This section presents an integrated design process which takes into consideration the climate, the social and environmental context, and the functional requirements of a school that help to create a comfortable and sustainable environment. The thermal and visual performance of the design have been optimized by incorporating various principles of solar passive architecture that are supported by the use of various tools such as the bio-climatic chart, climate consultant, radiance, and eQUEST. Since the school is located in a remote area with scarce resources, other aspects, such as water and waste management, on-site power generation, promotion of pollution free environment, and low-cost construction technologies have also been incorporated in the design. The attempt is to provide a centre for learning that is appropriate to the local context and provides a stimulating environment for the students at large.

Brief climatic characteristics

The Education Park is located at Bhikangaon (latitude: 21.49°N, longitude: 75.37°E). The climate in Khandwa–Khargone district is composite in nature which shows three distinct climatic conditions throughout the year. During summer, temperature goes up to 47°C, while in winter, temperature can go below 15°C, and humidity in the region can go up to 70%. Therefore, the school is designed for a composite climate. Resisting heat gain, particularly during summer, is the major design consideration. During monsoon, ventilation helps to alleviate discomfort.

The courtyard concept

The basic design strategy is inspired by the concept of a courtyard, which will act as an environment modulator for the spaces around it. The external skin is treated as a thermal mass with operable windows for cross ventilation

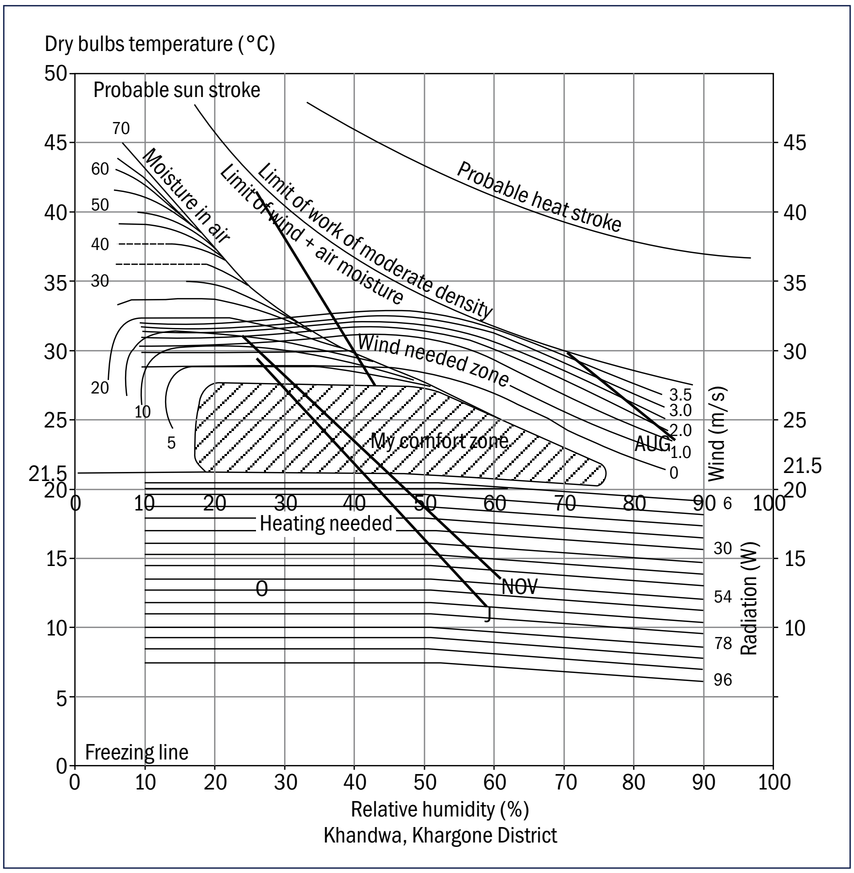

Figure 3 Bio-climatic chart shows that the main criteria for design is controlling heat gain in summer

Figure 4 Demonstration of filler slab and unplastered walls in the constructed building

and clerestory windows for daylight. For better thermal performance many features are incorporated; these include, doubly loaded green corridor with a north-south orientation, internal courtyards to provide comfort, and semi-open interaction spaces. Windows are appropriately shaded on both sides, north and south, with 0.6 m deep *chajjas* (cover of a roof) on the north and 0.75 m deep *chajjas* on the south. It may be mentioned here that deep *chajjas* have been provided on the north mainly to seek protection from rain, even though they are not required for shading.

The campus design is made sustainable through various design considerations such as provision of walkway to encourage the pedestrian movement, no disturbance to existing site features such as *nullah*, wells, and contours. Almost 1,300 trees have been planted onsite to rejuvenate the environment and to pre-cool the air entering the building premises. Low cost technologies such as filler slab, unplastered walls, RCC door frames, composite RCC, and load bearing structure have also been incorporated in the design and construction of this building.

Simulating the daylighting feature

A number of studies with the help of radiance software have been carried out to optimize the daylight. The daylighting performance (for the daylighting strategy-side lighting) has been studied for typical north and south side classroom. The simulation study is carried out to investigate the performance of two different functions of windows—(a) daylight and (b) vision window. It is found that the side lighting with daylight windows on both sides and vision window on one side provides adequate sunlight in the classrooms. To optimize the daylighting levels in classroom on the southern side, a light shelf is recommended on the south part. In general, high surface reflectance of walls, light shelves and ceilings, and higher visible transmittance of glass improves the performance of daylighting. The reflectance values considered for walls and ceiling is 0.7 and for desks and floor is 0.4. The visible light transmittance (VLT) for the vision window is 0.6 and for the daylight window above the light-shelf it is VLT 0.86.

Figure 6 Triangular shaped window for improved ventilation and light-shelf to illuminate classrooms with diffused light

The building geometry

The geometric form of the building has been developed in response to solar geometry. Walls of the building are aligned in east–west direction (to minimize the heat gain from the sides; heat gain from the top is reduced with the help of filler slab), while in order to make better ventilation; windows are aligned (made perpendicular) to the natural wind direction during summer, which is the north–west part. This requires triangular-shaped window, as shown in Figure 6. Various green building methods, for example, using renewable energy sources, water and waste management, energy efficient fixtures and equipment are proposed to make the campus self sustainable and ultimately a zero energy campus.

