CSP electricity generation

At the beginning of 2009, more than 700 MWth of grid-connected CSP plants were installed worldwide with another 1,500 MW under construction. The majority of installed plants use parabolic trough technology. Central receiver technology comprises a growing share of plants under construction and those announced. The bulk of the operating capacity is installed in Spain and on the south-western regions of the US. In 2007, after a hiatus of more than 15 years, the first CSP plants came on line with Nevada Solar One (64 MWe, USA) and PS10 (11 MWe Spain). In Spain, successive royal decrees have been in place, since 2004, and have stimulated the CSP industry in that country. As on November 2009, 2,340 MWe of CSP projects had been pre-registered for the tariff provisions of the royal decree. In the US, more than 4,500 MWe of CSP is, currently, under power purchase agreement contracts. The different contracts specify when the projects must start delivering electricity, between 2010 and 2015. More than 10,000 MW of new CSP plants have been proposed in the US. More than 50 CSP electricity projects are currently in the planning phase mainly in North Africa, Spain, and the US. In Australia, the federal government has called for 1,000 MW of new solar plants covering both CSP and PV, under the solar flagships programme. Figure 3 shows the current and planned development to add more CSP capacity in the near future.

In recent years, hybrid solar/fossil plants have received major attention and several integrated solar-combined cycle projects have been either commissioned or are under construction in the Mediterranean region and the US. The first such plant was set up in Morocco (Ain Beni Mathar: 470 MW total, 22 MW solar), which began operating in June 2010, and two additional plants in Algeria (Hassi R' Mel: 150 MW total, 30 MW solar) and Egypt (Al Kuryamat: 140 MW total 20 MW solar) are under construction. In Italy, Archimede is another example of an ISCC project; however, the plant's 31,000 m^2 parabolic trough solar field will be the first to use molten salt, as the heat transfer fluid.

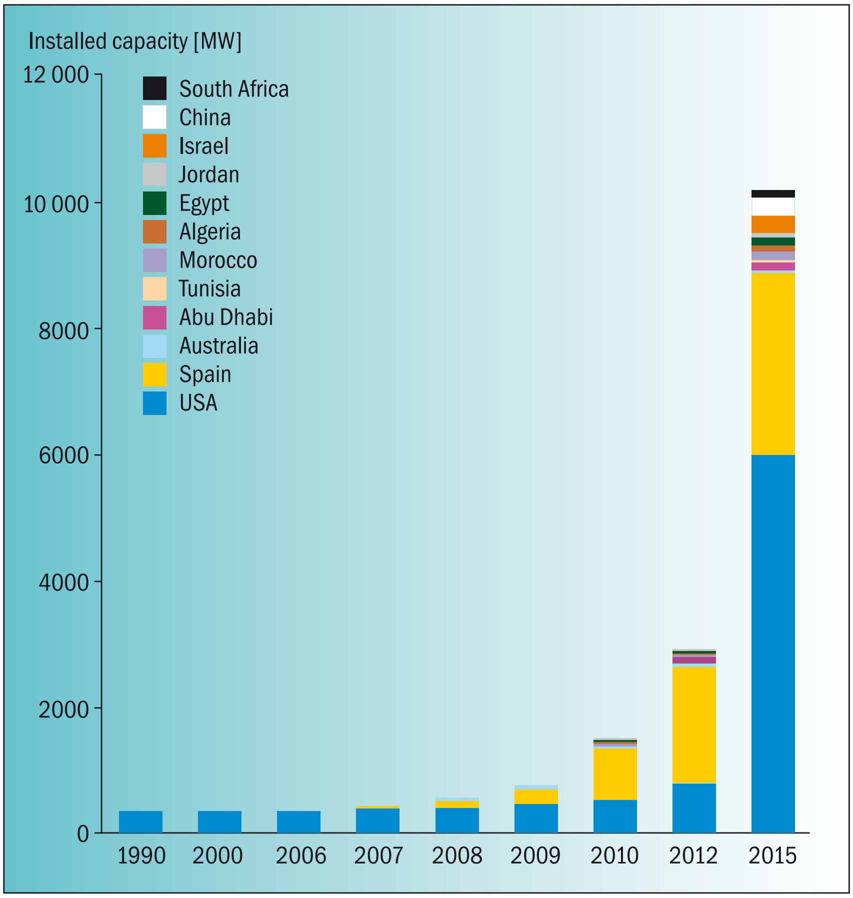


Figure 3 Installed and planned concentrated solar power plants by country
Sources Bloem *et al* 2010

Solar fuel production technologies

Solar fuel production technologies are at an early stage of development. The high temperature solar reactor technology is typically being developed at the laboratory scale of 1 to 10 kWth solar power input. Direct conversion of solar energy to fuel is not yet widely demonstrated or commercialized. But, two options appear commercially feasible in the near to medium term; 1) the solar hybrid fuel production system (including solar methane reforming and solar biomass reforming) and 2) solar PV or CSP electrolysis.

Case study: India

The Indian solar energy technology development programme took off quite early. Several universities, research laboratories, the Indian Institutes of Technology (IITs), and few public sector units contributed towards the initial development of the technologies. Amongst the initial range of products developed were solar lanterns, indoor and outdoor lighting units, solar water heaters, solar stills, and box-type solar cookers. Perhaps the national solar power scenario has gained some positive foothold with the launching of the Jawaharlal Nehru National Solar Mission (JNNSM) in late 2009. This mission targets a total capacity of 22,000 MW by 2022. The following points showcase the current outlook of solar energy developments in the country.

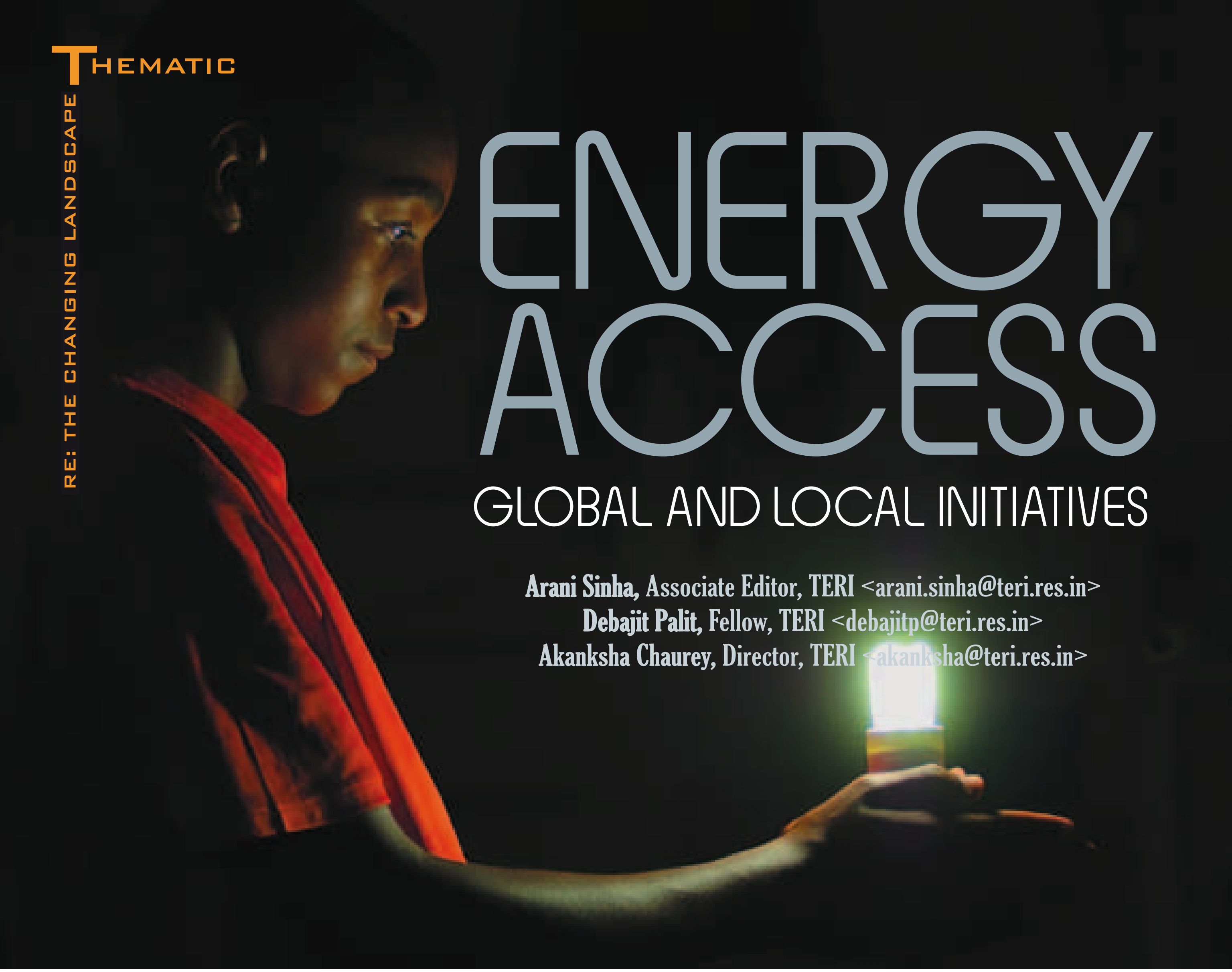
- The first phase of the JNNSM has already taken off, under which a combined solar capacity of more than 700 MW stands allocated.
- India contributed about 1% of the global PV market installations aggregating to more than 17,000 MW in 2010. This share is expected to surge

manifold, once the capacities targeted under the solar mission are realized.

- The price availability for the levelized tariff fell in the range of ₹10.49/kWh to ₹12.24 for solar thermal area, while it was between ₹10.95/kWh and ₹12.75/kWh for solar PV.
- Solar power has the potential to meet almost 7% of our power needs by 2022, mitigate 2.6% of our carbon emissions, and save over 71 MTPA of imported coal by 2022, according to the just released KPMG report.
- The all-India grid parity is expected to come through by 2017/18, under an aggressive case for the rooftop PV systems, and in 2019/20 as per a base-case scenario.
- Solar water heating systems find maximum use in the residential sector (about 80%), followed by hotels (6%) and industry (5%).
- Solar power has the potential to replace about 30% of diesel consumption in the telecom towers, which are expected to swell up to 700,000 from 360,000 by 2020.

- The cost of solar modules is falling; while as the cost of balance of system (45%–50%) is going up. The manpower-related costs for civil works and installation-cum-commissioning seem to offer the maximum possible scope for price reduction, for example, in a PV-grid connected power plant.
- The majority of the concentrated solar power plants, approved under the first phase of JNNSM, are based on parabolic trough technology.
- As per the available information, till date, power purchase agreements, corresponding to a CSP capacity of 525 MW, have been signed in India.

