# Solar PV on top of the world

**In September 2001 the Indian Government approved a programme to electrify an entire region of northern India over five years using solar PV. A proposed 24,000 solar home systems, 12,000 solar lanterns and over 2 MW of solar PV power plants are to be installed in the remote mountain region of Ladakh, located on the Indo–Tibetan border. The summer of 2002 saw the implementation of the first phase of this huge programme, with the installation of 10,000 solar home systems and the distribution of 6000 solar lanterns. JOS VAN DEN AKKER and JIGMET TAKPA report on this challenging, and in many ways unique, programme, which will ensure Ladakh has one of the highest installed PV rates, per capita, in the world.**

Ladakh, the 'land of many passes', is situated between two of the world's mightiest mountain ranges, the Himalayas and the Karakoram, at altitudes between 2500 metres and 7000 metres above sea level. It borders Pakistan, Tibet and the troubled Kashmir Valley, and consists of India's two northernmost districts, Leh and Kargil.

Ladakh is the most sparsely inhabited part of India with a population density of just 1.7/km$^2$. It has a mixed population of Buddhist and Muslim subsistence farmers and nomadic herdsmen, the Buddhists having strong

**MAIN PHOTOGRAPH** **Donkey caravan heavily loaded with SHS pushing up Sengge La Pass – 5000 metres above sea level**

historical ties with Tibet. Farming depends entirely on irrigation from mountain meltwater, which is directed through an intricate network of channels to the terraced fields. In the days of the great trans-Himalayan trade caravans, the capital of Ladakh – Leh – was a nodal point and resting place for traders to recover from the extremely harsh conditions on the mountain trails.

The high mountains all around Ladakh form a natural barrier for the rain-bearing Indian monsoon clouds, and Ladakh receives less than 100 mm of rain per year. It is a high altitude, cold desert, with temperatures dropping to as low as –40°C in winter.

The estimated population of 170,000 Ladakhi live in very remote villages and hamlets, most of them with no road access. Donkeys, ponies and yaks are used to carry heavy loads to the villages, though people themselves often carry goods on their own backs, sometimes for several days of walking. Many villages get completely cut off from the outside world for more than five months each year, due to heavy snowfall on the high passes that give access to them.

1 Ladakh's villages are located in spectacularly isolated locations

## Superb for solar

Ladakh is not connected to India's national grid. The extremely rugged terrain makes it physically impossible to electrify all the remote villages, quite apart from the prohibitive cost. The main towns have a diesel generator set, a mini- or micro-hydro scheme, or both.

Running and maintaining the diesel generator sets is extremely expensive, and they normally supply only 3–4 hours of power in the evenings. Getting the diesel to these remote places is a logistical nightmare, and there are frequent breakdowns; this often means that a village is thrown into darkness, sometimes for long periods, until a technician can come to carry out repairs. The problem with the hydro installations is that, due to the extremely low temperatures in winter, most rivers and streams freeze completely, and the hydro plant has to be shut down.

These same extreme climatic conditions mean Ladakh is ideally suited for solar PV applications. Average daytime ambient temperatures, even in the middle of summer, rarely exceed 27°C, which means solar PV modules are at their most efficient in producing electricity from the sun. In wintertime, the modules have a higher output than their rated STC (Standard Test Conditions) specifications due to ambient temperatures well below zero, which increases the modules' efficiency.

## High installed PV capacity, getting higher

India has implemented some of the largest solar PV programmes in the world, driven by government subsidies, tax and other financial incentives. Significant progress has been made over the past 20 years in the

2 A donkey loaded with battery acid – a hazardous journey

deployment of small solar home systems (SHS) and solar lanterns, as well as streetlights, water pumping systems and stand-alone PV power plants, with an estimated overall installed capacity of 60 MW. Worldwide, this places India in fourth position – behind Japan, the US and Germany – in terms of installed PV capacity (figures from the Ministry of Non-conventional Energy Sources [MNES], 2002).

There are some 80,000 villages in the country that are still to be electrified, and hundreds of thousands of others that get only irregular service on the best of days. Of these 80,000, there are an estimated 18,000 villages in remote and difficult to access areas which cannot be electrified by conventional grid extension. Most of these villages are in hilly areas, forests, deserts and on islands.

On 19 July 2001 the Ministry of Non-conventional Energy Sources (MNES) called a meeting for the complete solar electrification of Ladakh. At that meeting, the Ladakh Renewable Energy Development Agency (LREDA) and the Ladakh Autonomous Hill Development Council (LAHDC) submitted a Rs 3.4 billion (US$70 million) proposal for solar installations in all households, and government and religious institutions (i.e. schools, monasteries and mosques) of Ladakh. On 3 September 2001, the MNES and the Government of India Planning Commission sanctioned this proposal – in record time – and the preparatory work could start. However, work could only begin once the high mountain roads giving access to Ladakh were open again, which would not be until the spring of 2002.



