HERE COMES THE SUN

India has had mixed results with its solar programme. The government is now gearing up to launch several mega schemes to harness this abundant source. The solar mission aims to do exactly that. Industry has also shown interest in tapping this energy source of the future. Technology and financing, though, remain question marks.

How can India realize its solar dream?

Picture thousands of solar reflectors, spread over parts of the Great Indian Thar Desert, glistening under the sun, quietly and efficiently generating emission-free, green electricity, at competitive costs. Solar thermal power plants, also called concentrating solar power (CSP) generating systems, can make this a reality. The potential is unlimited. Covering just one per cent of the world's deserts with CSP systems would generate more energy than the current global energy demands. For India the potential stands at six million terawatt hours (tWh) per year. In 2006-07 India generated 662.5 tWh.

A square piece of land, 55 kilometres each side, in the empty desert, is enough to meet India's current energy demand.

With more than 300 sunny days each year, large parts of Rajasthan and Gujarat can produce 6-6.4 kilowatts per square metre. Sparsely populated, these areas are ideal for renewable energy. This potential is yet to be realized.

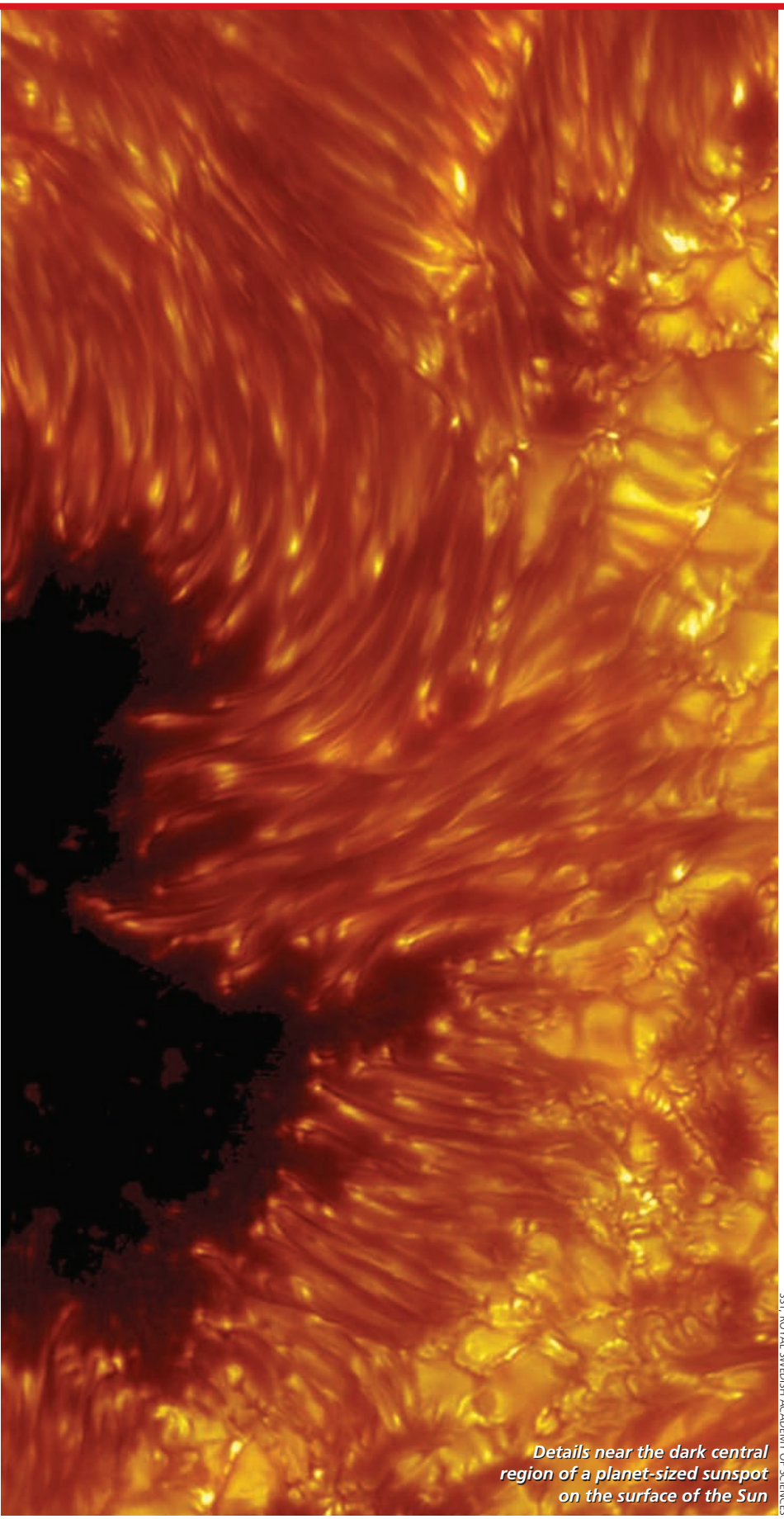
No commercial CSP system operates in the country. To induce projects, the Union Ministry of New and Renewable Energy (MNRE) announced in January 2008 a generation-based incentive scheme for solar thermal and solar photovoltaic (PV) ventures. The incentive for generating one unit of electricity from solar thermal is fixed at Rs 10. By June 2008, the government had received applications to set up 500 megawatts (MW) of solar thermal plants. "Companies are coming up with offers of huge capacity of 50 MW and more, but we cannot sanction them without verifying if they would be able to deliver," said an MNRE official.