The above-mentioned figures make it clear that solar technologies can lead to a visible and positive change in our environment. Solar products may not exactly compete on a cost-to-cost basis with conventional products, but can mitigate our climate change concerns to a large extent.



ENERGY ACCESS
GLOBAL AND LOCAL INITIATIVES

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Global scenario

Access to energy services is a key element in poverty alleviation and an indispensable component of sustainable human development. Clean, reliable, affordable energy services is almost imperative for global prosperity. Current statistics indicate, worldwide, about 2.5 billion people still rely on traditional biomass for cooking and heating and about 1.4 billion have no access to electricity. A billion have access to partial and unreliable energy sources. More than 99% of the people without electricity live in developing regions, and four out of five of those live in rural South Asia and Sub-Saharan Africa. Thus, given the widespread lack of energy access, we can conclude that the present structures and processes within the energy sector are functioning to the advantage of the poor people.

Energy security is one of the main catalysts for reducing poverty and improving the living conditions. It also promotes national and international economic growth. Though there are no Millennium Development Goals (MDGs) for energy, yet energy access is considered as essential for achieving many of the goals. At the global level, the vision to achieve the target of the Universal Energy Access by 2030[1], as proposed by the UN Secretary General, is gaining momentum. The importance can be judged from the fact that all major international energy bodies and forums are now focusing on energy access. The United Nations has also declared 2012 as the International Year of Sustainable Energy for All[2].

Energy poverty in developing countries and a strategy for prioritizing energy access agenda is the main focus of the Vienna Energy Forum (VEF)[3]. The forum discussed that energy poverty, as a major development obstacle, can be eliminated only with the help of enhanced energy access. Participants worked towards promoting global initiatives to achieve universal access to sustainable energy for all, as called

[1] UNEAP, Framework Document, 2011
[2] United Nations Foundation, Bringing Energy Efficiency to all consumers, 2011
[3] http://www.unido.org/index.php?id=1001185

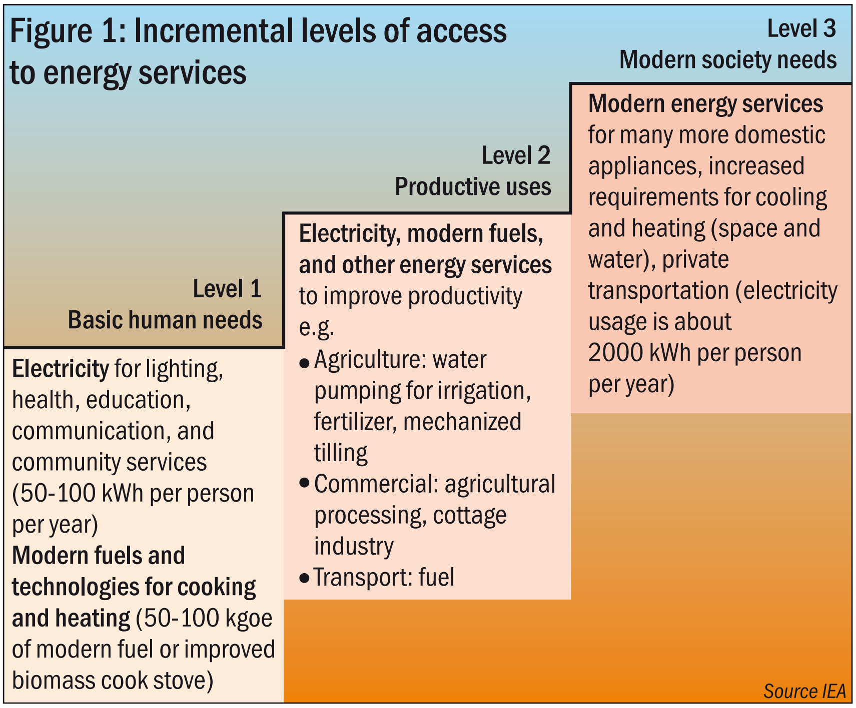
for by the UN General Assembly. The primary findings of the Global Energy Assessment[4] put forth the view that with the right mix of technologies, policies, and management, the next energy transformation can address poverty, development, sustainability, and climate change objectives in a cost-effective and sustainable manner. The assessment estimates that the cost of sustainable energy investments required for maintaining temperature increase to 2 °C will amount to about $1.5 to 2 trillion per annum in 2050, of which 5%–40% would be incremental, offset in large parts by co-benefits in energy access, security, pollution, human health, and climate objectives.

The Asia Clean Energy Forum 2011[5] organized in June 2011 with the theme *New Business models and policy drivers: building the low-carbon* also sought to promote best practices in clean energy policy and regulation, financing and investment, innovative business models, and energy access. The parallel breakout sessions provided opportunity to discuss innovative and creative methods to break down barriers for large-scale clean energy development and deployment in the Asia-Pacific.

Defining energy access

Though the buzz word at the level of global developmental agenda is energy access, it is also ironical that there is no consensus over the definition of energy access. Some researchers opine gaining access to grid electricity and using modern fuel as the threshold of achieving energy access. But, in many parts of the world, despite having access to grid, people are unable to derive benefit from it due to erratic and minimal supply. The same is the case with improved cook stoves, which though have been disseminated widely, but its long-term sustainability was not given due importance as however, many users reverted to their traditional devices after few months of use. We need to realize that if the world is to achieve the target

Figure 1: Incremental levels of access to energy services



of Universal Energy Access by 2030, which among others will also require framing policies for achieving the target, then a concrete definition of 'energy access' will have to be agreed upon. One way of understanding what energy access actually means is to consider the incremental level of access to energy services. According to this approach, we may have three levels of access to energy and the policies for achieving the universal energy access can be classified under three heads:

- Electricity for lighting, health, education, and communication
- Modern fuels and technology for cooking and heating
- Mechanical power for productive use

Based on the inter-linkages between the three stages and for developing robust and inclusive policies, universal energy access can be defined as "access to clean, reliable, and affordable energy services for cooking and heating, lighting, communications, and productive uses"[6]. Figure 1 shows the incremental levels of access to energy services.

TERI's initiatives

Over the years, TERI has been attempting to address the issue of 'energy access' in a holistic manner. TERI's approach to energy access not only falls within the framework of the incremental levels of energy access but have also been creating the ground for a sustainable future. TERI's understanding of energy access is developed on the following lines:

- *Is clean energy available* (macro-level physical dimension of the challenge, that is, rural electricity distribution backbone/micro-grids/decentralized energy options are available at all habitations?)
- *If yes, is it accessible* (micro-level connectivity and market dimensions, that is, infrastructure available at the door-steps, do people find it easy to take a connection, can people buy solar or improved cooking devices of their choice as and when they require?)
- *If yes, is it affordable* (are the product/ services packaged and customized to meet the people's "ability and willingness to spend"?)

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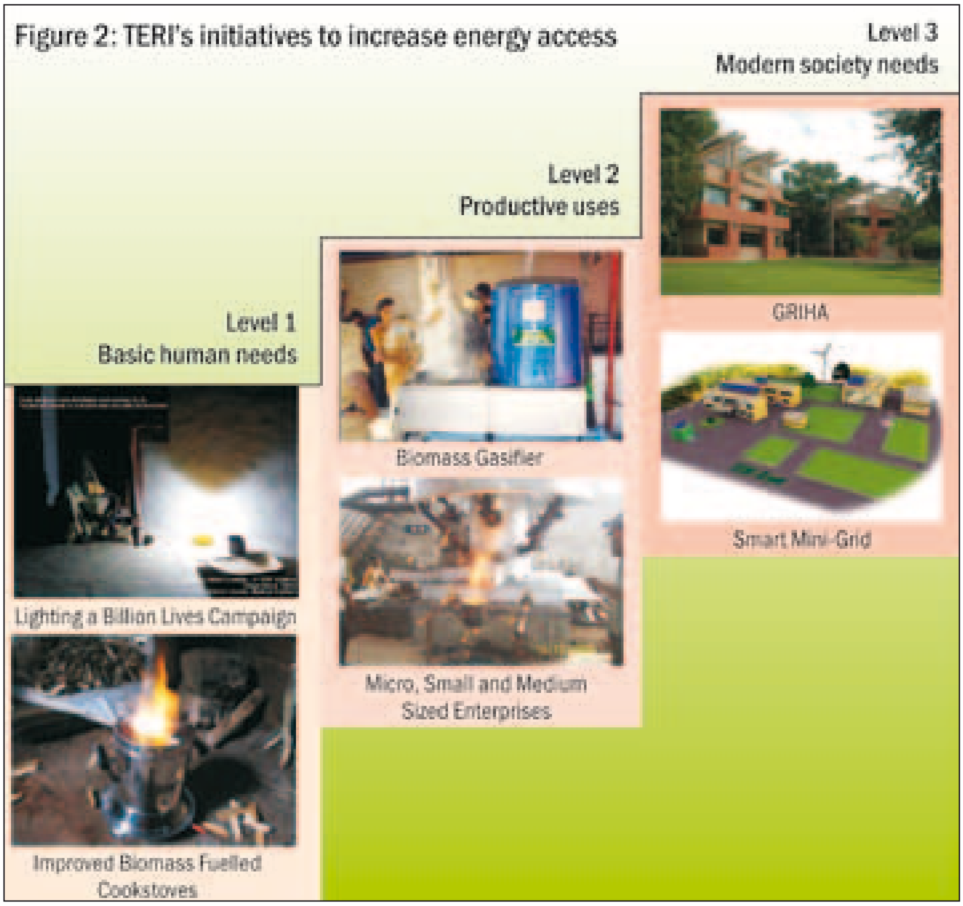
[4] http://www.iiasa.ac.at/Research/ENE/GEA/index_gea.html
[5] http://beta.adb.org/news/events/6th-asia-clean-energy-forum-2011
[6] B Morgan, N Patrick, C Anil, e.al, *Measuring energy access: supporting a global target*, The Earth Institute Columbia University, 2010



- *If yes, is it being used* (human behavioural issues and other dimensions, that is, do people have reliable and safe appliances to use electricity, do they want to shift from traditional cook stoves to improved designs in view of traditional cooking habits, taste, flavour, and so on?

With the above understanding, TERI has designed and developed the value chain and processes (both internal and external) to facilitate an assessment of research and knowledge gaps in order to scale-up specific initiatives as well as advance the energy access agenda as a whole.

Let us look at some of the specific initiatives undertaken by TERI to advance the energy access agenda. Figure 2 shows TERI's initiatives to increase energy access.

