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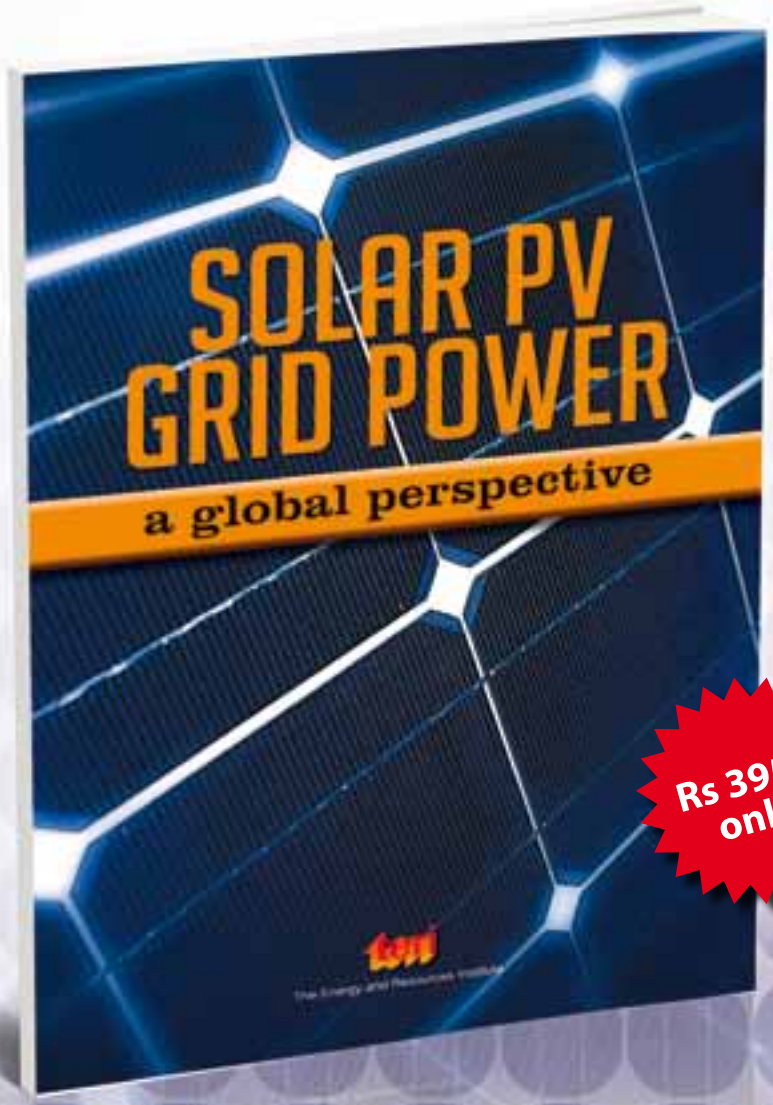

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SOLAR THERMAL ENERGY: GROWING SCOPE FOR SOLAR RADIATION ASSESSMENT

Presently, serving as Director in the Ministry of New and Renewable Energy (MNRE), Dr Ashvini Kumar is the Divisional head for Solar Thermal Power and Solar Thermal R&D programmes including solar radiation resource assessment and testing centres for solar thermal devices and systems under the Jawaharlal Nehru National Solar Mission (JNNSM). He has also worked at the Solar Energy Centre of the Ministry and has been instrumental in establishing solar thermal testing facilities there. Prior to joining the Ministry in 1986, he worked at IIT-Delhi after completing his Ph.D. He has co-authored three books; several review articles, 80 research papers and over 50 International Journals. Currently, he is editing the SESI Journal, a technical journal brought out by the Solar Energy Society of India.

With more than 30 years of experience in the area of solar energy, Dr Ashvini Kumar talks to *The Solar Quarterly* about the emerging thrust on solar radiation measurement programme moreso in the backdrop of JNNSM.

You have had a long drawn practical experience and a direct association in the solar thermal energy area in varying roles and responsibilities. Kindly tell us about your most cherished aspect of this fast evolving technology route.