The scheme has a number of limitations. The total installed capacity under the scheme (combined for solar thermal and solar PV) is limited to 50 MW for the duration of the 11th five-year plan (2007-2012). Each project developer is limited to a maximum of 5 MW and each state is limited to a maximum of 10 MW. "The cap of 50 MW is because of unstable grids and solar systems deficient in producing peaking power, which is generally needed during the evening hours," said B Bhargava, senior director (photovoltaics) MNRE.

This may change. Industry sources revealed the government was considering increasing the overall cap to 1,000 MW. Till now, only one 2-MW plant has been sanctioned under the scheme in West Bengal; construction is yet to start.

Mirror mirror on the wall...

In a solar thermal power plant, mirrors are made to concentrate sunlight trapped in a pipeline to heat oil, molten salts or other chemicals which can trap heat for a longer duration of time. This heat is used to generate steam in a boiler that runs a turbine to produce electricity. CSP technologies vary in how they concentrate sunlight. For example, in parabolic trough systems, parabolic trough-shaped mirror reflectors concentrate sunlight on thermally efficient receiver tubes placed in the trough's



Details near the dark central region of a planet-sized sunspot on the surface of the Sun

SST, ROYAL SWEDISH ACADEMY OF SCIENCES

focal line. A heat transfer fluid is circulated through the receiver tubes and heated to temperatures up to 400°C. The fluid passes its heat to other working fluid, typically water or steam, through a series of heat exchangers, which is further used to drive a conventional turbine generator. Other systems include the power tower system and the parabolic dish system.

CSP has higher operating efficiency and lower cost compared to PV. While even the most efficient solar PV can generate about 20 MW per sq km (km^2), for solar thermal generation it is about 35 MW/km^2. CSP also has major advantages in energy storage, a critical component of technologies harnessing intermittent energy sources like wind and solar. The storage allows for higher plant capacity factors, compensation for vagaries in solar radiation, increased ability of the plant to provide firm capacity and consequently greater carbon dioxide (CO_2) emissions reductions.

These assume greater importance in India, given its weak inadequate grid and generation capacity, translating to limited grid back-up capability. CSP systems can be easily integrated into conventional power plants as they utilize the same generator as most other fossil fuel based thermal power plants.

The exact cost of CSP systems is currently a grey area, primarily because of a lack of standardization as the technology is still developing. Apart from technology, the plants vary greatly in specifications like storage capacity, efficiency of solar field, and generation capacity of the plant. However, qualified cost forecasts put down the capital costs of a parabolic trough plant—with 12 hours of storage capacity, no fossil fuel back-up and a nearly 55 per cent capacity factor—at US $4,816 per kW (total plant capacity of 100 MW) in 2004, and US $3,220 per kW (total plant capacity 400 MW) in 2020. The respective costs of electricity are US 10.37 cents and US 6.21 cents per unit. These costs are far lower than even the most efficient solar PV systems on per watt basis. CSP plants present the possibility of a high local content during construction and operation and maintenance, unlike solar PV where silicon—the major cost component—has to be imported. Additionally, carbon credits can serve as an income stream to reduce the cost.