Level 1: Basic human needs

a) Extending clean lighting

Around 400 million people in India continue to live without electricity. Inadequate lighting is not only an impediment to progress and development opportunities, but also has a direct impact on their health, environment, and safety, as they are forced to light their homes with kerosene lamps and other inefficient devices after sunset. Electricity is one of the basic human needs and recognizing this along with the need to change the existing scenario, TERI, has undertaken the initiative of 'Lighting a Billion Lives' (LaBL) through the use of solar lighting devices.

The campaign aims to bring light into the lives of one billion rural people around the globe by replacing the kerosene and paraffin lanterns with solar lighting devices. The entrepreneurial model of energy service delivery, especially targeting the 'bottom of the pyramid' population, forms the basis of implementing LaBL initiative at the village level. The LaBL operates on a 'fee-for-service' model wherein charged solar lanterns are rented to households and small businesses in the village for a nominal rent that is collected by the operator of the charging station (referred to as the LaBL Entrepreneur), who have been trained under the campaign to sustainably run the station. A part of the rental is used to meet the operation and maintenance costs of the charging station to ensure operational sustainability, the remainder constitutes the entrepreneurs' monthly income.

At the institutional level, the project is being implemented by TERI in association with grassroot-level non-governmental organizations, community-based organizations, microfinance institutions (NGOs/CBOs/MFIs) and so on, referred to as the LaBL Partner Organizations (PO), selected as per the criteria developed by TERI under the LaBL initiative. This network of institutions plays a significant role in coordinating, sustaining, and advancing the campaign. After sales service, one of the most critical aspects in distributed energy sector is being ensured through setting up of technology resource centres covering a cluster of solar charging stations to ensure technical sustainability. An integral component of the LaBL programme is to create capacities at all levels to sustain such an initiative. About 70 training programmes for technicians, rural communities, and NGOs have already been conducted across India.

The solar lanterns have been developed by TERI in partnership with leading solar lantern manufacturers of India and are customized to the needs of rural communities. To address the challenge of making available quality products at an affordable price, LaBL has also developed its own standards and performance specification based on the international standards. Under the initiative, continuous improvements in products and procedures are carried out to ensure customized service delivery, lower cost for setting up the charging stations, greatest efficiencies, and the highest quality of products and services to meet the needs of rural users.

The LaBL campaign runs on twin objectives: (a) taking solar lanterns as a non-polluting means of night illumination to poor rural households in a sustainable manner and facilitating economic opportunities to the rural poor through the use of these lanterns. While, the LaBL initiative has reached about 650 villages, spread over 15 states, impacting about 175.000 rural people, it has also successfully demonstrated how solar lanterns could impact the community; be it for lighting or for livelihood generation at the household and village level. Apart from providing energy at an affordable price, the campaign also contributes towards global environmental benefits through this local action. Each solar lantern in its useful life of 10 years displaces the use of about 500–600 litres of kerosene, thereby mitigating about 1.5 tonnes of CO_2.

The impact of the LaBL initiative is not only in the field of lighting, but it is actually an instrument by which lives can be transformed and hopes and aspirations generated on a plane that clearly enhances human welfare in a sustainable manner. The initiative is further strengthened in India and is also being extended to cover African and other South Asian countries.

b) Making cooking easier and cleaner

More than 50% of the rural and urban slum households in India use open fires or traditional cook stoves, inside poorly ventilated houses, thereby exposing the women and children to high levels of toxic smoke from the solid fuels. It is estimated that about half a million women and children die each year, and nearly 500 million cases of illness are estimated to occur annually in India alone, from indoor air pollution.

TERI has been associated with alternative cooking technologies (improved biomass fuelled cook stoves [ICs] and biogas) since the last two decades. While there are multiple alternative cooking technologies available (most notably LPG), TERI focused its research on development of ICs for two reasons: firstly, the percentage of biomass energy within the total share of different energy sources is set to treble from 10% to 30% by 2050 (International Energy Agency), with 632 million expected to be dependent on solid unprocessed biomass for cooking and space heating needs in 2030, in India, alone. This would have major impacts (both positive and negative) on poverty reduction and protection of ecosystem services.

Secondly, since biomass is largely produced and consumed locally, it does not require creation of elaborate and expensive supply chains (unlike LPG or kerosene). Large-scale adoption of this (transition) technology is, therefore, potentially more affordable and accessible for economically marginalized sections of the society, not only in India but also in Sub-Saharan Africa and other parts of South Asia, than other alternatives.

Adopting a holistic approach for stove development, TERI researchers conducted a comparative assessment of indoor and ambient air quality to determine the pollution concentrations inside and outside the households, using traditional stoves; evaluation of commercially available stove models; and accordingly developed its own prototype version. TERI's model of cook stove, a single burner forced draft and a two burner forced draft stove, was designed to achieve higher a efficiency level of about 35% and is priced at ₹2000, which is almost 40% less than a commercial model with comparable performance.

At the same time, TERI has also been conducting extensive field trials and disseminating cook stoves to rural communities for customization of technology. The entire process is based on user preferences and attitudes related to cook stoves with the objective of bringing about a transition in the existing cooking energy regime. Creating awareness amongst rural communities to switch to cleaner cooking technologies and training of stove builders have also been an integral part of this holistic exercise to induce more households with cleaner cooking technologies.

Level 2: Productive use

At the second level, electricity and modern fuels to improve productivity is the key energy access agenda. The intervention which clearly stands out at this level is TERI's work on biomass gasification and in micro, small and medium sized enterprises.

a) Using waste for cleaner fuel

TERI's work in biomass gasifier technology, started in late eighties, is aimed at providing cleaner and convenient way of utilizing biomass residues and wastes for process industries, thereby, improving their overall efficiency and reducing costs and using biomass-based gasifier for improving energy access in rural areas. TERI's fixed bed gasifier technology system is designed to operate with large-sized fuel wood. The unique pedal blower system reduces the startup and shut down time. Ovens, kilns, and furnaces coupled with biomass gasifiers have been developed for industries such as silk reeling, textile dying, brick drying, cardamom drying, arecanut processing, and so on. Currently, more than 450 gasifiers designed by TERI are operational in various sectors in India and abroad. To ensure adequate after-sales maintenance of the installed systems, local nodes (local service providers) have also been developed who help in further dissemination of the systems.

At the other end of the spectrum, TERI is also engaged in efforts to disseminate biomass gasification-based packages for distributed electricity generation and, also, in development of advanced biomass gasifiers for power generation. Keeping in tune with the Government of India's target of providing 'power to all by 2012', TERI has been disseminating small capacity gasifier power plants in the rural areas. These systems, typically of 10 kWe capacity, are designed to use locally available biomass fuel, and are set up within the villages along with the required distribution network. They cover about 100 households to meet the basic lighting need of a community as well as power small micro enterprises such as flour or rice mill.

TERI also has developed a strong monitoring and feedback system. The experience from the field learnt through a robust monitoring-feedback mechanism is being utilized to develop a two stage gasifier for rural applications in collaboration with Technical University of Denmark (DTU) and National Thermal Petroleum Corporation (NTPC) Ltd. This will considerably improve the productivity and performances of the small capacity gasifier based power systems to bring in the much needed reliability for improved rural energy access.

b) Increase productivity in a sustainable manner

Micro, small and medium sized enterprises (MSMEs) need power as well as other forms of energy for various process needs. Poor availability, reliability, and high cost of grid power adversely affect the competitiveness of MSME units.

TERI has been working on development and dissemination of energy efficient coke-fired cupola melting furnaces for small-scale foundry units, with the support of the Swiss Agency for Development and Cooperation (SDC). Recently, when the state power utilities in Coimbatore foundry cluster in Tamil Nadu imposed severe restrictions on the use of electric power by the industrial sector, a majority of foundry units operating electric induction furnaces were forced to cut production and had difficulties in meeting their market commitments. Under these circumstances, many of the foundry units in the cluster switched over to coke-based melting DBC technology provided by TERI. Thus, development and dissemination of energy-efficient technologies would go a long way in overcoming the problem of energy access in MSME clusters. And TERI is working towards this objective.

Level 3: Modern societal needs

The third level in the energy access ladder points at the modern societal needs to better the lives of people. As our demand for energy increases in this resource-constraint economy, following a sustainable path can provide better comfort while consuming the same level of energy. At this level, there are two TERI initiatives—GRIHA and Smart Mini-Grid that .are attempting to fulfill the energy demand of the modern society in a sustainable way. As we advance, our demands for energy increases and those demands will have to be fulfilled for further advancement. GRIHA is helping access energy and improving the living standards in a much more sustainable manner. Also the Smart Mini-Grid through smart controllers and advanced control techniques is managing load and energy resources.

a) GRIHA

Buildings have major environmental impacts as they consume huge amount of energy over their entire life cycle. The need here is to design buildings (green buildings), without compromising the comfort of the inhabitants. The essence is to address all the issues in an integrated and scientific manner. While, it may be true that the cost incurred in designing and constructing green buildings is little higher, it is also a proven fact that it costs less to operate a green building (payback period is between 3–5 years) that has tremendous environmental benefits and provides a better place for the occupants to live and work in.

TERI conceived the idea of Green Rating for Integrated Habitat Assessment (GRIHA) and worked with the Ministry of New and Renewable Energy (MNRE) to develop it as the National Rating System for green buildings in India. GRIHA is an evaluation tool to help design,

build, operate, and maintain a resource-efficient environment. It emphasizes on end-use energy optimization (within specified comfort levels) and integration of renewable energy; thereby providing a framework which looks at long-term policy options, both on the supply and demand side, consistent with the aspirations of economic growth. Considering the integrated approach adopted under GRIHA to improve overall efficiency, thereby, reducing the cost and achieve the best results, MNRE has now mandated that all new buildings of the central government and Public Sector Undertakings (PSUs) to have minimum three star GRIHA compliant. Further, given that even the Central Public Works Department (CPWD) has committed a minimum of three star GRIHA compliance for their buildings, the entire plinth area rates and specifications are being overhauled for green compliance, which shall take the construction industry standards to a new level.

In order to provide impetus to GRIHA compliance, the MNRE and the State Bank of India at the national level, and municipal bodies such as Pimpri Chinchwad Municipal Corporation

Courtesy: A M Faruqui/MPRLP

at the local level, are also offering financial incentives for government and private projects. Recently, the Ministry of Environment and Forests (MoEF) announced that green pre-certified/ registered buildings shall be prioritized in the environmental impact assessment (EIA) clearance process. GRIHA rating covers all aspects that are meant to be evaluated during an environmental clearance process and also enables qualification of environmental benefits. For instance, the energy performance of a building is quantified as unit of electricity consumed per unit area of built ups and compared with nationally accepted norms for similar buildings. Due diligence carried out during GRIHA rating shall feed into the environmental impact assessment (EIA) system as a compliance check. Based on actual project performance, it has been found that GRIHA's performance-oriented approach also helps avoid 0.17 Mt CO_2 annually per million square metre of GRIHA compliant built space.