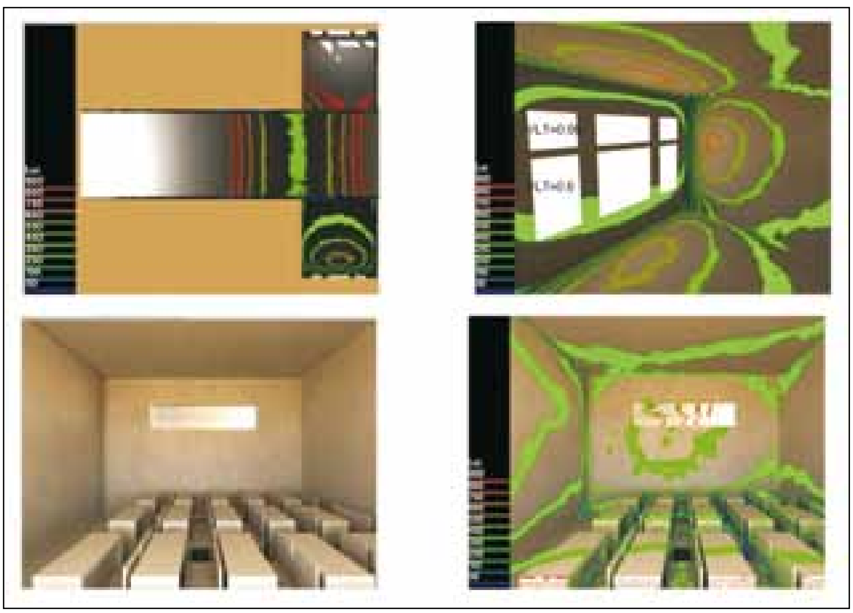

Figure 5 Typical north (top) and south (bottom) side classroom illumination levels in December. Adequate daylight is made available by optimizing window design

Post construction evaluation

The performance of the school building in terms of comfort has been assessed by taking onsite measurements of daylighting, temperature, and humidity. A post occupancy evaluation of the comfort level has been also carried out. There is a high level satisfaction among the students. In fact, daylight is found to be sufficient and no tubelights are required during the school hours. No fans have been installed in the classrooms, in the past one year, as adequate cross ventilation is available. It is expected that once the trees grow and evaporative cooling is introduced, the environment within the classrooms will become even better.

Sizing a solar PV system

The energy needs of the Education Park is minimized by using solar passive architecture elements, while the remaining energy requirements of electronic loads (computer, printer, and so on) and lights and fans (unplanned space) is fulfilled by a solar PV system. The daily electricity requirement of the load is summarized in Table 2.

In order to supply electrical load at the Education Park, a standalone PV system has been designed. The sizing of the components used in the PV system is given in Table 3. In order to supply 5.1 kWh of daily energy consumption,

Table 2 Electrical load and its usage supply by solar PV system

Name of load	Power per unit (watts)	Number of units (#)	Total power (W)	Number of hours of operation (hrs)	Total energy (Wh/day)
Laptop	80	3	240	6	1440
Desktop	300	1	300	4	1200
Printer	900	1	900	1	900
Projector	600	1	600	0.5	300
Fan	50	3	150	6	900
CFL	18	3	54	8	432
Total energy required					5172

Figure 7 The Education Park building in use

PV array of 1.5 kWp capacity is being used. In this way 3.44 kWh of energy is generated daily, per installed kWp of solar PV modules. The overall PV system efficiency is about 65%.

The educational path ahead

Successful demonstration of the concepts as enshrined within the Education Park is expected to have a multiplying replication effect in the country. The need of the hour is to involve the budding youngsters and teachers alike in this task of monitoring the energy parameters on more or less a regular basis. Facilities like these may ultimately come to be recognized as classical examples of capacity building initiatives, more so in the realm of ongoing Jawaharlal Nehru National Solar Mission (JNNSM). After all, energy efficiency measures go hand-in-hand with actual deployment of renewable energy technologies like solar. ■

Table 3 PV system component capacities

PV system component	Capacity
Solar PV array	1500 Wp
12 V low maintenance tubular plate lead-acid battery	680 Ah
Inverter (230 V, AC)	1400 VA
Energy delivered to the load	5200 Wh/day

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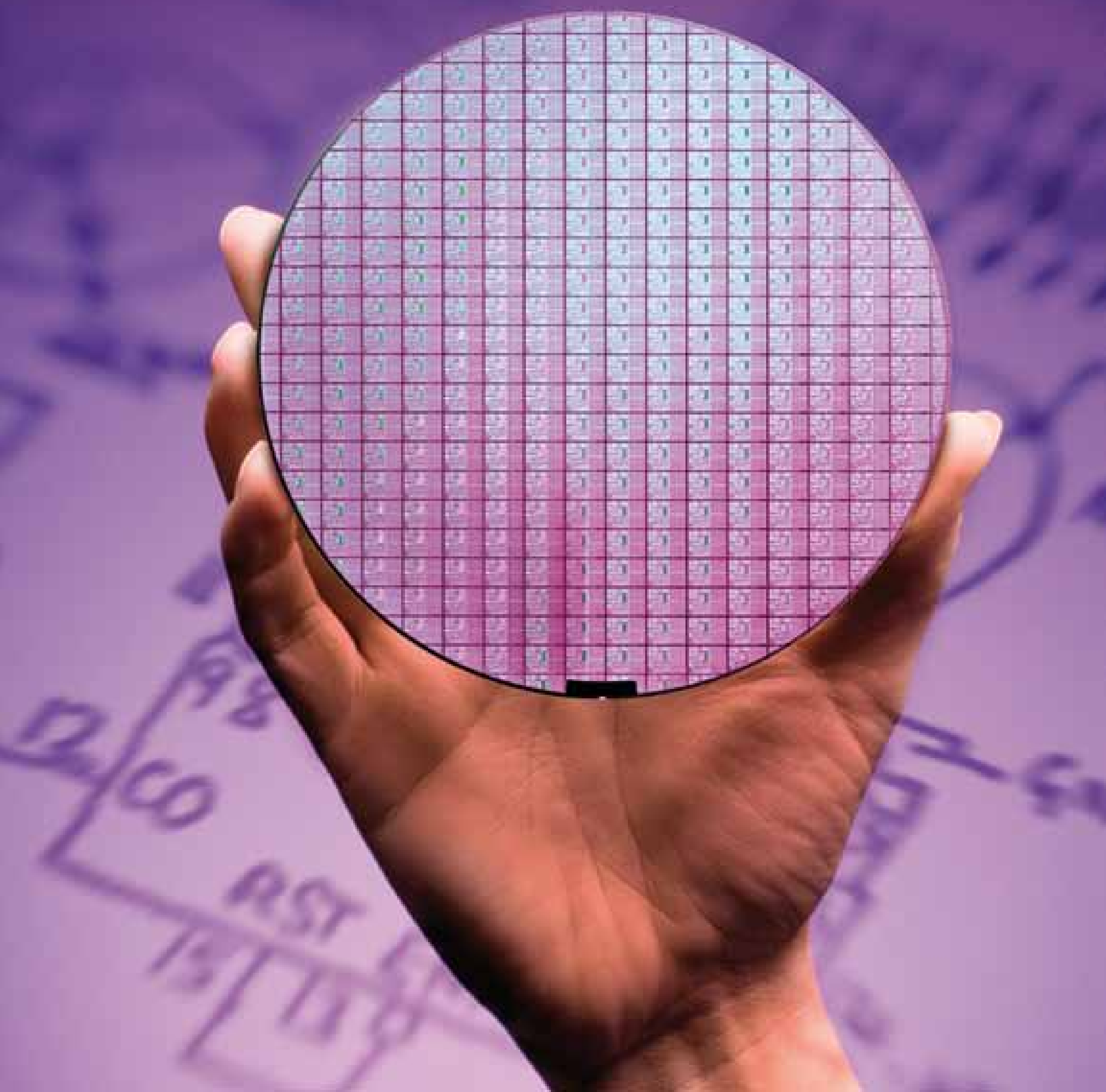
Building of **Positive Achievements** for Global PV Market in 2011