I have been involved in this sector for a long time now. Basically, I started as a researcher at IIT Delhi (IIT-D) for the doctoral programme followed by my tenure as a scientific officer there. At that time, (during the early eighties), this sector was in its nascent stage in India. There were lots of opportunities to work, but limited options to get any financial support. The Department of Non-Conventional Energy Sources (DNES) was also in its formative stages. But, certainly, it provided a focal point for an effective consolidation of R&D efforts. At IIT-D, it was a very inspiring experience, and I still cherish being a part of that initiative. Later, I joined the then Department of Non-Conventional Energy Sources (DNES) and directly started working at the Solar Energy Centre (SEC), Gual Pahari, Haryana.

Till now, the focus of solar energy programmes was largely on off-grid applications and meeting heat requirements in the low temperature applications. Now, the focus is on capacity addition through solar power projects. That requires good quality data to optimally design the projects and achieving minimum costs.

During that time, solar thermal industry was shaping up and thermal applications such as box type solar cookers, solar hot water systems, solar stills and solar air-heaters, were being manufactured in the country. These were largely based on indigenous efforts. The Government had started popularizing these applications by providing some financial support for good quality products. This necessitated setting up standards and the testing cum characterization facilities. My stay at SEC helped me in contributing to these innovative efforts. Of course, the moment of declaration of "National Solar Mission", which aims to give solar applications a decisive boost to be able to contribute meaningfully to the overall energy situation in the country is the most cherished moment for all solar energy professionals and enthusiasts including me.

Solar photovoltaic modules often lose power at higher temperatures (i.e., under bright sunshine availability). Do any of the modern day solar thermal systems suffer from this type of disadvantage in any manner?

This is not entirely true about solar photovoltaic technology. The whole sector is evolving, and technologies are emerging to address various field-related issues. In fact, the ultimate parameters are the per unit cost of generation and the accompanying life of the system. We are all witnessing the industry/market growth and fall in the costs. As a part of the Mission, significant objective is to attain grid parity by 2022, but the present cost trajectories suggest that it may happen sooner than expected. We all must appreciate that all the solar systems, especially the part which collects solar energy, are meant for an outdoor exposure. It is characterized by the prevailing air temperatures, wind velocity, solar radiation (UV-component too, whatever is able to reach the surface) and other weather-related elements. Depending upon the materials used, degradation is imminent.

I do not understand what you mean by 'modern day' systems. Are these the polymers reflecting and transparent surfaces, or the anodized aluminium kind of reflectors? Yes, there are issues related to their degradation and loss of efficiency because of that. But, all these effects have to be examined in a specific perspective.

Solar radiation availability data is presently available from both the sources – national and international. How important is it to know the most credible source from the key consideration of designing a well-performing solar system under the actual field operating conditions?

Indian Meteorological Department (IMD) is a statutory body of the Government of India for monitoring weather parameters including solar radiation across the country. Based on the long-term series of data available with it, handbooks were made available. This data is based on actual surface measurements, and in principle, is the best. However, with the launch of Jawaharlal Nehru National Solar mission (JNNSM), the activity level has got enlarged covering even the remote areas for power generation. These were the missing gaps in the availability of data. Various stakeholders then got in touch with the global organizations to have data, which basically is the data estimated from satellite images, or, based on some correlations. So, it is anybody's guess about the uncertainties being present in the data. Since solar power generation, like any other solar application, is quite capital intensive, availability of accurate data is the key determinant. That's why, the Ministry of New and Renewable Energy (MNRE) took a major initiative in augmenting network of solar radiation monitoring stations

The availability of solar radiation is strongly dependent on micro-climatic conditions and the geographical parameters represented by latitude, longitude, and altitude. There are a few technical references suggesting that solar irradiance may be considered same in a radius of 5 km for such land terrains.

with emphasis on sites having high potential for solar power generation. To begin with, 51 such stations have been added so far, and Centre for Wind Energy Technology (C-WET) has been assigned the task of implementing this project. More such sites are envisaged to be covered in the second phase.