To take the GRIHA compliance across the country, a pool of about 700 professionals has been trained across the country. These trained professionals can further train other architects and engineers as well as evaluate buildings for GRIHA compliance. These professionals are also providing regular feedback to ADARSH (a society jointly established by MNRE and TERI to implement GRIHA) for any upgradation of the rating systems. ADARSH is now in the process of developing Simple, Versatile and Affordable (SVA) GRIHA, specifically for smaller projects (< 2500 m^2) and guidelines for large development such as educational campus, hospitals, and other institutions. There is also a robust online tool that maintains project-wise information (such as overall rating being targeted by the project, feedback from site visits and their documentation) accessible to all project proponents to make it a transparent platform for achieving the GRIHA ratings.

b) An intelligent and sustainable electricity distribution network

TERI's emphasis has always been on finding innovative solutions for making the world, urban or rural, a better place to live. With this objective, TERI developed the Smart Mini-Grid (SMG) which is an intelligent electricity distribution network, operating at or below 11 KV and uses advanced sensing, communication, and control technologies to generate, manage, distribute, and utilize electricity more intelligently and effectively. The initiative is taken forward with twin objectives: firstly, to promote energy efficiency in the urban, commercial, and industrial sector through better demand-side management and autonomy to customers to manage their loads and increased reliability, safety, and efficiency of the electricity grid. Secondly, the SMG will also use a diverse range of distributed energy resources (such as small conventional generators and a range of renewable generators) either alone or in combination with each other to improve (quality and availability) the energy supply in rural and per-urban areas, thereby, improving the access.

RETREAT, the residential complex of TERI Gram, Gual Pahari, hosts the first-of-its-kind Smart Mini-Grid in India that optimizes the use of multiple energy resources namely solar, wind, biomass, and diesel to meet different loads on the campus in a reliable and cost-effective manner. As a next step, TERI plans to take it to rural areas and test the concept for improving electricity access in villages.

To conclude...

It is true that the world has recognized the need and importance of energy in the lives of people and that development can only take place when we have access to various forms of energy. But, we need to realize two more points: in the context of global warming and climate change, we will have to find ways to access energy in a sustainable fashion and, more importantly, all this can only be realized if we undertake initiatives at the local level. In this article, we have explained the case study of TERI, an organization which is relentlessly working to help people and communities access energy in a sustainable manner. We need such local initiatives at a mammoth scale to bring about significant changes at the global level.

SOLAR REVOLUTION: A PEOPLE'S INITIATIVE

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Background

The need for promotion of renewable energy technologies, as a tool to counter the challenge of climate change and enhance the country's energy security, has been proved beyond doubt. In fact, what is simultaneously needed is to become more energy efficient and save energy by adopting the best possible usage practices. The latter may also be seen as behavioural changes towards energy conservation. The logical step is to deploy these sustainable systems on a massive scale using innovative business models. One possible mechanism, which is presented below, is simply involving the common citizens in the country's green energy revolution. The proposed business model shall enable ordinary people to directly participate in the country's green energy movement, and is expected to result in three-pronged benefits of greater awareness generation, availability of low-cost funds, and provision of a new tax saving instrument.

Pathbreaking initiatives

As part of its commitment towards combating climate change, the Government of India has taken various initiatives to chart out a low-carbon growth trajectory. This includes amongst others, promotion of renewable energy (RE) technologies by introducing favourable policies and supporting regulations.

The National Action Plan on Climate Change (NAPCC)[1] has called for higher share (15%) of RE in the country's energy mix by 2020.

With the current 20,000 MW of renewable power capacity[2] being dominated by wind energy, the policy-makers have now shifted their attention towards harnessing other renewable sources, including the 'ubiquitous sun'.

Thus, came into being the 'Jawaharlal Nehru National Solar Mission' (JNNSM)[3], under which 20,000 MW of grid-connected capacity solar power projects and 2000 MW of off-grid solar applications have been envisaged for installation by 2022. The Mission shall help India soar high in the area of solar energy.

The visible constraints

Though the government has announced several such programmes in the recent past, stakeholder participation has been limited to policy-makers, regulators, equipment suppliers, Engineering, Procurement and Construction (EPC) companies, project developers, and electricity utilities.

Being inherently capital intensive and associated with emerging technologies, the RE sector does not stimulate much interest in the banking community. The sector for sure requires support in terms of availability of long-duration, low-cost funds.

In the light of the above stated facts, active participation from the common citizenry in the RE sector shall help the sector grow manifold, with mutual benefits. And one of the best areas to initiate this activity is in the solar sector.

The moot question is how can any ordinary citizen participate in India's renewable movement, in this case, the Solar Mission?

It is commonly construed that the only way in which ordinary citizens can participate in the country's green energy movement is by way of using low-cost end-use systems like the solar water heaters, solar photovoltaic lights, lanterns and biogas plants, and so on. In any case, they would not have the financial strength and business acumen to invest in the capital-intensive MW scale grid-interconnected projects.

For making India's renewable movement participatory and more inclusive in nature, some out-of-the-box ideas and innovative business models are surely required.

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[1] india.gov.in/allimpfrms/alldocs/15651.doc
[2] http://www.mnre.gov.in/
[3] http://mnre.gov.in/pdf/mission-document-JNNSM.pdf

Bonding with the rest

If a citizen is allowed to invest in photovoltaic modules used in solar energy projects, under a mechanism, which is similar to the existing tax-saving infrastructure bonds (eligible under section 80CCF of the Income Tax Act[4]), it shall trigger a surge in the development of the country's solar programme by way of infusion of huge amount of low-cost funds.

Under the existing mechanism[5], individuals can invest a maximum of ₹20,000 in long-term infrastructure bonds as notified by the central government[6] issued by the infrastructure finance companies (IFC), like Power Finance Corporation Ltd (PFC), Rural Electrification Corporation (REC), Power Trading Corporation (PTC), Larsen and Toubro (L&T), India Infrastructure Finance Company Ltd (IIFCL), Infrastructure Development Finance Company (IDFC), and so on. The money is in-turn invested in infrastructure projects such as roads, railways, seaports, airports, power, urban infrastructure, gas pipelines, Special Economic Zones, and so on.

Understanding the number scheme

In order to achieve 20,000 MW grid-connected capacity target by 2022, set under the National Solar Mission, for the next 10 years, 2000 MW would be required to be installed on an annual basis.

Assuming equal contribution from both the solar photovoltaic and concentrated solar projects (CSP), it is envisaged that India may witness installation of over 10,000 MW solar PV-based power generation projects.

A number of state governments have also announced their state-specific solar programmes; notable among them are the states of Gujarat[7], Rajasthan[8], and Karnataka[9].

It may be assumed that all these programmes would result in capacity addition of 20,000 MWp solar PV capacity in the country during the next 10 years, which will require 2,000 MWp to be added, annually, over the next 10 years, till 2022. Assuming the project cost at ₹150 million per MWp[10], the annual capex requirements for 2,000 MWp would be ₹300 billion.

Setting up of 1 MWp (1,000 kWp) capacity of a solar photovoltaic (PV) plant would require 5,000 modules of 200 Wp (commonly used wattages in MW-scale solar projects range from 100–230 Wp). Assuming a cost of ₹100 per peak watt[11], each 200 Wp module would amount to ₹20,000.

Now, assume 5% of the country's 25 million income-tax payers[12] with salary greater than ₹0.5 million[13] (equaling 1.25 million tax-payers) investing ₹20,000 each, to purchase a 200 Wp PV module. This shall lead to a subscription of 1.25 million of solar PV modules, equivalent to 250 MWp capacity.

Even in case of availability of modules with a different capacity, investment of up to ₹20,000 can be made. Investment can be made in more than one module, or as a certain percentage cost contribution of a module.

It may be noted that this mechanism shall be akin to investment under the long-term tax-saving infrastructure bonds.

The right fitment

If 10% of the total solar PV modules to be used in a 1-MWp solar PV project (500 of the total 5,000 modules) are offered to citizens for tax-saving investment purposes, it shall attract ₹10 million as equity contribution, equivalent to 7% of the total project cost of ₹150 million. This shall involve participation of over 500 citizens in the solar project. This, in turn, shall facilitate collection of ₹25 billion public investments *annually*, associated with solar PV projects of 2,500 MW worth of capacity.

The upper cap of 10% shall ensure that the equity contribution by the developer does not get diluted below the 20% level, assuming a debt equity ratio of 70:30.

Yet an other mechanism is possible within the existing tax-saving mechanism (long-term infrastructure bonds). As solar energy comes under the infrastructure sector, the IFCs are well within their right to invest public deposits in grid-connected solar PV projects. Now, they may invest in solar projects and, the bond issued to an individual

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[4] http://infrastructurebond.in/section-80ccf-income-tax-act-1961
[5] http://www.rbi.org.in/scripts/BS_NBFCNotification View.aspx?Id=6054
[6] http://www.saraltaxoffice.com/articles/tax-exemption-section-80CCF.php
[7] http://www.geda.org.in/pdf/Solar%20Power%20policy%202009.pdf
[8] http://www.indiaenvironmentportal.org.in/content/rajasthan-solar-energy-policy-2011
[9] http://kredl.kar.nic.in/Draft%20Solar%20Policy%202011-16.htm
[10] http://cercind.gov.in/2010/ORDER/Sept10/Order_255-2010_on_determination_of_bench_mark_capital_cost_11-12.pdf
[11] http://www.cercind.gov.in/2010/ORDER/February2010/Order_Solar_Capital_Cost_Norm_13-2010(Suo_muto).pdf
[12] http://longterminvestmentinstockmarket.blogspot.com/2011/05/number-of-income-tax-payers-in-india.html
[13] http://www.thehindu.com/news/national/article2045422.ece


Courtesy: A M Faruqui/MPRLP

tax-payer citizen may be tagged with the Unique Identification (UID) of the PV module offered.

Making the returns more attractive

As far as return on investment is concerned, a project achieves financial closure only if it is associated with the Internal Rate of Return (IRR) in the range of 12%–14%. Otherwise, it is not viable to set-up the project.

Now, if the project promoters offer returns marginally higher than the returns being offered under the existing tax-saving instruments (8%–9%)[14], but lesser than their capital cost (12%–14%), it shall lead to a win-win situation for both the investors and the project developers, benefitting both of them.

The lock-in period of investment can be fixed at 10 years, which shall be similar to the existing infrastructure bonds. This duration is well within the 25-years lifetime of a solar PV project[15]. Comfort can also be drawn from the fact that the module suppliers/EPC companies offer performance warranties for the entire duration of the project life.