A Mid-year Review

Suneel Deambi, Consultant, TERI <sdeambi@airtelmail.in>



The noticeable gains

The price line of solar PV modules is receding now. Subsequent to which, the profitability margins for the solar industry are also dropping. Nonetheless, the international PV market has gained ground in the first half of this year, i.e., 2011. As per market analysts, the rate of installations is expected to go up by around 20% for the full year. The global installations of PV systems on the residential and building rooftops including the large power plants may move up from an installed capacity of 17.66 GW in 2010 to around 21.2 GW in 2011. Likewise, the global PV industry revenue may register a modest increase of around 4% from $77.8 billion in 2010 to $80.7 billion in 2011. There are opinions galore as to what constitutes the real success of an annual PV market. However, by and large it is the growth in PV system installations that showcases the state of PV market. There are variety of reasons for the sharp drop in PV prices. In the supply chain, the price of solar wafers tumbled followed by a reduction in module prices as well during the first half of 2011. The global average pricing for solar wafers came down by a noticeable 17% in the second quarter as compared to the first quarter. During the same period, pricing for crystalline silicon modules declined by about 14%, while the price of solar cells also dropped by 6%. These reductions resulted in a collective reduction of installed PV system cost by about 4%.

Development of silicon material: pushing down the cost

The seemingly attractive profit margins till some time back were the mainstay of those involved in the silicon supply chain. Take for example the silicon wafers, which were off and on caught in the web of deficient supplies. There was also a huge cost difference witnessed between the contracted prices and on the spot prices of silicon material. The scenario has changed for the better now with major manufacturing capacity additions having been set up of late. It has resulted into a downward price pressure for wafers during the first half. Thus modules have become cheaper now facilitated in part by the accommodative attitude of the companies to diminish the gross margin. If viewed in totality, the selling price of PV is now steadily but surely inching towards the production cost levels. This market perspective is for the crystalline silicon cell technology, which commands around 80% of the concerned market today. Its immediate fallout was witnessed on the pricing of thin film modules too. It is a fact though that the lowest cost reduction was registered in the PV installation units. The cost as regards the balance of system (BOS) components, like for example inverters, etc., has not shown any visible price lowering as of now.

The highs and lows in PV country markets

Now let us deal with the country specific scenarios in terms of leads and lags. Currently Germany and Italy are edging past rest of the countries. Between them they are estimated to hold more than 50% share of the PV installations for 2011. As per the available estimates made by market research companies, like isuppli, Germany, is expected to realize an installation capacity of around 6.9 GW as against 7.4 GW recorded in 2010. Take the case of Italy, which has projected to increase its contribution to PV installations from 3.6 GW to more than 5 GW in 2011. It is pertinent to mention here that a new incentive structure put in place in Italy has led to this accelerated market growth. Perhaps this brightened up scenario may not last during 2012 keeping in view the likely emergence of new feed-in-tariffs, etc. Apart from Germany and Italy, the USA-based PV installations seem to record more than double capacity addition. It is expected to go up from 0.9 GW to around 2.4 GW during the year 2011. Special contribution to this capacity is coming in from an increased deployment of large scale PV power plants.

The corresponding capacity increase in 2012 is estimated at about 30% from the 2011 figures. The installed cost of solar PV systems in the US fell substantially in 2010 and into the first half of 2011 according to the latest edition of a PV cost tracking report released by Lawrence Berkeley National Laboratory (LBNL). The average installed cost of commercial and residential PV systems commissioned in 2010 fell by around 17% from the year before and by an additional 11% within the first six months of 2011. The grim outlook in Japan from the nuclear power installations may ultimately catalyse the fast growth of alternatives like solar

Mono silicon ingots

power. In 2011, the installation capacity may perhaps cross the 1 GW mark and shoot off to appreciable levels by 2015. It is not out of place to mention here that PV scenario may be easier to evaluate once the energy policies are clearly enunciated by the Japanese government.

The latest entrant to FIT regime

At this stage, it may be worth recalling that Germany was the first PV country to implement the feed-in-tariff (FIT) regime several years back. In sharp contrast, the National Development and Reform Committee of China has implemented the first nation-wide FIT norm for PV. It basically calls for projects approved by the NRDC before July 1, 2011, and completed by December 31, 2011, to receive 1.15 Renminbi (1 Renminbi= 7.41 Indian rupees) per kilowatt hour. That is not all, as newly approved projects and those not meeting the December 31 deadline will be granted a FIT of 1 Renminbi per kilowatt hour. There are, however, a number of issues awaiting a suitable explanation in this newly announced FIT like for example the applicable period and grid evacuation mechanism. Nonetheless, market experts sound optimistic on capacity of additional installations touching 1.5 GW in the two year period between 2011–2012.

Comparative PV rankings

Table 1 gives comparative rankings of top 10 PV countries in the world for the year(s) 2010 and 2011. It also indicates the relative gain or loss in these rankings for the said period.

Quite clearly Germany and Italy are expected to retain their no. 1 and no. 2 market leadership positions for the year 2011 too. The US will have a gainful markup from its position in 2010. Incidentally, India which has an ambitious mission driven ongoing solar programme is, however, yet to make its presence felt in this top grouping. Though India may finally emerge as the world's biggest PV market, the positive indicators to such a positive outlook is in terms of strong and largely dispersed sunshine, expanding manufacturing base, reducing prices of solar modules and importantly, the low BOS cost (engineering and labour).

Table 1 Comparative rankings of top 10 PV countries

Country	2010 Ranking	2011 Ranking	Change in Ranking
Germany	1	1	—
Italy	2	2	—
Czech Republic	3	—	—
USA	4	3	+1
France	5	6	–1
Japan	6	5	+1
Spain	7	9	–2
Belgium	8	—	—
China	9	4	+5
Australia	10	7	+3

Table 2 presents the PV market position(s) for countries with front-running PV programmes across the world by 2014. India may come to occupy the fifth slot with an estimated market size of 3000 MW, which is less than half of what Germany could have in terms of MWP.

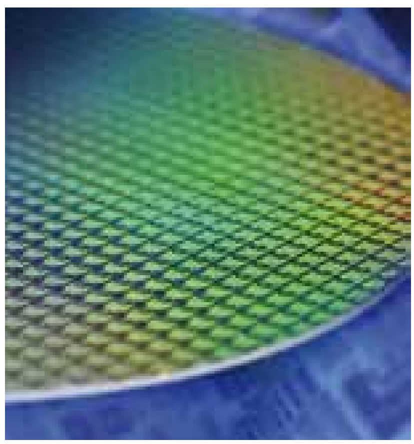
Table 2 PV market positions

Country	Estimated Market size (MWp)
Germany	6500
Italy	5500
USA	4500
Japan	3300
India	3000
China	2000
Australia	1400
France	1100
Spain	800
Greece	750

The table is again indicative of the continued dominance of Germany as no. 1 PV nation of world followed up closely by countries like Italy and USA. Spain which had come to occupy the centre stage in 2008 may just end up on the ninth number. Instead, Spain seems to be racing ahead in terms of the concentrated solar power plant installations.