Initially, projects in solar thermal failed to take off. New incentives have resulted in renewed interest

Over the past two years, rising oil prices have brought CSP systems into sharp relief. Countries such as the US and Spain have taken the lead; Australia, Israel, Morocco and even the oil-rich countries of Iran and Algeria have shown progress. In Spain, construction of the world's biggest solar thermal power stations—Andasol 1 and 2—are almost complete.

By early 2008, as much as 4,000 MW of solar thermal was in the pipeline in Spain and five more plants are underway. The German company Solar Millennium AG and the Spanish plant builder Cobra is building Andasol. They are working on liquid salt, which can be heated to 500°C—oil can be heated to only 400°C. The plants would use liquid salt to store heat during the day to generate electricity at night.

India stumbles

Though India was one of the first industrializing countries to show interest in CSP technology, it failed to keep up the momentum. As early as 1988, a 50-kW parabolic trough technology pilot project provided by the German company MAN Technolgie GmbH and Co, was established at the government-run Solar Energy Centre campus in Gwalpahri near Delhi. Within two years the glass casing that maintains the vacuum around the pipelines that trap the heat started cracking due to excess heat rendering the plant inefficient. "Being imported, damaged parts could not be replaced," said Prakash, caretaker of the facility.

In 1994 a feasibility report was prepared for a fossil fuel-solar hybrid project in Mathania, near Jodhpur in Rajasthan. India was the first of the four countries to be given the Global Environment Facility (GEF) grant for this project of US $49 million.

Despite arranging for complete finance for the project, it was abandoned due to rising prices of naphtha (the primary fuel), limited guarantees by private contractors for working and spare parts, and lack of commitment to lay down a gas pipeline to substitute naphtha with natural gas as primary fuel.

In 1995, a Solar Energy Enterprise Zone (SEEZ) was also envisioned in Rajasthan and three power purchase agreements were signed with AESDP, Sun Source Ltd and Energen International Ltd for a total solar generation capacity of 300 MW. None of projects of the SEEZ ever took off, owing to lack of finances.

The MNRE scheme has led to renewed interest in CSP. The Rajasthan Electricity Regulatory Commission had invited expressions of interest (EOI) for solar PV and thermal power plants in February 2008. EOI to setup 900 MW has been received so far.

"Companies such as India Bulls and Essar have responded with an EOI. Applicants were required to pay Rs 25,000 per MW for registration," said A K Patni, in charge of the solar cell at the Rajasthan Renewable Energy Corporation Ltd.

MNRE recently proposed another scheme for installing 20,000 MW of electricity from solar thermal and PV by 2020. But the incentive pattern it proposed is so high that the cost to the exchequer would be about Rs 20,000 crore per year in subsidy alone.

Many in the government believe it is not viable at this stage and that the ministry will find it impossible to fund such a scheme.

AGNIMIRH BASU / CSE

Shine a light

Solar lanterns were promoted specially for use in rural un-electrified villages. Costing Rs 2,000- 5,000 for a 7-11 watt power lamp, it requires little maintenance.

A solar lantern is made of three main components: the solar PV panel, the storage battery, and the lamp itself. The solar energy is converted to electrical energy by the solar PV panel and stored in a sealed battery for later use after sundown.

A single charge can operate the lamp for about four-five hours. But it varies upon the kind of material used—it can go up to five-six hours. The wide difference in the cost of these lamps is due to the material used.

A battery costs Rs 400-500 while a lamp costs Rs 700-800; the rest is the cost of the PV panel. "The cost of the lamp can go up with the use of light-emitting diode (LED) bulb instead of compact fluorescent lamp (CFL) but the cost of the PV panel will accordingly come down because LED requires smaller panels.

The difference in the material used (crystalline or amorphous) in the panels also contributes to the cost difference," said G Giridhar of Solar Energy Centre.