Scheme safeguards

To improve the acceptability of the scheme, the provision of risk-guarantee fund may be explored. This shall ensure a kind of payment guarantee to the investors, who have made investments in solar projects, but could not recover their returns due to project failure. Support under the recently set-up National Clean Energy Fund[16] (NCEF) can be considered.

It may be worth mentioning that solar projects being currently developed under policy initiatives of the government such as the National Solar Mission, state solar policies, Generation Based Incentives (GBI), and so on, are regularly being monitored by several government agencies. A feature unique to all of these programmes is that the incentives are being offered only on actual generation. It is at variance with the customary practice of passing incentives on the basis of capacity. Hence, the chances of projects not getting commissioned, or under-performing, would be negligible and, so shall be the chances of default of repayment to the investors after the expiry of the lock-in period.

The developer may issue a share/bond certificate to each investor, associated with a unique number of the PV module allotted. It may be noted that under the JNNSM, it has been made mandatory for each solar PV module to be inscribed with a unique identification number[17]. Due to the unique identification number allotted to each module, the probability of duplicity in issuing the same module to more than one investor gets ruled out.

Benefits to project developers

With access to low-cost public deposits (available at 8%–9%), for a tenure of 10 years, and with no repayment obligations during the lock-in period, the project shall become attractive for both entrepreneurs and financiers alike.

Now-a-days, most of the RE projects being set-up in the country are in the Independent Power Producer (IPP) mode. The investors (private equity/ venture capital / foreign investments) are keen to unlock the project value after commissioning of the project, simply by taking the route of the capital market.

With common citizens as equity holders at the stage of project inception itself (500 investors in 1 MWp project), it shall further facilitate the entrepreneur/developer to leverage the market through the Initial Public Offer (IPO) route.

Availing the income tax depreciation benefits will not be a difficult task for the project developers, as this mechanism shall be similar to other tax-saving infrastructure investments.

Impact on existing schemes

The programme shall not decrease the availability of low-cost capital towards setting up infrastructure based projects in the country, as solar energy (part of

[14] http://www.finance-trading-times.com/2011/02/2212-pfc-infrastructure-bonds-for-tax.html
[15] http://cercind.gov.in/2010/November/Signed_Order_256-2010_RE_Tariff_FY_11-12.pdf
[16] http://pib.nic.in/newsite/erelease.aspx?relid=58419
[17] http://mnre.gov.in/pdf/jnnsm-g170610.pdf

the RE sector) falls under the category of power, which is part of the infrastructure domain.

With the assumption of 5% participation by citizen tax-savers in the proposed tax-saving mechanism, the likely deposits shall be capped at ₹25,000 million, which is less than 10% of the maximum value of ₹300,000 million, permitted to be collected under section 80CCF of I-Tax Act[18]. This means that enough funds shall be available to support other infrastructure sectors like roads, railway, ports, airports, and so on.

On the other hand, it shall provide citizens with yet another income-tax saving opportunity, thereby, enabling them to participate in the country's green energy revolution.

Going up the project path

With a large number of solar projects currently being implemented in the country, it may be difficult for people to choose the right type of projects for investment purposes.

To assuage the fears of the ordinary citizens, having limited knowledge on solar energy technology, it would be useful to undertake a grading exercise of the projects based on certain parameters like track record, technical competence, supplier's credentials, contractual terms, project management capability, revenue generation, profitability, and so on. The accreditation process may categorize project entities into various grades, which may be made publicly available to increase the acceptability of the scheme.

Reputed credit rating agencies (like Credit Rating and Information Services of India Ltd [CRISIL], Internet Content Rating Association [ICRA], CARE, and so on), may be involved in this activity. It may be noted that in the National Solar Mission, entities (channel partners) have been accredited under a similar procedure[19].

To ensure transparency in the whole programme, a web-based directory may be created and maintained in the public domain. It should provide up-to-date details of all the graded projects,

Courtesy: DOE/NREL

with their unique module numbers, besides project implementation status, power generation reports, and so on. The above activity shall be enabled by the availability of robust and low-cost project monitoring systems[20].

Weaving together the opportunities

To sum up, this unique business model will be a win-win situation for all the stakeholders, with the following accompanying benefits.

1 Setting up of over 2,000 MWp worth of power projects based on solar PV technology
Helping India to chart out a low-carbon growth trajectory
2 Participation of ordinary citizens in the development of RE
Initially, 1.25 million citizens expected to participate which shall go up in future
3 Availability of low-cost funds for a longer duration to the project developers
₹25 billion worth of funds available at 8%–9%, on an annual basis, for 10 years
4 Reduced equity requirements in the project leading to enhanced participation by entrepreneurs to set up more solar projects
Upto 7% of project capital can be arranged under this route
5 Newer avenues for saving income-tax available to the citizens
Associated with higher returns
6 Better performance of projects
Monitoring by a number of state agencies and by the investor community, facilitated by online directory
7 Creating awareness in the country on using RE technologies
Large-scale participation by ordinary citizens

Even a modest participation from 5% of the income-tax paying individuals towards development of solar energy projects shall provide a thrust to its development in the country, by way of funding support of ₹25 billion, associated with capacity development of 2,500 MW.

With the passage of time, this mechanism may lead to wider participation from the 25 million strong tax-paying community in the country, abetting the development of the solar sector in India, thereby, helping it meet the targets set under various solar programmes, including the ambitious Jawaharlal Nehru National Solar Mission.

Thus, large-scale participation of ordinary citizens in the development of the RE sector shall help the sector get the desired attention from key stakeholders, be it policy-makers, regulators, investors, financiers, entrepreneurs, and, also, the common man, thus, helping India lead the global clean energy movement.

The views presented in this article are strictly those of the author and not of the organization to which he belongs.

[18] http://indiabudget.nic.in/bill.asp
[19] http://mnre.gov.in/pdf/channel-partners-offgrid-decentralised-solar-application.pdf
[20] http://www.solarnetholdings.com/product_detail.aspx?gid=685&pid=22457


सत्यमेव जयते
Government of Gujarat
Nature cares for us,
Let us care for it too
Let us take a pledge to create a greener, safer and a more sustainable future.
Let us become 'Champions for Nature'
Gujarat's Contribution for Protecting the Environment
1st in India and fourth in the world to set up a separate climate change department
Above ₹ 15 crores provisioned in the current budget, for mangrove plantation of over 16,830 hectare helping in conservation of coastal areas and marine life
Focus on Clean Energy
– Asia's biggest Solar Power Park being set up at Charanka with 500 MW generation capacity
– With the second highest potential of wind farming in India, Gujarat is currently expanding on an installed capacity of 1,864 MW
Highest Carbon Credit earning state of the country
... and many other initiatives
Issued by Commissionerate of Information, Gujarat
*Above facts and figures are as of May 2011
Shri Narendra Modi
Hon'ble CM, Gujarat

CSP TECHNOLOGY

WITH AN INDIGENOUS TOUCH

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Courtesy: DLR

Background

Quite often, solar photovoltaic (SPV) is in the news for a variety of reasons. Of late, solar thermal technology, in the form of concentrated solar power (CSP) systems, is catching worldwide attention. The reasons are not hard to find for this type of technology consideration, amongst a growing tribe of stakeholders. The CSP thermal technology for electricity production is an ongoing process. Several organizations the world over are competing with one another in the race for technology with better conversion efficiency and, importantly, for lower capital costs. Even India has joined the race, though the initial trends of technology development/adoption leave enough to be desired.

Expected gains

Let us first take a quick look at the expected gains from the CSP mode of power generation. The following are some of the most important advantages that can be reaped from a megawatt scale solar thermal power plant.

- Concentrating solar collectors are quite capable of producing high temperature heat. It can be used to run steam and gas turbines, combined cycles or standalone engines for electricity.
- SPV technology relies on expensive battery storage. In contrast, thermal storage systems allow for night time solar power generation.
- CSP technology offers large scale potential for sustainable development. For example, the concentrating solar power potential exceeds the global electricity demand by as much as 100 times, if, not more.

CSP: the process flow

The CSP thermal technology is mainly divided into the following three processes.

- Thermal concentration field
- Thermal storage
- Steam generation and turbines to produce electricity

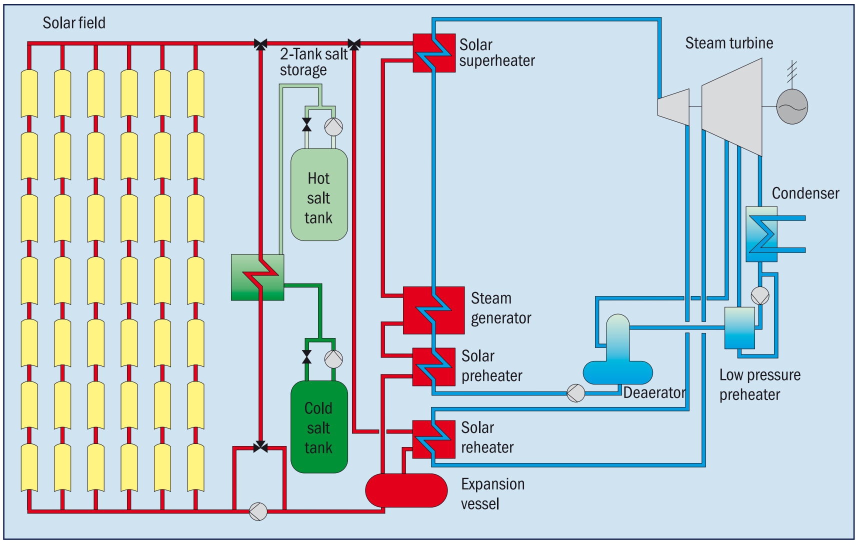


Figure 1 Solar thermal power plant – line diagram

Thermal concentration field

Heat from the sun is concentrated, collected, and then stored. There are four principle techniques to concentrate the heat from the sun. Figure 1 gives a line diagram of a solar thermal power plant.

Parabolic trough technique

In this case, solar energy is concentrated by parabolically curved, trough shaped collectors onto a receiver pipe. It runs along the inside of the curved surface. This energy heats the oil flowing through the pipe. Heat energy is then used to produce electricity in a conventional steam generator. The temperature attained in this process touches about 400 °C.

Central receiver (solar tower)

This type of technology makes use of a large number of sun tracking mirrors, better known as heliostats. The idea is to focus sunlight on a receiver at the top of a tower. A heat transfer fluid heated in the receiver is used to produce steam. It is used in a conventional turbine generator to generate electricity.

Parabolic dish

These consist of a parabolic shaped, point focus concentrator in the form of a dish. It reflects solar radiation onto a receiver mounted at the focal point. These concentrators are mounted on a structure with a two-axis tracking system to follow the sun. The heat, thus collected, is then used directly by a heat engine mounted on the receiver moving with the dish structure.