The final count

The global PV market is fast counting in the scheme of things at the highest policy level forums across both the developed and developing regions of the world. The hitherto distantly placed grid parity of PV power seems to inch closer now. However, the onus lies on the PV industry worldwide to showcase the best of its capabilities be at the level of site resource assessment, system designing component assembly, component engineering, economic analysis and installation aspects. Importantly enough, one should not lose sight of operation and maintenance issues especially when large scale power plant installations are spreading their wings fast. India is also witnessing some sweeping changes in its PV programme from a variety of end-use considerations. ■



Solar cell

References: Solar Plaza, Solar Buzz, IMS, isuppli, Navigant, EPIA etc.

THE INDIAN PV GROWTH STORY AND THE HRD CHALLENGES

tracing the past and new connections for Indian solar

Ravi Kumar Gurumurthi, SEMI, India <rgurumurti@semi.org>

Backdrop

India was one of the few countries to realize the immense potential of solar energy as early as in the seventies. Accordingly, it launched a major initiative to develop crystalline silicon cell technology along with commercial considerations. This responsibility was entrusted to a public sector enterprise namely Central Electronics Limited (CEL) under the ambit of National Solar Photovoltaic Energy Demonstration Project (NASPED). Thus CEL gained an envious distinction of being the first Indian PV company to indigenously develop cell and module technology. It soon paved way for design, development and field installation of a range of PV systems for meeting various end-use applications like lighting, water pumping, battery charging, and rural electrification. Majority of these systems were put up under the purview of a nation wide PV demonstration programme with full government support initially.

The commercial turn

The late eighties saw a major market transformation when the Department of Telecommunication (DoT) opted for solar power for its ambitious programme to provide rural telephone connectivity across the country. Thus thousands of solar systems were procured for Multi Access Rural Radio (MARR) systems and several hundreds for power packs to energise the rural telephone exchanges. Soon other ministries took a strong cue from the potential of PV technology and began experimenting with the solar solutions in their own programmes. For example, under the National Literacy Mission (NLM) implemented by the then Ministry of Education, several Adult Education Centres were provided with solar lights. Likewise, the Department of Rural Development went for solar powered pumps to make available the facility of drinking water in the rural areas of the country. The paramilitary and defence establishments were also quick to realize the potential in solar systems. They sought specialized solar power packs for their mobile communication sets and also for lighting in their remote border posts. It was a near cascading effect of sorts as almost simultaneously, other government agencies chose solar solutions. The Director General of Civil Aviation (DGCA) chose solar power for its obstruction warning lighting systems in airports, and for the warning systems at level crossings in railways. The oil and gas major—ONGC also took an early decision to opt solar power for the telemetry equipments in oil platforms in the Bombay High.

Laying a manufacturing base

Some of the major companies which had realized the importance of sustainable energy technologies far ahead of the time took note of the growing opportunities. Companies like Tata BP Solar; Siemens besides few more started their own solar manufacturing operations to serve the

above markets. Other PSUs like Bharat Electronics Limited (BEL) and Indian Telephone Industries (ITI) also entered this lucrative space.

With a noticeable growth in the solar PV market and the entry of several new players in the private sector, the Indian Renewable Energy Development Agency (IREDA), a financing arm of the Ministry of New and Renewable Energy (MNRE) felt an emerging need for providing specialized training in solar system design and engineering aspects. Utilizing the World Bank's market transformation fund, IREDA awarded a three-year training programme contract to Siemens Solar Inc, USA, the then largest PV Company. This company already had a very well established training centre with many ongoing training programmes. The Indian programme was aimed at training 200 system design engineers, 600 solar technicians besides sensitizing over 100 senior executives in the industry over the three-year period between 1995 and 1998.

The training programme was conducted by Siemens India and Siemens Solar in collaboration with the Indian Institutes of Technology located at Mumbai, Delhi and Chennai in the first year. The second and third year programmes were held at IIT Madras in the well-equipped laboratory and training facility in its Central Electronics Centre (CEC). The training programme received all round approbation for its comprehensive coverage of the subject and the high quality of training provided at various levels. Several of the engineers and technicians trained under this programme currently serve the PV industry in senior positions. Simultaneously, the CEC has also now grown into a full-fledged solar training and testing centre.

The big push to capacity building

The solar PV market has been steadily growing since the turn of the century with expanded government programmes, the growing non-subsidy, and off grid markets. Increased market opportunities have spawned the growth of cell and module manufacturing, especially the latter. Associated with this growth was the growth of equipment and material suppliers. However, all this growth did not really create much of a manpower challenge to the industry. With clearly defined market segment and standardized products, on-the-job training to the fresh recruits slowly became a well accepted norm.

Incidentally, the launch of the ambitious Jawaharlal Nehru National

Solar Mission (JNNSM)- based programme, however, changed the Indian PV scenario as never before. It established India as a promising and fast emerging solar market destination. The same is evidenced by the fact that the mission launch followed a dramatic spurt in the number of fresh entrants in the PV business. This ranged from the domestic infrastructure majors, international, and domestic material, and equipment suppliers to EPC and financing institutions.

The sudden growth has undoubtedly brought into sharp focus the challenges relating to manpower development in the Indian solar sector. Many of the domestic companies had no prior exposure to the industry by themselves and thus were left with no option but to pick up inadequately trained personnel to manage their technical and managerial functions. Expectedly, with the further expansion of JNNSM and other state government programmes too, the need for quality manpower would only brighten up.

Networking for capacity building

With an increased competition, growing customer awareness and demanding timelines, solar companies no longer have time to engage in training the recruits. They would rather prefer to recruit well-trained people with basic grounding in the technology and business operations. While framing the JNNSM policy, the government could foresee the manpower challenges associated with the actual implementation of ambitious JNNSM programme so as to install 20GW of solar power by the year 2022.

Outlining the Human Resource Development (HRD) measures, the mission document envisaged that premier engineering colleges and the IITs would be involved in designing and developing specialized training programmes. The establishment of the National Centre for PV Research and Education (NCPRE) at IIT Bombay is a step forward towards this visionary objective. The document has also spelt out that the Director General of Vocational Education and Training (DGVET) would be involved in the development of skilled workforce.

Teaming up with the sun

It is significant to note herein that Germany despite its low level of solar radiation but with a high degree of manufacturing automation has employed as many as 150,000 people in the year 2009. The US solar industry, as per the solar census conducted by the US solar foundation in collaboration with Cornell University and Green LMI, put the number of people engaged in 2010 as 93,000. In comparison to these figures, the JNNSM's projection of 100,000 personnel, however, seemed a little conservative.

