solar dryer.

type solar dryer, costing about Rs. 3500 per m^2, has been extensively tested for drying onion, okra, carrot, garlic, tomato, chillies, ber, date, spinach, coriander, salt coated amla etc. (Thanvi and Pande, 1987). The powdered products from some of these solar dried materials have been tested for instant use. Local entrepreneurs have adopted such inclined solar dryers (Fig. 8) of variable capacities (10-100 kg). One can save about 290 to 300kWh/m^2 equivalent energy by the use of such dryers and farmers can accrue higher benefits from solar dried products.

Solar water heaters

Substantial amount of fuel can be saved by using solar waters heaters for domestic purposes like bathing, washing of clothes and utensils and in industries like textiles and dairy. The natural circulation type solar water heaters with flat plate collector have been found suitable for hotels, hostels, guest-houses etc. (Nahar *et al*., 2003). Collector-cum-storage solar water heaters reduces the cost, almost half of the cost of conventional solar water heater. Now evacuated tube collector type solar water heaters are available in market and can be used in hotels, guest houses, etc.

Conclusion

Energy forms an integral part of Ladakh's physical infrastructure set-up. There is a great shortage of power in the region, constraining the development of all other sectors in turn. Solely depending on the fossil fuel based energy, which again very scare throws up a host of problems, including environmental degradation and economic unsustainability. Moreover, it is very difficult to supply power through gridded network in remote areas of Ladakh. Several future renewable energy utilization options are discussed here, which can be exploited in Ladakh and several of discussed technologies here can suitably be adopted by people in rural areas.

References

Murkute, A.A. and Singh, S.B. 2015. Solar thermal greenhouse. *Current Science* 108(1): 12.

Nahar, N.M. 2003. Year round performance and potential of a natural circulation type of solar water heater in India. *Energy and Buildings* 35(3): 239-247.

Pande, P.C., Singh, A.K., Ansari, S., Vyas, S.K. and Dave, B.K. 2003. Design development and testing of a solar PV pump based drip system for orchards. *Renewable Energy* 28(3): 385-396.

Pande, P.C. 2009. Performance of PV winnower cum dryer for processing of agricultural products. In *International Solar Food Processing Conference 2009*. http://www.solarfood.org/solarfood2009/3_Full_papers/Technologies/27_Pande.pdf

Renewable Energy Network for 21st Century, REN21 (http://www.ren21.net/status-of-renewables/global-status-report/)

Santra, P., Pande, P.C. and Singh, A.K. 2014. Solar photovoltaic pumping systems for enhancing energy and water productivity in arid western Rajasthan. In *Proceedings of International conference on Renewable Energy (ICORE)-2014*. pp. 301-306. Solar Energy Society of India, New Delhi.

Shulka, A., 2014. Solar Air Heating in Ladakh: An Economical, Reliable, Easy-to-Maintain Technology Solution to Combat Extreme Winters in Ladakh Region. Alshay Urja, October 2014, 22-25 (http://mnre.gov.in/file-manager/akshay-urja/september-october-2014/EN/22-25.pdf)

Thanvi, K.P. and Pande, P.C. 1987. Development of a low-cost solar agricultural dryer for arid regions of India. *Energy in Agriculture* 6(1): 35-40.

Triquet, M., Tokmat, T., Dorjai, K. and Stauffer, V. 2009. Passive solar greenhouse in Ladakh: A path to income generation and livelihood improvement (http://www.solaripedia.com/files/1087.pdf)

World Energy Council 2015 (https://www.worldenergy.org/publications/2015/world-energy-issues-monitor-2015/)