Linear Fresnel Reflectors

It makes use of lenses or mirrors to direct a large area of sunlight onto a small surface. The key advantages of using this technology are in terms of a simple and robust design. Take for example the flat mirrors, which focus the sun's heat onto long elevated receivers. The receivers are made of boiler tubes within which water flows. The concentrated sunlight boils water in the tubes, thus, generating solar steam for use in power generation.

Parabolic trough technology: the cutting edge

Out of the above four techniques, only the first one, that is, parabolic trough, is a time tested and proven CSP technology. The other technologies are relatively new in comparison and at various stages of commercial development.

The main components of this technique are parabolic trough-type mirrors with linear focus and receiver tubes. They have glass components, such as mirrors and receiver tube made of metal tube in evacuated glass tube (refer Figure 2 and 3).

The design challenge

Accuracy of the parabolic shape of the mirrors is critical. This helps in

Courtesy: Lkruijsw

concentration efficiency by focusing on single line. Bending the glass sheets to the exact contour of parabolic shape is a challenge due to complicated glass processing. Being an insulating material, the glass takes a long time to heat up. Thus, the thin glass sheets have to be uniformly heated, so as to prevent their cracking during heating. This is important because the area of the glass sheets to be handled is large. After heating the sheets to softening point, they have to be bent to take the exact shape using properly designed moulds. In turn, mould design is very important and accuracy of the mirrors depends on its proper design. Similarly, after bending, the glass sheets have to be rapidly cooled. Necessary precautions have to be taken to prevent them from warping out of shape. This is another critical point in the process and has to be done by using proper jigs. Care has to be taken to ensure that the smooth surface of the glass sheets is maintained during cooling of the glass. All these processing steps have to be undertaken carefully by highly experienced hands. Ensuring process quality control is also very important for the accuracy of the parabolic shape and better efficiency of the mirrors.

Thin coating

Once the glass sheets are bent to the required parabolic shape, they have to be coated with metal on convex side to form mirrors. Reflectivity of the mirrors is important and this depends on the quality of the metallic coating. It is a very thin coat of silver or aluminium of about 1µm thickness. The metal coating has to be protected with a thin film of heat resistant paint. This ensures long working life of the mirrors. There is a proposal to make another addition in the design.

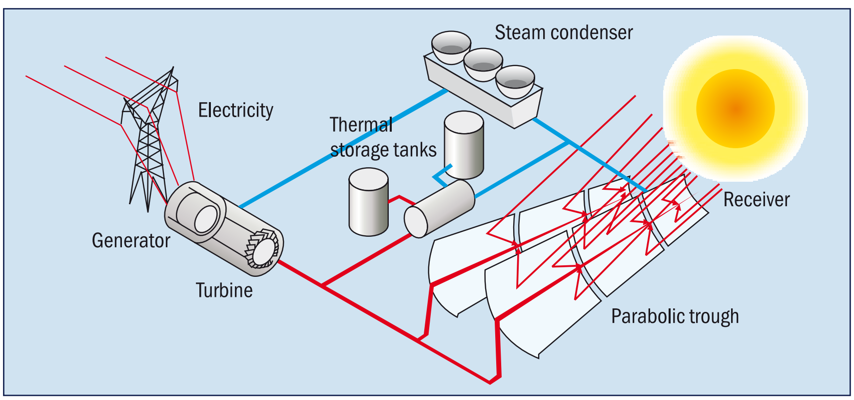
Innovating for better gains

Normally, one more protective layer of polymer is added to increase the life of the mirrors. Silvering (as this process of metal coating is called) could be carried out manually for silver metal coating. However, it happens to be an expensive process. Moreover, the thickness attained is not uniform, which results in poor quality of coating and lower reflectivity.

Our company intends to use state-of-the-art vacuum metalizing technology. The main objective is to achieve a uniform coating thickness that can extend the life of the coating. In this way, optimum reflectivity from the mirrors can be expected. A thin layer of heat resistant paint coat is used for protection from thermal deterioration. Polymer layer is used for extra protection. Receiver tube is another critical component affecting the energy conversion efficiency of the heat concentration system. It is a metal tube with non-emissive coat as surface finish for minimum emissivity to prevent thermal losses. In this component, a metal tube with a higher coefficient of expansion is fitted inside the evacuated glass tube. It has a negligible coefficient of expansion. Expansion of the metal tube is taken up by fitting expansion bellows on the metal tube at both the ends. Here, the real challenge lies in maintaining vacuum throughout an active life (25 years or more) of the system. Special end covers with metal-to-glass sealing are provided for this purpose. With a special coating on the glass tube, we expect to minimize the effective emissivity of the receiver tube.

Additional material changes

It is our clear cut intention to use thin glass sheets of 2 mm thickness. Accordingly, the supporting structures required shall be of a very lightweight material. It is expected to result in reduced overall cost of the solar thermal



Fugure 2 Parabolic trough – operating principle

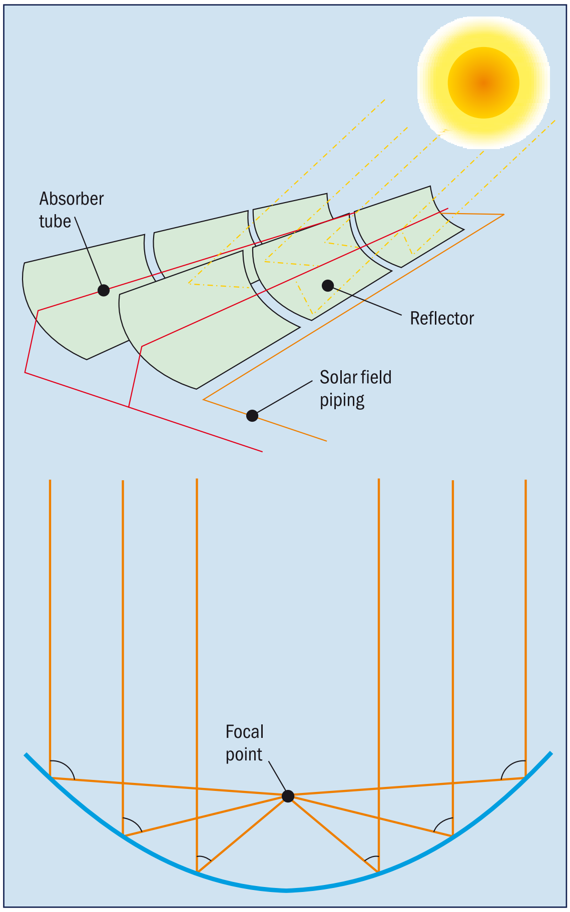


Figure 3 Thermal concentration principle – parabolic troughs

concentrating field. With all the above arrangements, we expect to reduce the costs of concentration field by at least 40% as compared to current international costs. All our designs, processes, and complete components shall be patented.

Thermal storage is another area where we have tried to reduce cost by using new materials along with traditional materials. We plan to use solid metals in a certain form and forge designs for faster heat transfer as storage materials. We also plan to use fewer materials of superior quality for storage tanks and pipelines using some novel designs. Storage tanks could be partially located underground for better insulation, in order to minimize thermal losses.

Few more design considerations

Special heat exchangers with enhanced heat transfer rates have been designed in-house for steam generation. These are of a desirable quality to operate the electrical turbines. Rest of the power generation unit components shall conform to the best available design standards available, internationally.

In any thermal power plant, the use of suitable quality water for steam generation as well as for cooling purpose is an important factor. The CSP-based thermal plant is no exception. It is, thus, more important for these new generation power plants to be located in water-rich areas and not in desert areas. Ideally, we should use technology, which requires minimal or no water. For example, using hot air to operate gas turbines for electricity generation is a case specific example.

Alternately, using water for generation of steam and using air for cooling should be another option to reduce the dependence on water. Both these options could be used though with some compromise in the solar energy conversion efficiency. It would be most advantageous to locate a CSP thermal plant in areas having water of any quality, typically a seacoast. This will relieve us of all the problems related to the use of water as desalinated water could be produced at negligible cost using waste energy from solar plant.

Seeking waiver

The technology described above is a perfect solution to meet the fast growing energy requirements in India. Perhaps, availability of indigenous CSP technology should be given precedence over the expensive choices available at the moment. It may be suitable to seek concessionary support from the Ministry of New and Renewable Energy (MNRE). This could well be in terms of waiving off the experience as being sought from the technology providers under the ambit of the Jawaharlal Nehru National Solar Mission (JNNSM). After all, CSP technology providers cannot vouch for any tall claims unlike the PV technology counterparts. Also the government should provide grant and soft loans for research and development. This provision is already present under the JNNSM but due to some reason The MNRE is yet to implement this provision.


Courtesy: DLR

Courtesy: UN Photo/R Kollar

The energetic promise

In India's strategy, the sun occupies the centre stage, as it should, being literally the original source of energy. We will pool all our scientific, technical, and managerial talents, with abundant energy to power our economy and to transform the lives of our people. Our success in this endeavour will change the face of India.

— Hon'ble Prime Minister Dr Manmohan Singh at the launch of The 'National Action Plan for Climate Change', 2008

MAPPING INDIA'S SOLAR FUTURE

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Background

As per the 2011 census, the population of India stands at 1.21 billion. Currently, more than 60,000 villages, mostly located in the states of Jharkhand and Odisha, are not electrified. Providing the much needed energy security to its citizens is one of the biggest challenges that the country faces today. Also, the country is heavily dependent on the import of petroleum products. We are importing coal to meet the needs of ultra mega power projects. The nuclear power production, once touted as a cheap and secure route of power generation, is yet to touch the 5,000 MW mark. These facts and figures reveal a huge opportunity for renewable energy technologies, particularly solar energy, to prove its worth.

The long drawn solar promise

The currently installed power capacity in India is 173,626.40 MW. Out of this, power supply from renewable energy is 18,454.52 MW (about 11%). Amongst renewables, wind power stands tall at a total installed capacity of 14,158 MW (as on 31 March 2011). In comparison, solar photovoltaic (SPV) grid interactive power capacity is a meager 37.66 MW. However, with little push, this capacity can reach appreciable heights. As is well known, India receives solar energy equivalent to more than 5,000 trillion units per year. Further, the daily average solar energy incident per square metre varies between 4–7 units, much in accordance with the location. Also, most parts of India receive about 300 clear sunny days. All this augurs well for solar energy development through well devised policy-cum-programme initiatives. In this context, let us take a look at the recently initiated Jawaharlal Nehru National Solar Mission (JNNSM).