Stimulating the market further with the growing emphasis on domestic content, the network of small enterprises serving the off grid market across the country, the growing institutional and urban markets, the Renewable Purchase Obligations (RPOs) are all likely to push the solar industry further amongst the top employment generators in the current decade. The Green jobs market is expected to be a front-runner within the next 5-10 years.

Fortunately even before the launch of the JNNSM, several universities and autonomous institutions geared up and build up the required infrastructure. They also created a faculty to offer not only full time post graduate programmes in renewable energy but also encouraged an active perusal of research activities. Some engineering colleges even offered optional semester level courses in solar technology.

The SEMI India Initiative

Several companies like Juwi, Tata BP Solar, UL, SMA and others have developed training programmes/modules that could benefit both the students and companies alike. However, it is important to reinforce the linkages between the industry-academia. The underlying rationale is to develop a true synergy between the classroom and practical learning. The training programmes organized by the Indian arm of the global industry association Semiconductor Equipment and Material International (SEMI) in collaboration with NCPRE offers such a mix.

Selling solar, unlike selling other products, requires much more than basic selling skills. Sales executives need to get some basic grounding in solar technology and its benefits and the ability to assess and offer economical and satisfying solutions to the customers. Customer Service and customer relation is another key area for long-term sustainability of a business enterprise which is overlooked more often than not

NGOs showing a skilled path

It is befitting to highlight the role being played by several NGOs like the Social Work and Research Centre (SWRC), Tilona, Rajasthan, through their *Barefoot College* initiative. Under this initiative, SWRC has been training several Barefoot Solar Engineers (BSE) to assemble, install, test, repair and maintain solar lanterns and lights independently. The M.S. Swaminathan Research Centre using ISRO's Edusat infrastructure provides training opportunities through the Village Resource Centres (VRCs) to expand the outreach of solar programmes further.

The role of NGOs in training and creating livelihood opportunities to rural youths and the consequent positive social impact need not be overemphasized. Credible initiatives by leading NGOs with a proven track record should be co-opted to participate in the skill development initiatives elsewhere.

While government and international agencies could infuse funds into these programmes, solar companies can offer quality training modules and equipment too. The programme can indeed evolve into a large scale effort at providing clean energy access to the rural mass and thus promoting an all inclusive growth.

Therefore, it is very evident that no single training programme or a single organization is capable of meeting the challenge of providing the varied knowledge and skills required in the industry today.

All stakeholders thus need to closely work together so as to continuously design, deliver and upgrade training modules that would meet the needs of the industry across the value chain. It could be for ordinary villagers or a Bollywood filmstar investing his money in setting up a solar power plant and in providing employable skills to the barely educated rural youth.

The experience of leading overseas training institutions like the Florida Solar Energy Centre (FSEC), Boots on the Roof, and the US Solar Institute, which regularly organize different short training programmes at various levels so as to qualify for the certification by the North American Board of Certified Energy Practioners (NABCEP) could be also be sought in building rich and interesting content in the indegenosuly available training modules.

Solar energy: the solution for all

There are enough reasons and indications to believe that emission reduction compulsions and the imminent technological breakthroughs in PV technologies would sooner than later push solar business into a phenomenal growth orbit. Undisputably then, the time to invest in manpower development has never been so ripe. Let us try to empower every one around us with the mighty power of the all-pervading sunshine. Who knows every household in India may don two dishes on its rooftop—one to receive the direct to home signals and the other one to turn sunshine into usable electricity! ■

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unleashing consumption capacity for solar products

Nikhil Jaisinghani, Director, Mera Gaon, Micro Grid Power

Courtesy: LaBL, TERI

The underlying scenario

In a country like India, wherein nearly 400 million people are living without electricity, the potential for use of innovative technologies and renewable energy solutions is quite high. The Institute for Finance and Management Research (IFMR)[1] in conjunction with the World Resources Institute (WRI) has estimated that the annual market potential for solar home systems and solar lanterns could be as high as $45 million per year. This has been estimated from a sector modelled to serve some of the world's poorest people.

Even more startling is the fact that the market potential for off-grid energy services could be as high as $2 billion per year, as per the IFMR. The question is why is the market potential for off-grid energy services so high. Is it because the targeted customers of off-grid energy services are wealthier? In fact, the customers who would prefer services rather than products are poorer than the rest.

The services spread out the cost of serving customers over the years instead of demanding upfront payment; bottom of the pyramid customers prefer energy service companies (ESCOs) to products that must be purchased upfront. These targeted customers, (some of the world's poorest), are often unable to pay the cost of the system they need. They by and large settle for poor quality substitutes such as kerosene for lighting and batteries for radios and phone recharging. While these products provide a poor quality service at a high long-term cost (a year's supply of kerosene costs the average off-grid household ₹1,800 per year, equal to or more than a variety of quality solar products available in the market today), they are priced in line with their spending abilities.

The perceptible change

Solar has always been criticized as being an expensive source of renewable energy. No doubt, the user benefits from a long operational lifetime, dependable energy supply, and low maintenance requirements; but the cost of solar systems are often very high, particularly for the rural poor. Despite the presence of D. Light, Greenlight Planet, Barefoot Power, Solid Waste To Electricity Company (SELCO), and many others, the majority of India's off-grid households continue to use kerosene for night time lighting. To address the cost barrier, companies such as D. Light have been designing cost-effective solar lanterns. However, the lower price tag comes at the cost of effective performance.

A number of innovative business models have now emerged that have enabled companies to build cost-effective as well as quality solar technologies while still generating attractive repayment rates and long-term profitable solutions. The companies and NGOs implementing these initiatives are leading the industry towards service based solutions rather than product based, and their innovations are only the tip of the iceberg. As their experience expands and other organizations add innovations, the models will improve and their commercial viability of off-grid energy service providers will stand to gain as well.

This article will explore the models of Simpa Networks, Mera Gao Power, and Lighting a Billion Lives (LaBL).

Courtesy: D-light

Simpa Networks

A typical solar home system includes solar panels, a charge controller, battery, wiring, and lights. The panels generate power during the day, which is conditioned by the charge controller and used to charge the battery. At night, the battery powers the lights or any other appliance of the user's choice. The cost of such systems range from as low as a few thousand rupees to ₹15,000. Over the period these offer a far cheaper source of energy for the customer's desired uses

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[1] *Power to the People*, IFMR, <http://ifmr-cdf.in/mod/file/pdfFiles/Power_to_the_People_low_res.pdf>

than the traditional sources. However, as off-grid households also tend to be poor, their ability to bear these costs is limited and micro-finance institutions do not often lend for such purchases.

Simpa Networks helps distributors of solar home systems reach a greater user base by allowing the users to repay the system cost over a period of few years. The initial cost of the system is borne by Simpa and its finance partners while users access the system's energy on a pay-as-you-go basis. Based on the projections, users will repay the cost of the system after two years after which they will own the system.

The protective cover

To protect its investments, and thus ensure that customers make payments, Simpa installs locked enclosures around the charge controller, battery, and a custom-designed meter. The customer pays beforehand for a quantity of power which the meter then tracks. When the customer has consumed all the power they have paid for, they then locate their nearest payment agent and purchase more power. The agent, upon receipt of payment, sends an SMS with the customer number. Both the agent and the customer, if they have a cell phone, receive a code by SMS which can be entered into the meter to raise the credit.