Solar energy resource assessment seems to have gained an added prominence more so under the ambit of the JNNSM. What exactly has changed since the early inception of the solar energy programme in the country then and now?

Till now, the focus of solar energy programmes was largely on off-grid applications and meeting heat requirements in the low temperature applications. Now, as I said earlier, the focus is on capacity addition through solar power projects. That requires good quality data to optimally design the projects and achieving minimum costs.

Solar radiation data is normally treated to be a representative data within a radius of 50 km or so. Does this notion prevail more so in the backdrop of the climate change issues, etc.?

The availability of solar radiation is strongly dependent on micro-climatic conditions and the geographical parameters represented by latitude, longitude, and altitude. The aerosols in the atmosphere have a detrimental effect on the solar irradiance of a place, especially its direct component. In case, the terrain is flat, not much change is expected in solar irradiance for long distances. There are a few technical references suggesting that solar irradiance may be considered same in a radius of 5 km for such land terrains.

The MNRE has just embarked on a nation-wide project to develop a Solar Atlas for the country. In wide ranging terms, is this going to be the ultimate solar radiation resource tool?

Yes, we expect it to be a source of reliable and accurate data for Indian locations.

Solar radiation measuring instruments offering the highest possible accuracy are generally perceived to be expensive for a majority. Has the MNRE approved any such projects which are aimed at low cost development of instruments like pyranometers, etc.?

I would say that measurement of accurate data is not expected to be done at each and every level. The whole idea of taking up solar radiation monitoring programme by the Government is to make available accurate data. This data should be good enough to design various solar energy applications. For large projects and also for research purposes, there could still be a need to set up solar radiation monitoring stations. However, in these cases, cost is not expected to be a deterrent. I would like to inform that various cheaper models of sensors are also available for the measurement of solar radiation. These can well be used for other usages. However, no such project has been received by the Ministry.

Would you please like to convey any special message to the young readers of The Solar Quarterly more so in the realm of offering any job potential in the specialized area of "Solar radiation resource assessment"?

Solar radiation data monitoring and its analysis is quite an involved activity. We all have to understand that setting up solar radiation monitoring stations in all the locations is not possible. Therefore, help of computer models is still required. Estimation of solar radiation data from the satellite images, their ground trothing against the surface measurements coupled with use of simulation models for interpolation of data between various locations are some of the well recongnized elements of this area. On a pleasing note, solar energy sector is opening up and the competition between the project developers is also gearing up. In this type of scenario, there is a good scope for those professionals who are well-trained and knowledgeable in this area. ■

SOLAR TECHNOLOGICAL UPDATE

Commercial 'green' solar cells may be possible

Developing solar energy that is low-cost, light weight and energy efficient has proven to be one of the greatest challenges the world of science faces today. Although current plastic solar cells are low in cost and easy to produce, these are not energy efficient and, therefore, not easily commercialized. With grant funding from the National Science Foundation, researchers at the University of Pittsburgh are predicting a way to produce solar cells that will offer more flexibility in generating green energy.

Guangyoung Li, assistant professor of electrical and computer engineering at Pitt, explains that most plastic solar cells today are made from a blend of semiconducting polymers and other carbon-rich molecules. Although this material is usable and costs little, it does not assist with energy efficiency-though it could. Li's solution is to use a method called Kelvin Probe Force Microscopy (KPFM) that studies the surface potential of cells through microscopy. Although KPFM is not a new idea, Li plans on using it in a dramatically different way.

This instrument could help Li and others explain the conditions that plastic solar cells should have for better energy efficiency. Currently, plastic solar cells have achieved an energy efficiency rate of 8.6 per cent. Li says if he can produce solar cells with a 10 per cent or higher efficiency rate, they would have a broad impact on the energy market.

Li notes this research will not only help reduce energy consumption, but will also help train young scientists, including the undergraduate and graduate students from underrepresented areas involved in the project.

Source: http://www.solardaily.com/

Nanoparticle electrode for batteries could make grid-scale power storage feasible

Stanford researchers have used nanoparticles of a copper compound to develop a high-power battery electrode that is inexpensive to make, efficient and durable that it could be used to build batteries big enough for economical large-scale energy storage on the electrical grid_- something researchers have sought for years. The research offers a promising solution to the problem of sharp drop-offs in the output of wind and solar systems with minor changes in weather conditions.