JNNSM: arrives on time

The JNNSM, launched in 2010, has been a blessing for the country. Since the launch of the mission, there has been a dramatic change in the way solar technology is perceived, both by the companies and the customers. The mission was launched at the time when the price of solar modules was getting reduced by almost 50% in 2009. This has made SPV systems more affordable and accessible than ever before. It is now widely believed that the solar mission targets are achievable. Table 1 shows the broad targets of the mission.

Table 1 Broad targets of the JNNSM

Year	Total solar grid power capacity target in MW
2022	20,000
2030	100,000
2050	200,000

The period 2022–2050 is expected to generate a staggering investment opportunity of ₹850,000 million to ₹1,050,000 million. If, realized, it is likely to make India a global leader in solar energy.

Site consideration

As stated above, solar resource availability is highly dependent on a given location. The site-specific considerations play a pivotal role in the techno-economic viability of solar power generation. With such massive investments involved, it is very important for the government and the private players to analyse the location of the investment. Simply put, the project developers need to study the local conditions with a clockwork precision. Realizing the importance of the site, a study was undertaken at the Center of Ecological Sciences, Indian Institute of Science, Bengaluru. The main objective of this study was to analyse the hotspots of solar potential in India and, thus, attain clarity on investment-specific decisions.

A techno-economic analysis was also undertaken for solar technologies like SPV and concentrated solar power (CSP). This study is expected to help potential investors with investment grade research, which can help those taking decisions to get the best return on their investment.

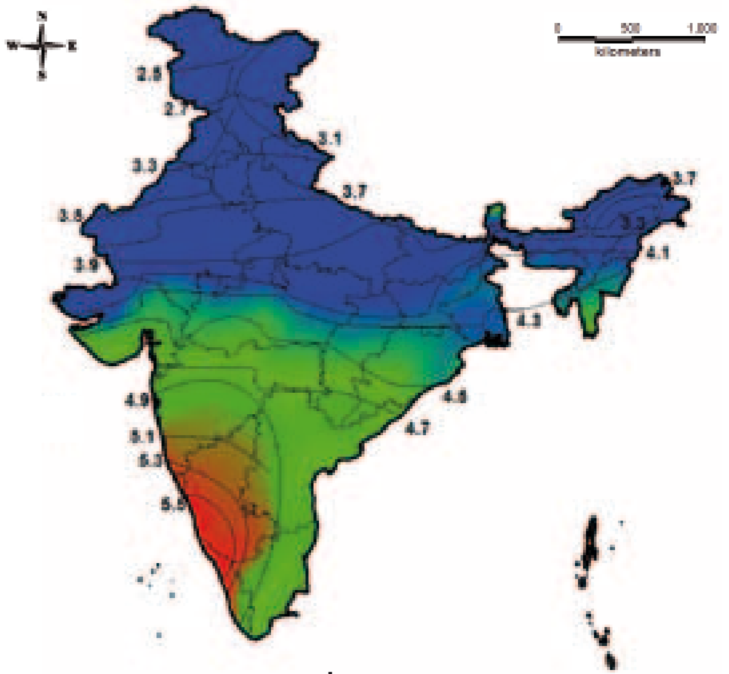
Solar mapping

Currently, India has only 45 solar radiation centres spread across the country. Thus, it was a tough task to study the site variability with such sparse data. The present study was carried out with the help of NASA meteorological dataset, as available for a period of 22 years. Radiation data was available for over 350 points in India and was observed to have a variation to that of ground observed data. Under this study, maps depicting solar radiation availability were created to analyse the radiation patterns. In all, 13 maps were published in this finding, which included all the monthly maps as well as an average radiation map. The maps with detailed analysis are available on the website <www.sciencedirect.com> along with an article titled "Hotspots of Solar Potential in India". The article was published in Renewable and Sustainable Energy Reviews.

Outcome of the study

It is observed that for effective investment opportunities, average radiation higher than 5.25 kWh/m^2/day would be required. Solar radiation between 4–5.25 kWh/m^2/day is considered to be good, below that it is of little value. From the monthly maps, it can be concluded that global insolation, throughout India, increases from January to May (gradually from south to north India). Insolation decreases after May. A slight increase in

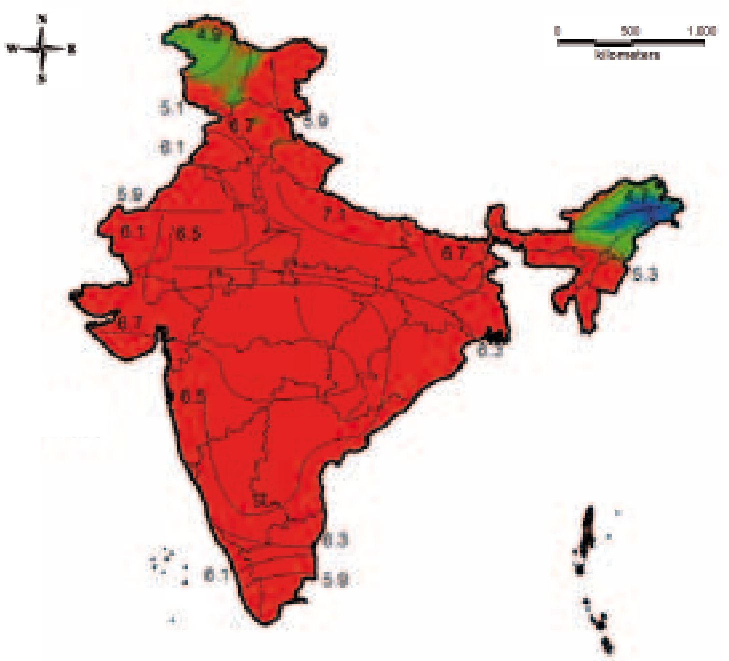

Courtesy: David Trattnig



January
Insolation on Horizontal Surface (kWhr/m²/day)

> 5.25
4 – 5.25
< 4

Map 1



April
Insolation on Horizontal Surface (kWhr/m²/day)

> 5.25
4 – 5.25
< 4

Map 2

radiation is observed in central and eastern India, but this can be attributed to a decrease in cloud cover in the post-monsoon period, in these regions. Few of the maps (refer Map 1–3) are given here and the rest can be accessed via *Science Direct*.

Map 4 shows the average variation of solar radiation with area within the dotted lines indicating places with radiation greater than 5 kWh/m^2/day.

The places with insolation higher than 5 kWh/m^2/day are considered to be the hotspot (s) of solar potential in India. It was found that the Gangetic plains (Trans, Middle, and Upper), the plateau (central, western, and southern) region, the western dry region, Gujarat plains and hill region, west coast plains, and ghat regions receive annual global insolation above 5 kWh/m^2/day. These zones include states like Karnataka, Gujarat, Andhra Pradesh, Maharashtra, Madhya Pradesh, Rajasthan, Tamil Nadu, Haryana, Punjab, Kerala, Bihar, Uttar Pradesh, and Chhattisgarh. The eastern part of Ladakh and some parts of Himachal Pradesh, Uttarakhand, and Sikkim which are located in the Himalayan belt are the solar hotspots. These cover nearly 1.89 million km^2 (~58%) area of the country and present favourable prospects for solar energy utilization.

Solar: the new power house

The SPV is a semiconductor based technology, which converts sunlight directly into electricity. The European Photovoltaic Industry Association (EPIA) and Greenpeace predict that by 2050, solar power will meet about 21% of global electricity needs.

As per the current estimates, more than 3 million people, globally, benefit from small SPV systems. Also, the price of solar panels has reduced by 50%–60% in 2009, as compared to 2008. This has brought the per peak watt price of solar modules to less than ₹100.

India, currently, has very few major PV plants connected to the grid. The grid-connected SPV systems are in states, such as West Bengal, Maharashtra, Karnataka, and Punjab. A large number of such installations are expected to come up in the best sun-soaked regions of the country—Gujarat and Rajasthan. (Please note that the capacity figure has been purposely avoided keeping in view the fluctuating nature of market reports). A SPV-based system, without battery backup on-site, may actually be able to provide just about 67.5% of the maximum power output, on a clear sunny day. This is attributed to factors, such as time of the day, internal heating, dust, module mismatch, wiring, and DC-AC conversion losses affecting the overall system performance. If, a battery is added to the system, the net power output may further reduce by 6%–10%.

Direct radiation driving the CSP power

The SPV modules are capable of using both direct and diffuse components of solar radiation. In contrast, solar thermal power systems work with just the direct beam radiation. In this case, sun rays are concentrated to focus it on a point or a line.

Depending on the design of the plants the temperature may vary from 300–1500 °C. Heat collected in a plant can be stored in various forms for later use. A distinct benefit of CSP over SPV technology is the availability of a heat storage option. It is relatively simpler and cost effective as compared to conventional battery storage. The CSP generally operates as a hybrid system utilizing air during winters and as a combined cooling system during summers, in order to optimize the running cost. The CSP has very specific requirements, due to the inherent nature of technology and the cost involved. These require about 2 ha (20,000 m^2) in semi-arid and arid regions with clear skies.

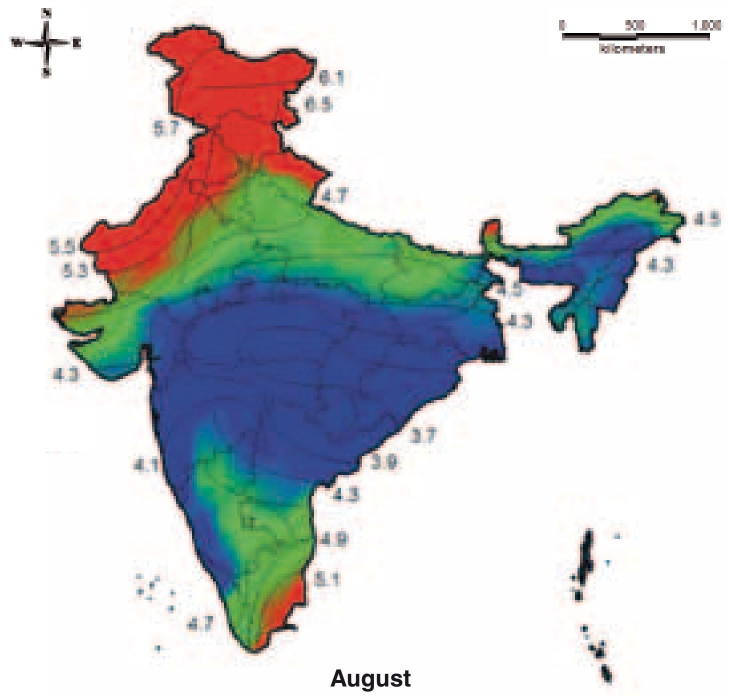
It is very important to have knowledge of yearly direct solar insolation data prior to their installation. The threshold value is generally 1900 kWhr/m^2/year to 2100 kWhr/m^2/year.