The Union Ministry of New and Renewable Energy has reportedly proposed a scheme to distribute lanterns with a subsidy of Rs 3,000 on each. But energy experts differ. They say it would be better to provide low-interest loans to lantern manufacturers instead.

They estimate the costs of the lantern can be recovered without using a subsidy mechanism. In the past subsidies for such technology dissemination have often failed.

CURRENT TRENDS

ARVIND YADAV / CSE

Solar photovoltaics is the fastest growing area in the energy sector. Of the US $71 billion invested in renewables worldwide in 2007, 30 per cent was in solar PV. According to market analysts, between 2007 and 2011, this industry is poised to grow at a whopping 73 per cent. By March 2007, India had 120 MW of installed PV capacity. However, less than 2.5 MW is generated by grid-connected solar power plants. The rest is generated through stand-alone systems like solar street lighting (about 70,474), home lighting (4,02,938) and solar lanterns (6,70,059).

The government has several schemes supporting and subsidizing various kinds of solar power systems. The emphasis is on encouraging manufacturing and industry rather than on installations as solar PV manufacturing is capital intensive. Through the special incentive package scheme, the government offers capital subsidies to state-of-the-art semiconductor manufacturing and related units, including solar PV. Eligible semiconductor "fab" projects must have a net present value of at least Rs 2,500 crore. The subsidy available is 25 per cent of the capital expenditure; it is 20 per cent for projects in a special economic zone. The response was good. "Most of the manufacturers who have applied under the scheme want to invest in photovoltaic technology. Proposals roughly worth Rs 1,40,000 crore from 14 manufacturers are lying with the ministry of which 12 are photovoltaic manufacturers" said K S Chari, director in the Union Ministry of Communications and Information Technology, the nodal ministry. Most of the proposals have been forwarded to a technical evaluation committee and decision is expected "shortly".

The recently announced feed-in-tariff incentive scheme of MNRE has also sparked considerable interest. The scheme is aimed at encouraging a small number of megawatt-level projects. Under the scheme, the project developer makes a power purchase agreement (PPA) with the state utility at the highest existing market rate. The MNRE, through the Indian Renewable Energy Development Agency (IREDA), augments this rate, to a maximum of Rs 15 per kWh. The maximum supplement incentive from MNRE is restricted to Rs 12 per kWh. This will be reduced by 5 per cent for projects commissioned from the beginning of 2010 onwards. The supplement is available for up to 10 years. Till June the ministry received applications to set up PV plants totalling 2000 MW. The proposals are currently being scrutinized.

Globally, solar PV projects are being installed in large numbers each year. In 2007, more than 2,260 MW of PV capacity was installed, an increase of more than 50 per cent over the previous year. This brought the total installed capacity to 7,800 MW. About three-fourths of the total solar PV capacity was installed in Germany and Spain alone. If Japan and the US are also included, then over 90 per cent of PV installations in 2007 occurred in four countries.

Germany: Powering ahead

Germany currently accounts for about half of the world's installed solar power capacity—3,862 MW. This growth happened due to its market support measures promoting grid-connected rooftop systems and large PV power plants. Germany's innovative feed-in tariff (FIT) scheme has been the main driver for the solar market. The German FIT scheme, governed by the country's

Table 1

Solar PV installation in 2007

Country	Solar PV installation in 2007 (in MW)
Germany	1,135
Spain	512
Japan	210.4
US	206.5
Others	236
Total	2,260

Source: Trends in photovoltaic applications: Survey report of selected IEA countries between 1992 and 2007, International Energy Agency

Table 2

2008 Feed-In Tariff rates in Germany (€/kWh)

Building-mounted systems			Free-standing systems
<30 kW	30–100 kW	>100 kW	All sizes
0.4675	0.4447	0.4398	0.3549

Note: Rates are given for 20 years

Renewable Energy Sources Act (EEG) guarantees generous fixed rates for all solar PV electricity generated for 20 years from completion of the project. An important feature is that the rate guaranteed for new projects decreases every year—currently by 5 per cent but this is set to increase in 2009.

The decrease in tariff is part of the policy package as it works to push manufacturers to reduce costs and to increase efficiency of their systems. This tariff reduction encourages industry to develop cheaper, more efficient systems and to lower installation costs. The precise rates given depend on the system size and location.