The benefit of this model is that it takes advantage of all the existing suppliers and distributors of quality solar home systems, helping them expand their market and increase sales, while reducing the upfront cost on consumers. Simpa believes that its model prices of power are affordable for the rural poor, while still allowing Simpa to cover its costs of finance, labour, and technology that enable the pay-as-you-go approach.

The model is, however, not risk free. The commercial viability of Simpa's model is based on customer top-offs. If the systems are placed in the hands of customers who cannot afford regular credit top-ups, repayment will take longer than the projected two years. Simpa is using a data-driven approach to better identify good customers so that they can target these customers with a regular service. Power theft is also a risk; once installed, if users are able to use this power without paying, Simpa's sunk costs will result in losses rather than profit. Hence, the company has strengthened its technical design and is developing social processes which together will reduce the risk of power theft.

The model is being demonstrated through a pilot scheme with SELCO in Karnataka and should reach 150 customers by the end of 2011 and a further 1,000 through SELCO's branches in 2012.

Mera Gao Power

While Simpa Networks work at the household level, Mera Gao Power (MGP) builds systems which provide power at a village level. Technically, MGP's micro grids are very similar to Simpa's solar power system technology. Solar panels are installed on the roof of a house in an off-grid village; batteries and a charge controller are installed in a locked cabinet which is placed inside the same household. The distribution wires carry 24 volt direct current from the battery bank in multiple directions across the village by potential customer households, and lights installed in the individual households provide seven hours of lighting daily. Similar to Simpa's system, the MGP also

Courtesy: LaBL, TERI

covers the up-front cost of its systems. Off-grid households in Uttar Pradesh, where the MGP operates, typically pay between ₹40 to ₹100 per month for kerosene to witness a few scarce hours of dim light from kerosene wick lanterns. MGP's customers pay less than ₹100 per month for seven hours of light through two lights which are more than ten times brighter than the unhealthy kerosene lanterns. Unlike the on-grid households, MGP's service is dependable operating every night during a pre-scheduled seven hour period agreed upon by the villagers. Customers are at a liberty to subscribe and unsubscribe from the service easily.

The technology attribute

Unlike other solar powered micro grids, MGP's facility design is low cost and built around an existing infrastructure. By focusing on lighting, a typical village level facility only requires four panels and four batteries, thus reducing the power production capacity (and thus the facility cost) by more than 90%. MGP's micro grids are also at half the cost per customer for biogas and gasification-powered micro grids. Better yet, they have no input supply system to manage and are low maintenance. This reduces the operational expenses of MGP's facilities significantly. As a result of the low up-front cost and low operational costs, MGP has what it believes to be the lowest cost micro grids in operation. This allows it to pass the savings on to its customers while still projecting a three year repayment period and an attractive five year return on the investment.

The main risks to MGP's business models are from power thefts, repayment, and the ability to access sufficient financing to take to scale rapidly. MGP has addressed power theft by distributing power at 24 volts direct current and installing one amp circuit breakers on each distribution line serving 10 to 15 households. This reduces the number of appliances that can be run on the system by tripping the distribution lines when users attempt to draw more power from the system than what the installed lights would require. MGP's NGO partner, the Sarathi Development Foundation, also conducts social engagement before MGP installs its systems to ensure that the end-users understand the consequences of power theft and what MGP expects of its customers.

MGP currently has 50 customers in one village of Fatehpur district, Uttar Pradesh, and plans on expanding its network to 7,000 customers in 100 villages by the end of 2012.

Lighting a Billion Lives (LaBL)

The Lighting a Billion Lives (LaBL) initiative by The Energy and Resources Institute (TERI) began in 2007 with the goal of reaching one billion lives by 2020. LaBL's model is to install solar charging stations which charge solar lanterns during the day. Customers then rent the lanterns for a few rupees at night. Solar panels are installed in a central location within a village and connected to a charge controller. Unlike the Simpa and MGP models, there is not a single battery bank per set of panels; instead, each solar lantern has a battery of its own. Each charging station can charge forty to sixty solar lanterns per day.

D-Light

While LaBL's initiative is not commercial and does not generate a return on investment, yet it points to a potentially attractive business opportunity. Customers get high quality light only when they can afford it and daily rental rates are low. If operational costs can be controlled, it is plausible that this model could have a repayment period of a few years.

This model has been tested commercially in India and Laos with mixed results. The major risks which have been identified are the abuse of the lanterns and high operational costs. Since customers trade their lanterns each morning and receive a new lantern each night, there is little incentive to maintain the equipment. Customers also try to tap into the lantern battery so as to use the power for other undesignated purposes such as charging of mobile phones and running televisions. This drains the battery and affects its long term performance thus increasing the cost of its maintenance too. As the model requires one person to oversee the lantern collection, charging, and rental, a good portion of the revenue generated goes to paying the salary of personnel.

TERI has so far deployed the LaBL model in 659 villages in 16 states across India with 37,000 lanterns reaching 180,000 beneficiaries.

SELCO Light

Lighting the road ahead

Simpa, MGP, and LaBL are each taking a unique approach to reducing the high cost burden of solar products on the rural poor. The commercial viability of these models will be evident after a few more years once Simpa and MGP are expected to have achieved the desired scale, and LaBL has moved towards a for-profit model. The common challenges that these models will face are ensuring payment for their services, accessing cheaper financing to expand services to more customers, and controlling operational costs.

Payment collection is perhaps the most important of these isues. As the cost of these systems are covered by the companies and institutions promoting these models, their ability to recoup that investment and make a profit is limited by their ability to collect timely payment from the customers. Without earning any profit, the larger private capital market will not be available to fund their expansion, thus limiting their impact to a small fraction of the unmet demand which can be served with non-profit funding.

Leading from the front

These models can benefit from lessons learnt from the micro finance sector. Micro finance institutions (MFIs), which make small loans to poor people and recoup their investment plus profit through regular loan repayments, faced the same challenge of developing processes which ensure high rates of loan repayment. The explosive rate at which microfinance took to scale in India was enabled by finding a solution to this challenge. Showing that MFIs were able to profitably serve poor clientele enabled a greater rate of capital flow and operational support resulting in maturation for the sector. Micro-financial services are now provided to 26 million borrowers in India alone and nearly 100 million globally.

The distributed energy service sector is on the verge of a similar growth trajectory and could reach tens of millions of households and hundreds of millions of beneficiaries in the next ten years. To do so, they will have to resolve challenges and learn from the past experiences of related industries. The path is long and full of challenges, but Simpa, MGP, and LaBL are boldly leading the way. ■

CSP TECHNOLOGY

AN OUTLOOK

Anand Upadhyay, Research Associate, TERI <anand.upadhyay@teri.res.in>

Concentrating Solar Thermal Power or simply CSP is a set of technologies which may be used to concentrate solar energy to produce electricity. CSP requires clear skies and high levels of falling solar radiation. In India, this is abundant in some parts of Rajasthan and Gujarat. The Indian government through the Jawaharlal Nehru National Solar Mission (JNNSM) has provided strong support to the growth of solar industry. A target of 20 GW by 2022 has been set under the mission.