CSP: presenting great opportunities

Nearly 50% of the investments in CSP-based power plants is used to purchase locally available materials like steel, mirrors, concrete, besides the labour cost. It, thus, provides socio-economic stability and local support. Undeniably, CSP adapts well to the Indian socio-economic conditions, but needs vigorous research and development for up-scaling. The CSP systems, however, can only be installed at specific places. As such, electricity generated may be transferred to different places using dedicated High Voltage Direct Current (HVDC) arrangement. In the present context, serious efforts are underway to design and develop CSP plants suitable for Indian conditions. The solar mission targets electricity generation of 500 MW by 2013 and 10,000 MW by 2022.

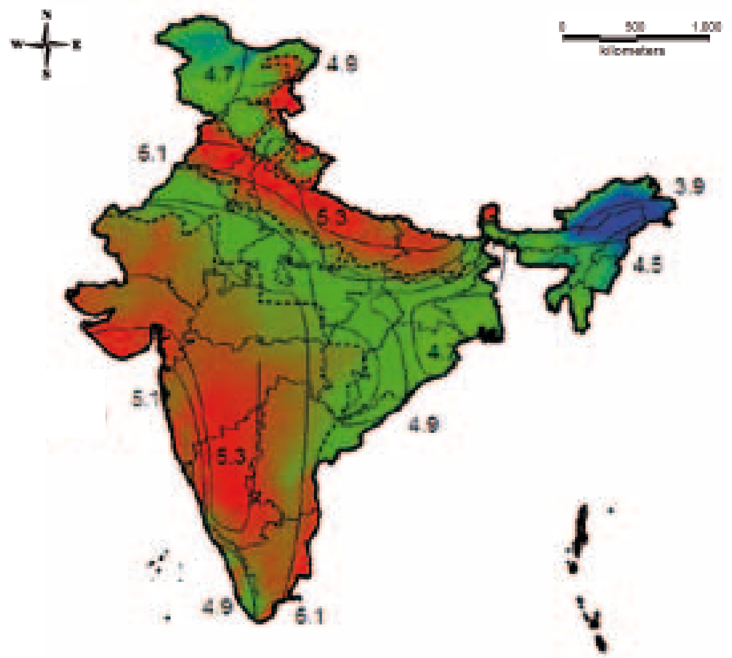
The sunny path ahead

Solar hot spots can be easily converted into major hubs of power generation. However, what is really important is to delve deep into site-specific considerations. Thereafter, a clear understanding of the relevant solar technology nuts and bolts is required from a variety of end-use considerations. It is about time that we witness both the SPV and solar thermal power plants dotting the rural and urban landscapes alike. Thus, on an optimistic note, today, India is well poised to become a global leader in solar energy in the near future.



August
Insolation on Horizontal Surface (kWhr/m^2/day)
> 5.25
4 – 5.25
< 4

Map 3



Average value throughout the year
Insolation on Horizontal Surface (kWhr/m^2/day)
> 5.25
4 – 5.25
< 4

Map 4

BEYOND LIGHTING

SOLAR TECHNOLOGY FURTHERING THE UNITED NATIONS MILLENNIUM DEVELOPMENT GOALS

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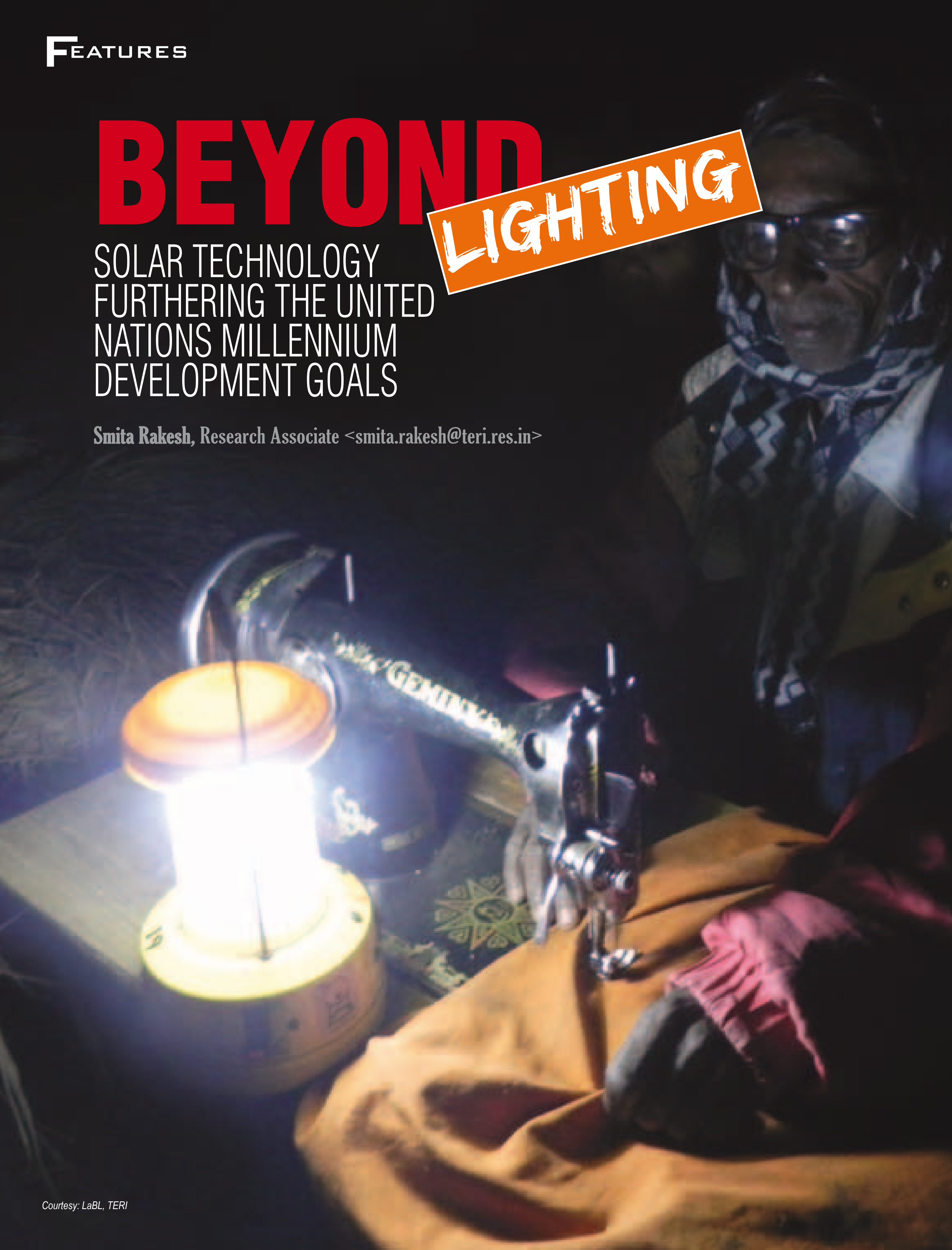

Courtesy: LaBL, TERI

Background

What kind of benefits does one perceive when one talks about providing electricity to remote rural areas? We think of children studying or women doing household chores more comfortably. However, lighting positively impacts several aspects of development and goes far beyond these conventionally expected benefits. It is heartening to know that there is a far greater variety of lighting-induced impact. Lack of access to energy, in general, and to lighting, in particular, is a major impediment to development. Thus, sometimes, even a small intervention, such as a solar lantern acts as an agent of change, catalysing enormous shifts that contribute to social and economic development.

Dandapadia and Talapadia, two villages in Odisha, where The Energy and Resources Institute (TERI) has set up solar charging stations under the Lighting a Billion Lives (LaBL) campaign, stand testimony to the above fact. The solar lanterns have become an inextricable part of the lives of these inhabitants. These two villages are situated in the Tangi Chowdhwar block of Cuttack district. Recognizing the need for a cleaner and more reliable lighting facility, TERI, with the help of a local NGO partner, 'SAMBANDH', has set up the charging stations in these villages. This case study outlines some of the unconventional benefits that spearhead the revolution that lighting brings about in peoples' lives.

Livelihood enhancement

Access to clean and better quality lighting directly contributes to an increase in income, simply by adding more productive hours to the day. The villagers can now dedicate more hours in pursuing their vocations, such as mat making, leaf plate making, bamboo mat making, basket and plate making from Sal leaf, tailoring, and so on, and can also do the work much better and faster. This is an additional source of income for them, since farming is both seasonal and dependent on the monsoon. The existence of LaBL charging station in the villages now enables them to put in three extra hours for such activities. This has resulted in doubling of their incomes. In most cases that we surveyed, the extra income is being spent on their children's education. It is heartening to note how one change leads to another, thus, having a cascading effect on several spheres of life.

Change in gender dynamics

In order to achieve all inclusive growth, TERI encourages more and more women

Courtesy: LaBL, TERI

Courtesy: LaBL, TERI

to come forward as entrepreneurs and run the solar charging stations. Fortunately enough, many women have come forward to play the role of change makers in their villages. This has ensured that the focus does not shift from the lighting-related needs of women and has resulted in more and more women now using solar lanterns. For these women, apart from getting a chance to voice their concerns and needs, light also takes care of their basic safety and security. Thanks to the solar lanterns, mobility is definitely easier now, more so for the womenfolk. Most of these villages do not have toilets in the houses, thus, forcing the women to go out in the fields. Now, at least, they can use the solar lanterns when they go out at night.

A new found pride

Parbati is an enterprising lady operator of the LaBL solar lantern charging station in Dandapadia. She also supports her husband in running his grocery store. Parbati agrees to a positive change in her status within the village, and adds that she herself feels more confident in voicing her opinion during the village meetings. Indeed, she has now become a household name. She proudly echoes her sense of achievement when the entire village comes to her doorstep to drop their lanterns every morning. She feels that she is doing her bit for the village folk.

Enhancing health facilities

A number of remote villages do not have easy access to health care facilities. Most people have to travel a sizeable distance in order to avail any medical help. Emergencies and critical situations at night are a nightmare, since it entails travelling through areas infested with wild animals, snakes, and other insects. There are innumerable incidents of snake and insect bites, while commuting from one place to another, more so after sunset. In such cases, the lantern, being a mobile source of lighting, has made their lives somewhat easier. Villagers do not have to think twice or wait until dawn to take patients to the nearest possible health facility. For villages like Dandapadia and Talapadia, SAMBANDH has set up a health centre at Kochila Nuagaon. It serves the medical needs of villages within 10 km radius. The villagers visit the health centre, whenever they need, even during the evening hours with solar lanterns in their hands. In case of a serious illnesses or emergencies, such as snakebite when patients cannot walk, it is a usual practice to carry them in baskets to the health centres. Along with carrying the patient, the carriers have to