In 2008 they stand as shown in Table 2 (see facing page).

The FIT scheme is backed by favourable loans from KfW, a government-owned financial institution. Loans are provided in collaboration with individual banks; interest rates are dependent on credit ratings and the value of collateral, starting at 4.63 per cent. The programme as a whole has created a very large consumer base for solar PV in Germany. This, along with special financial incentives packages for manufacturing in certain regions and funding for research, has helped to create a flourishing PV production industry in Germany.

Critics of the German scheme say it is too generous—the cost to energy consumers is too high and the use of such an expensive technology in a country with relatively low sunlight hours is inefficient. However, on the whole, it is estimated that the FIT programme is responsible for an increase of €1.01 in monthly household electricity bills.

Photovoltaics need aggressive support. Feed-in-tariffs guarantee investors long-term security

Leading the charge: California

California was the first state to introduce feed-in remuneration. Its tightly restricted feed-in programme will supply the development of up to 480 MW of total generating capacity (roughly equivalent to a small coal based power station). In all cases, feed-in contracts for 10-20 years can be entered only for installations up to 1.5 MW capacity and the range from US 8-31 cents per kWh, depending on the time the power is delivered—peak consumption time, winter or summer. As a result of this policy directive, the two big power utilities of the state—Southern California Edison and Pacific Gas and Electric Company have signed power purchase agreements—for 245 MW with eSolar and 500 MW with Bright Source,

Water heaters

Despite several schemes, both centrally and state sponsored, to promote solar water heaters sales have been low. A major reason has been a lack of trust on the quality of device supplied by the government appointed manufacturers. Under a central subsidy scheme of the MNRE a soft loan is made available at the rate of two per cent for domestic users, three per cent for institutional users and five per cent for commercial users who also avail of accelerated depreciation under the income tax rules. However, in few states including Himachal Pradesh, north-eastern states and Jammu and Kashmir an interest-free loan is given to domestic users. The scheme is implemented by Indian Renewable Energy Development Agency Limited (IREDA) through a select few nationalized banks. A person availing of this scheme needs to collect an invoice for the kind of solar water heater he is buying from one of the MNRE authorized dealers. He then has to approach a bank, which in turn issues a cheque in the dealer's name after verifying facts. The borrowers will be eligible for loan up to 85 per cent of the cost of systems repayable over a period of 5 years. The difference between the lending rate of the banks or financial institutions and the rate of interest given to the customer (2-5 per cent) is borne by MNRE. Under the scheme about 2.5 million square metres of collector area has been installed in the country till date.

Several states offer their own schemes to promote roof-top solar heaters. Delhi offers a rebate of Rs 6,000 to every customer who buys a solar water heater for domestic use. "So, if the cost of a heater with a capacity of 100 litres per day is Rs 16,500 along with 4 per cent VAT, he just has to pay us Rs 11,160," said Anuj Mittal of Natural Energy Systems, an approved dealer. This rebate can extend up to a maximum of Rs 60,000 for heaters with a capacity of 1000 litres for non-commercial/institutional users. The rebate is given by dealers who then claim the difference (Rs 6-60,000) from Delhi Transco Limited, which handles the scheme for the state government. "The scheme was launched in December 2006. Till date, 318 domestic users and 28 institutional users have availed of it," said Rishi Raj, public relations officer of Delhi Transco. To boost the usage, in September 2006, the Delhi government came out with a notification to make solar water heaters mandatory in certain buildings including government departments, institutions and agencies and all hospitals. All Delhi government departments, municipal bodies, Tihar and other jails of Delhi police were supposed to amend their byelaws, within a period of six months, to make the use of heaters mandatory. They also had to designate a nodal officer to monitor the progress and send a report of the same to Transco on a quarterly basis, which was assigned the responsibility of implementation. Till date no monitoring report has been sent to Transco. Since there is no clause for penalty for not following the order in the notification all departments go scot-free in case of non-compliance.

According to the calculations done by the Centre for Science and Environment, Delhi can save Rs 272 crores and reduce CO_2 emission by 7.7 lakh tonnes in winter, if 50 per cent households in Delhi install solar water heating system of capacity 100 litres per day/ 60°C. And if they operate for 320 days in a year, the annual saving would be around Rs 821 crores and the CO_2 reduction would be around 23 lakh tonnes.