### Working against the clock

On 4 June 2002, the first of a total of over 100 trucks loaded with SHS and solar lanterns left the manufacturing plant of one of India's largest solar PV producers, based in South India. Its final destination was Ladakh, a journey of more than 3000 km across the full length of the country, which would take an estimated two weeks to complete.

However, the truck journey up to Ladakh is in many ways the easy part of the whole exercise of getting the solar systems to the end-users. Once the truck reaches Ladakh, it is immediately directed towards the farthest point accessible by road, as close as possible to the more than 80 villages and hamlets where the SHS are eventually destined to be installed. These offloading points can still be up to a three- or four-day walk away from the actual installation sites. Once off the truck, the PV modules, batteries, battery acid jerrycans and accessories are all loaded onto local transport – donkeys, horses, yaks and people's backs.

The risks involved in this last leg of the journey are substantial, and during the project, three donkeys fell into fast-flowing rivers with their loads and perished. An additional risk is leakage of acid from the jerrycans, which can be damaged during the long journey, posing a risk to both people and animals involved in transportation.

Only two roads connect Ladakh to the outside world. One is via Kashmir valley and Kargil, following the Line of Control (LoC) with Pakistan, while the other, eastern route leads via Manali in Himachal Pradesh. Both routes are open for only about five or six months each year, due to heavy snowfall in winter on the passes, which are over 5000 metres in height. Under 'normal' circumstances, these roads stay open until end of October, but with the onset of global climate change, weather patterns in Ladakh are changing and becoming less predictable.

All systems had to reach Ladakh before these access roads closed; furthermore, all the SHS had to be installed, and all solar lanterns, distributed before the winter cold made this impossible. The official deadline given by the government was 30 September, leaving barely four months to complete the entire programme. A race against the clock had started.

### Fee for service

Most of the estimated 5000 SHS and 2000 solar lanterns that had already been in use in Ladakh before the beginning of 2002 were provided to the end-users free of cost; they had been regarded as a development tool, to provide basic electrical service to people who had no hope of ever getting connected to the national grid. This time, however, it seems some valuable lessons had been learned from past mistakes, and the SHS were not given to the end-users for free. Giving away SHS and solar lanterns free of cost meant that end-users attached no value to them, and the systems were not maintained properly. By charging a nominal fee, it is expected this attitude will change.

Not only do the end-users pay Rs 1000 ($20) as an initial installation charges per SHS, they also have to pay Rs 60/month ($1.25) towards maintenance and battery replacement (battery replacement is expected to be necessary after an estimated five years). Each end-user has to sign an agreement with the local government representatives (Panchayat) to this effect. The monthly fees are collected by the so-called 'village level workers', and kept in a revolving fund. This way the money stays in the community, being administered by the Panchayat. Refusal to pay the monthly fees can lead to removal of the SHS, which is directly enforced by local government officials.

Effectively, the SHS are being *rented* to the end-users, for which they have to pay the monthly fee, much like city dwellers in the capital Leh who have to pay for their monthly electricity bill. This is the well known 'fee for service' concept, which is already successfully used in locations such as Honduras, Morocco, Kiribati and South Africa.

Another way in which this programme differs from the previous ones is that the same companies that installed the SHS have also to maintain them for the first five years after installation. Because of the remoteness of the areas in which the SHS have been deployed,

M Watanabe

3 Lingshed village – a three-day walk from the nearest road
4 Buddhist monk with his new PV module. Access to PV electricity can transform daily lives

maintenance service centres are being set up a block level. Each block-level centre will be staffed by at least one trained technician, and will have a stock of spare parts.

More complicated repairs will be done at district level only. At this level, it will for instance be possible to repair the individual cells of the batteries by replacing the plates. Furthermore, component-level repairs can be performed on the printed circuit boards of the charge controllers and luminaires.

## Pushing the donkey

Meanwhile, the first trucks had reached Ladakh and offloaded at the various drop-off points. Following this, the villagers came to collect the systems to transport them to their final destinations.

Lingshed is one of the fortunate villages selected to receive the first batch of SHS. It can only be reached on foot, taking three days and crossing three passes of nearly 5000 metres in height – a remote location, even by Ladakhi standards. The village has a large gompa (Buddhist monastery) as well as a Buddhist nunnery. On the way back from a field inspection visit, the project managers came across a caravan of donkeys, lead by young chomos (Buddhist nuns), just about to reach the highest point on the route, the Sengge La pass, exactly 5000 metres above sea level. It was an incredible sight to see the donkeys and nuns, both heavily loaded with SHS on their backs, pushing their way slowly to the top of the pass. One young chomo was literally pushing a donkey

up the last few metres to the top of the pass. It was on this same route that a week before one donkey loaded with two solar batteries fell from a small bridge and drowned in the fast-flowing river.