Facing fierce competition from PV technology, CSP developers are improving system efficiencies. Storage is a big selling point for CSP developers these days, particularly since they are having a harder time competing with PV technologies that have become much cheaper in the last two years. Storing thermal energy for use after the sun sets means a CSP plant is more flexible in adjusting its power output to meet a specific utility's demand. PV power plant output can drop significantly in the late afternoon and early evening, when electricity use can increase. Although including storage means adding costs, the greater ability to provide power on demand makes a CSP plant more beneficial than one without storage or with PV. The CSP market so far has a bright future. About 17.54 GW of power projects are under development worldwide. As part of the National Solar Mission, 370MW solar power plants are coming up in India. About 1.17 Gigawatts of CSP power plants are already online. Spain has 582 megawatts of them, followed by the United States with 507 megawatts.

Economics

CERC has done a comprehensive study of solar economics in India based on cost-plus methodologies on existing Indian and international projects and arrived at benchmark costs for solar power plants. A summary of this analysis is provided below. Invited bid discount from CERC determined rate for FY 2010-11, ₹15.31/kWh for solar thermal, has yielded prices in the range of ₹10.49 to 12.24/kWh.

Table 1 Comparative costs of solar technologies for power

Head	Solar PV	Solar thermal
FY 2010–11		
Capital cost	₹16.90 Cr./MW	₹15.30 Cr./MW
Tariff	₹17.91/kWh	₹15.31/kWh
FY 2011–12		
Capital cost	₹14.42 Cr./MW	₹15.00 Cr./MW
Tariff	₹15.39/kWh	₹15.04/kWh

Table 2 Solar power tariff of states in India

State	Solar PV	Solar Thermal
Gujarat	₹12.54/kWh OR ₹15/kWh for 12 years, and ₹5/kWh for next 13 years	₹9.29/kWh or ₹11/kWh for 12 years and ₹4/kWh for next 13 years
Rajasthan	₹12.58/kWh	₹15.32/kWh
Maharashtra	₹15.61/kWh	₹15.54/kWh
Jharkhand	₹17.96/kWh	₹13.12/kWh
Madhya Pradesh	₹15.35/kWh	₹11.26/kWh

Keeping in line with the National Solar Mission, states of Gujarat and Rajasthan have announced their respective solar policies. Gujarat has been a frontrunner in this regard; through its own RPS and feed in tariff incentives the state is targeting 1000 MW capacity by 2013. Rajasthan too is trying to exploit this massive solar insolation potential with a target of 10–12 GW in 10–12 years with around 500 MW in the next 2–3 years. Other states in India like Uttar Pradesh, Delhi, and Maharashtra have recently started taking some steps in this regard. Delhi is on its way to implement a smart policy of promoting small roof top solar residential installations.

As cumulative costs increase, investment and energy costs are expected to decrease. The National Solar Mission aims to help solar energy achieve grid parity by 2030.

Key technologies and developers

Power plant designs that use parabolic trough reflectors and power-tower receivers are the most popular. Stirling engines make up the third common CSP technology. Serious and dedicated

Parabolic trough, SIEMENS

local developers like Cargo Motors, Coramandel; Enam Infrastructure; Electrotherm; Entegra; Lanco Solar; SunBorne; Suryachakra; Welspun; and Acme have emerged in the last two years. Similarly, large domestic construction companies are also gearing up and picking up pace in CSP. These include publically-traded EPC companies which include BGR, Essar, Gammon, GMR, GVK, Jaypee, Lanco, L&T, and NTPC.

Parabolic trough plants generally heat the heat transfer fluid to about 390 °C, which is lower than the temperatures from power tower plants and Stirling engines. Power tower designs can achieve around 550 °C and higher. Running a steam turbine at a higher temperature improves its efficiency. The thermal-to-electric efficiency of a parabolic plant is around 38 per cent while the efficiency for a power tower plant is up to 42 per cent. However, a power tower plant can end its operation for fewer hours each year than the trough plant, however, because power tower relies on a single receiver. The plant's output will be compromised if the receiver is not operational. A trough plant has many loops of tubes, so one problematic loop will not cause the whole plant to shut down. Furthermore on the basis of sunlight-to-electricity efficiency, Stirling engine can perform better than parabolic trough or power tower. As a result of higher concentration, the sunlight-to-electric peak efficiency is about 31 per cent for Stirling engine and 22-23 per cent for the other two. Stirling engines use far less water and needs it only for washing the dishes.

Drivers and barriers

The upcoming CSP plants the world over are driven by feed in tariff, tax credits and other government support mechanisms. CSP also makes a case for energy security and to tackle issues of climate change. A 50 MW CSP plant can help avoid 70,000-149,000 tons of CO_2 emissions. The fluctuating fossil fuel price led to the emergence of solar power sector, and it continues to be a key driver. However, there are still some technological and other barriers which need to be addressed. Financing becomes a problem due to high capital costs of CSP plants, as a result leading to high LCOE. Grid integration is still an issue due to the nature of solar resource, though lesser than in the case of wind energy which is more intermittent. The technology is still improving, leading to better efficiencies and cost reductions.

Environmental impact

Life-cycle of CO_2 emissions of solar-specific CSP plants are assessed at 17 g/kWh against 776 g/kWh for coal plants and 396 g/kWh for natural gas combined cycle plants. An 80 MW trough plant requires about 1.2 million cubic metres of water per year, mostly for cooling the steam cycle, and for cleaning the mirrors. Dry air cooling systems could considerably reduce the consumption of water, at a cost. The use of molten salts and synthetic oil in a CSP plant bears some risk of spillage or fire. This may in turn hinder acceptance of a project by the local population.

R&D priorities

One possible step of improvement with troughs would be direct steam generation, increasing the overall efficiency. Phase-change materials and concrete offer novel options for storage. Towers have even greater room for improvements. Many innovative designs have been proposed, and with one or several towers sharing fields of heliostats, there is a great variety of central receiver designs, heat fluids, and storage options. Towers with air receivers feeding the gas turbine of a combined cycle power plant could offer record solar-to-electricity efficiency of around 35%. ■

Panels that produce both electricity and heat could make better use of sunlight – but heat from the thermal absorber can damage the sensitive photovoltaic cells. The strengths and weaknesses of solar hybrid systems.

An odd couple

By Sascha Rentzing

Roofs are filling up. By 2020, the German government hopes to increase the share of solar electricity from 3% to 10%. At the same time, thermal collectors are to replace the ageing oil and gas boilers in German basements as quickly as possible. But is there enough room for all these systems? The solution could be simple. Photovoltaic (PV) cells only convert about 15% of the sun's rays into electricity; the rest becomes waste heat and is lost. If this lost energy is used instead, system efficiency could be significantly increased, and less space would be needed. So what are we waiting for? Let us throw some cells and collectors into a glass box and start seriously harvesting the sun's power. But it is not as easy as it sounds. Although research has been conducted on photovoltaic-thermal (PVT) panels for some time now, the technology has not had a strong showing on the market so far. The problem is that PV and thermal cause each other problems when they are put together under a single pane of glass. ''A thermal collector is operated at the highest possible temperatures, while photovoltaic cells work better the cooler they are," explains physicist Michael Powalla of Stuttgart's Centre for Solar Energy and Hydrogen Research (ZSW). In other words, neither electricity nor heat can be optimally produced.