Challenges of PV

The main component that converts photons into electricity in a solar PV is the layer of silicon semiconductors. In 2007, the solar PV industry along with the semiconductor industry consumed some 38,000 tonnes of poly-silicon. This grew to 58,000 tonnes in 2007. Increasing demand has led to price jump of more than 100 per cent from US $20 per kg in 2001 to US $50 in 2006.

The future of PV industry depends on two factors: bringing down the cost of the panels and increasing their efficiency. Currently, the panels use about 10 gms of poly-crystalline silicon to produce 1 W/p (watt/peak) of energy, which is down from 13 gms a few years ago. The efficiency of solar panels has grown from 10 per cent in the 1990s to more than 13 per cent at present. The monocrystalline cells have recorded efficiencies of almost 25 per cent under lab conditions, while polycrystalline cells have surpassed 18 per cent. Researchers are now trying to target PV cells that can function at 30 to 60 per cent efficiency. One such technology is the concentrated photovoltaic cells. There are also other technologies which are beyond conventional junction semiconductors and use photoelectrochemicals, polymers and dyes.

respectively. In 2007 around 70 per cent of all PV installations in the US were in California, which aims to install 3,000 MW in the next 10 years.

The California Solar Initiative provides two kinds of financial incentive depending on the system size. Systems under 50 kW are eligible for the expected performance based buy-down, a one time, up-front payment. The size of the payment is calculated from the estimated output of the system, based on rated capacity, but also an assessment of the quality of the installation, including geographical factors such as location, tilt and shading. Systems over 50 kW can receive the feed-in-tariff. For both payment methods, the rates applicable are linked to the cumulative capacity installed under the scheme, reducing in 10 steps as capacity increases.

India's solar future

Harnessing power from the sun is one of the biggest answers to challenges of energy security and climate change. Both solar thermal and photovoltaic will play a key role in addressing energy needs of the future. It is clear that the biggest challenge is to bring down the costs of solar PV—by cutting costs or by increasing efficiency.

The government has shown commitment but implementation and the nature of schemes have been found wanting. Take for instance, the heaters promotion scheme. "The problem with such schemes is that it comes through dealers designated by the government so it is difficult to trust the quality mostly," said Mathew Kochu SJ, director of Xavier's Institute of Technology in Mehsana district of Gujarat, who have installed solar heaters and lights in their entire institute. A national level certification and labelling programme is a must to ensure quality and performance.

Once this is done laws and regulations like changes in building bylaws making it compulsory to install both solar thermal and PV features are the kind of reforms the sector needs. "Like Europe and the US, we should make at least two to three per cent contribution from solar generation mandatory. Then, policy-making on the same will become faster," said an IREDA official.

Finances and the limited technical know-how remain the key barriers for the solar projects in India. Innovations are needed to make solar projects financially and technologically feasible. A hybrid system or a system with high fossil fuel back-up, along with increased government technical and financial support and incentives, facilitation of technology transfer, will increase the market interest in CSP technology.

The Indian government has announced a generation-based incentive scheme. It is even considering ramping up solar generation to 20,000 MW. But finances will remain a big issue. The feed-in (or preferential) tariff provides an incentive to set up the plant, but it also puts a huge burden on the exchequer. This is why governments only extend the high tariff incentives in a restricted capacity. India's solar programme must therefore be able to source new funds—through a programmatic CDM—instead of each project applying separately for CDM. The government can collect all the carbon credits from solar projects and sell it collectively in addition to securing international finances to pay for national mitigation actions.

The money generated from selling carbon credits can then be used to fund feed-in-tariff schemes and reduce the subsidy. Reducing or even eliminating import duties, will reduce indirect costs and ease technology transfer from countries such as Germany, the US and Israel—the world leaders in technology. Its strong engineering and manufacturing foundation will surely allow India to become a leader in solar technologies in the future. After all, a massively scaled up solar programme is good for India. It is good for the world. ■

With inputs from Ravleen Kaur and Arnab Pratim Dutta

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India must source funds for solar projects through programmatic CDMs, not project-based CDMs