The installer's field offices in Leh and Kargil had not been sitting idle while the SHS were still on the way to their final destinations. They had started to recruit installation technicians from among the local population, and ran a training programme to prepare them for their jobs. Over 50 technicians were trained, so an average of 100 SHS could be installed per day, during the three months of actual installation work in the field. Installing an SHS is not rocket science, but it does require some – especially hands-on – training. Apart from the standard technical training they received, technicians were also instructed in the importance of educating the end-user in proper operation and maintenance of the SHS.

Despite many years of familiarity with solar PV, it is surprising to see how end-users are still in many ways unaware of various aspects of operation and maintenance of SHS. For instance, batteries rarely get topped-up and if they do, people tend to put in a diluted acid solution which is available on the local market, instead of using distilled water. Furthermore, many previously installed modules were found to be (partly) shaded and/or covered in dust, and many charge controllers being bypassed. There is obviously still a lot of work to be done in the field to raise end-user awareness on operation and maintenance for SHS.

Apart from the lack of awareness among the rural Ladakhi population on practical operation and


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maintenance of the systems, there was also a remarkable complacency in the event that the SHS was not, or was only partly, working. Because SHS and solar lanterns were distributed free of charge in the past, with no maintenance follow-up of any kind, people were not expecting anything to be done if a system did not work properly, tending to look at such events in a rather fatalistic way. It had to be pointed out to them that this programme was different, in that they were paying for a *service* provided to them, and had the right to complain and get the system repaired if need be. In this respect, there is still a lot of room for improvement at the level of end-user awareness.

**5** Filling the battery with acid – handle with care!

**6** The SHS installed – a 75 Ah battery and two, 11 W tube-lights

**7** Switching on the solar light for the first time – a world of difference in quality of life

## Freezing batteries

The SHS cost about US$300 each, and consist of a 40 Wp PV module, a 75 Ah deep-cycle battery with oversized electrolyte reservoir, a solid state charge controller, and two 11 W fluorescent lamps. The system is sized to allow both lights to be used for three hours every night in winter, with a two-day ‘no sun’ back-up period.

The SHS had to incorporate some special features to cope with the extremely low winter temperatures prevalent all over Ladakh. Night-time winter temperatures of –30°C are not unusual, and there is a risk of freezing batteries. To reduce the chance of this, the acid used in the batteries was of a relatively high specific gravity (1280 g/litre), and the battery was also placed inside a battery box with polystyrene sheets all around it to give it some thermal insulation. Furthermore, as wires tend to be affected by the low temperatures and over time turn brittle and break, a special polyethylene-sheathed cable was used that can withstand the low temperatures.

## Lessons learned?

So far the programme has been well received, and the 10,000 SHS were installed in record time, before the winter snows closed the roads to Ladakh again. Most Ladakhis are quite familiar with solar PV, and its benefits are much appreciated. Its reliability, independence from the grid and safety are all well known. People call it ‘rangwang ot’, or ‘any-time light’. At the flick of a switch the light comes on; there is no more fiddling with cumbersome kerosene and wick lamps, producing smoke which is bad for health and can cause fires.

The biggest challenge for this project is yet to come, however. In line with their contract with LREDA, the same companies that installed the SHS will be responsible for providing maintenance for the first five years following installation. Maintaining these systems over the five

years – and beyond – is going to be a major challenge in the remote and inaccessible regions of Ladakh. Only if this difficult task can be accomplished can the programme be called successful and sustainable – unlike those previous programmes which have left unserviceable SHS and solar lanterns in many Ladakhi villages.

Time will tell whether the lessons we are now finally learning from our past mistakes, and have incorporated in programmes such as this one in Ladakh, are actually going to work over a long-term period, and will lead to a sustainable use of solar PV in remote areas.

*Jos van den Akker works for Auroville Renewable Energy (AuroRE), based in Auroville, Tamil Nadu, and was a programme manager during the execution of this project.*
*Fax: +91 413 262 2057*
*e-mail: jos@auroville.org.in*
*website: aurore@auroville.org/index/aurore.html*

*Jigmet Takpa is Project Director of the Ladakh Renewable Energy Development Agency (LREDA), based in Leh, Ladakh.*
*Fax: +91 1982 52249*
*e-mail: jigmett@yahoo.com*