The PV aspect is especially causing developers some grief. As the temperature increases, solar power production decreases by half a per cent for each degree Celsius. With a cell temperature of 25 °C and insolation of 1,000 watts (typical in Germany), a standard panel can produce 200 watts. At 90°C, it only produces 135 watts—about a third less. A simple PV panel deals with such temperatures only rarely, in the dog days of summer, but a thermal collector sees them quite often. High temperatures are necessary to heat up water in the solar thermal system's storage tank for showers or heating.

Sometimes the collector can get even hotter. In summer, the storage tank is often already full by the afternoon. In this case, a regulator stops the pump between the collector and the tank to prevent too much heat from the roof from bringing the stored water to a boil. "In these times of stagnation, the collector can reach up to 200 °C," says project engineer Alban Heßberger of German hybrid panel manufacturer PA-ID. At such temperatures, cells would only reach 12.5% of their nominal capacity—at a time that would otherwise be optimal for solar power production.

Excess heat

Besides the heat, size can also be a problem. Because of the attractive feed-in tariffs set down in Germany's Renewable Energy Act (EEG), most solar arrays are designed to produce more electricity than each individual household needs. A typical PV system on a single family home in Germany produces five kilowatts (kW) and measures a good 50 square metres. Thermal collectors only need a third of that area, since their size is related to heat demand. The rule of thumb for a supporting solar thermal system is that four square metres of collector area is needed per person—16 square metres for a four-person family. It would be counterproductive to cover the entire roof with PVT panels. "The temperature in the collectors would rise because so little of the heat would be used, thereby decreasing power production," explains Matthias Rommel, head of the Institute of Solar Technology at the Rapperswil University of Applied Sciences in Switzerland.

Does all this mean that the hybrid idea is doomed to failure? Despite the difficulties, Rommel believes there is a future for the solar duo. "The technology could be interesting for hospitals and apartment buildings," he suggests. Hybrid modules would be operated at low temperatures on the roofs of such building, because hot water would constantly be taken from the storage tanks while cooled-down heat-conducting liquid is pumped back into the insolation collectors. The cells would thus stay cool and keep their efficiency high.

Swedish firm Absolicon already offers a hybrid system specially designed for large-scale heat consumers. The Double Solar Technology system uses a semicircular parabolic trough that tracks the sun to collect light at a concentration of 10 times onto an absorber tube in the middle of the collector. The solar fluid circulating there transfers the heat to tap water or heating water before cooling down the cells on the side of the receiver facing the sun. "Our target customers are municipalities that want to produce district heating and power and buildings, like hotels, that

use a lot of hot water," says CEO Joakim Byström. Absolicon has already installed 25 PVT systems around the world, he says; the most recent—and the biggest at 200 square metres—support the biomass-fired district heating system in the Swedish city of Härnösand. In the summer, the system's thermal capacity of 100 kW contributes 5% of the city's heating and 20 kWof electricity, which is exported to the public grid.

With those figures, Absolicon's parabolic trough is still far from the ideal hybrid system, in which the two parts would work as well as two separate systems. In the Swedish company's concept, PV only plays a supporting role, producing just 100 watts per square metre of panel area—less than a normal standard PV panel, which would achieve 125 watts. In addition, the parabolic trough is not really designed for inclined roofs, and therefore does not save much space.

No real hybrids yet

Solarhybrid of Saxony, however, has designed a combination panel especially for use on roofs. It is built like a conventional thermal collector; to produce hot water, it makes use of the natural greenhouse effect in the air chamber between the front pane of glass and the absorber's surface. However, the high temperatures in the glass container can be a bit of a problem for the cells laminated onto the inside of the glass every so often in rows of three or four. Overheating can occur especially when too little heat is taken away to be used. "For this reason, we determine the storage tank's size exactly according to a household's daily heat demand," explains Solarhybrid CTO Peter Tyrra. If the storage tank is still full in the evening, energy has to be dissipated to unburden the system. At night, a heat exchanger transfers some of the stored heat to the solar fluid, which is then pumped to the roof and cooled down by the outdoor air. "That is how we make room for the next day."

However, this type of PV cooling has some disadvantages. The additional pumping uses more electricity, while unused energy is sent out into the night. And that is just for a relatively small PV component. Solarhybrid's most powerful combination panel, at 2.51 square metres, only produces about 193 watts, or 77 watts per square metre—a good third less than a normal PV panel. Interested parties must do their research to decide whether the new technology would really pay off, especially since, unlike simple collector systems, hybrid panels do not receive any funding from the German government's market incentive programme despite their thermal component. The feed-in tariff for solar power must, therefore, be enough to compensate for system costs and the lack of additional government support.

Other companies offering hybrid collectors—such as PA-ID, Anafsolar of Pavia, Italy, and Solarzentrum Allgäu—are, therefore, focusing on optimizing power production. "It is all about increasing electricity yield," says PA-ID engineer Heßberger. The front of his company's 2Power hybrid module is completely covered with crystalline silicon cells. The back functions as a heat exchanger, with a cooling medium flowing through it that takes heat from the cells and carries it to the tap water in a storage tank. PAID has also done away with the air chamber typically found in thermal collectors to allow less heat to build up. "The panel temperature therefore rarely exceeds 60 °C," Heßberger explains. The cooling system, he says, keeps the cells' efficiency stable, while the use of heat for tap water increases power production by at least 3%.

But PA-ID, too, faces the hybrid dilemma. When one side is optimized, the other loses some power. At 330 watts per square metre, the combination panel only achieves about two-thirds of a conventional thermal collector's thermal capacity. Cooling the solar cells also means that only low temperatures of 40 to 50 °C are produced for heating water.

For higher temperatures from the roof, you have to connect the PVT panel to an extra heat pump with a downhole heat exchanger. This system works like a refrigerator in reverse. A cooling medium is vapourized under pressure before being turned back into liquid. The heat that has been set loose in the process enters a separate water cycle. "Just a few degrees in the hybrid cycle here can generate 60 °C in the heat cycle," says Heßberger. Theoretically, a heat pump could be used to improve electricity yield, too. A conventional heat pump system with a downhole heat exchanger generally works at temperatures just above zero. The hybrid panel's solar fluid is, therefore, also quite cold and can cool down the PV component well. "Electricity yield is thus increased by 15%," Heßberger explains.

But even besides the need for more space and the extensive construction work needed for three-part hybrid solutions—heat exchangers and storage tanks must be installed underground—the heat pump complicates the already quite complex hybrid technology even more. It also drives up the price – the heat pumps and the electricity and regulators they need are not free. ■

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