The sun does not always shine and the breeze does not always blow and therein lie perhaps the biggest hurdle in making the wind and solar power usable on a grand scale. If only there were an efficient, durable, high power, rechargeable battery we could use to store large quantities of excess power generated on windy or sunny days until we needed it. Now Stanford researchers have developed part of that dream battery, a new electrode that employs crystalline nanoparticles of a copper compound. In laboratory tests, the electrode survived 40,000 cycles of charging and discharging, after which it could still be charged to more than 80 per cent of its original charge capacity. For comparison, the average lithium ion battery can handle about 400 charge/discharge cycles before it deteriorates too much to be of practical use.

The electrode's durability derives from the atomic structure of the crystalline copper hexacyanoferrate used to make it. The crystals have an open framework that allows ions – electrically-charged particles whose movements en masse either charge or discharge a battery – to easily go in and out without damaging the electrode. Most batteries fail because of accumulated damage to an electrode's crystal structure.

The speed of the electrode is further enhanced because the particles of electrode material that Wessell synthesized are tiny even by nanoparticle standards – a mere 100 atoms across. Those modest dimensions mean the ions do not have to travel very far into the electrode to react with active sites in a particle to charge the electrode to its maximum capacity, or to get back out during discharge.

A lot of recent research on batteries, including other work done by Cui's research group, has focussed on lithium ion batteries, which have a high energy density – meaning they hold a lot of charge for their size. That makes them great for portable electronics such as laptop computers. But energy density really does not matter as much when you are talking about storage on the power grid. You could have a battery as big as a house since it does not need to be portable. Cost is a greater concern. Some of the components in lithium ion batteries are expensive and no one knows for certain that

making the batteries on a scale for use in the power grid will ever be economical.

Source: http://www.sciencedaily.com/releases/2011/11/111123151916.htm

2012 Redstone-Sun Cup going electric with solar power at Baja 1000

At the kick-off of this year's Baja 1000, race organizer SCORE and Redstone Energy Group announced the Redstone Sun Cup Challenge, the most challenging automobile race in the harshest racing conditions on the planet. Their aim was to spur the best and the brightest in the electric vehicle and solar technology fields to work with racing teams to develop an electric-powered "EVPV" Baja race vehicle with battery charging provided by solar power. The organizers hope the challenge will serve as a catalyst for developing the clean technologies of the future and, in turn, help reduce the US dependence on fossil fuels. Racing has always translated to big advances on the highways.

Source: http://www.green.autoblog.com/2011/11/23/2012-redstone-sun-cup-going-electric-with-solar-power-at-baja-10/

Nanosolar and EDF Energies Nouvelles commission projects totalling six megawatts

Thin film solar printing leader Nanosolar Inc. announced its supply of Nanosolar Utility Panels to two separate installations totalling close to six megawatts (MWp) in partnership with EDF Energies Nouvelles (EDF EN) and its US subsidiary enXco. These projects are the result of a long-standing collaboration between Nanosolar and EDF EN.

About three MWp of Nanosolar Utility Panels were installed and commissioned in September 2011 as part of a larger EDF EN solar farm in Gabardan, France. ColSun, a joint venture of EDF Energies Nouvelles and Belectric, installed the project using SMA central inverters. This is the first utility-scale installation of Nanosolar Utility Panels by EDF EN.

A second approximately three MWp Nanosolar Utility Panel installation was also constructed and was commissioned in November 2011 near Amity, Oregon. Developed, designed and installed by enXco, the US subsidiary of EDF EN, at two separate sites using Advanced Energy inverters, the projects connect to the Portland General Electric distribution system.

Nanosolar's innovative; roll-to-roll printing process and utility-scale panel design enables the Nanosolar Utility Panel to significantly reduce both manufacturing costs and balance of system costs in multi-megawatt installations. In addition, it is the first solar panel to be certified to operate at up to 1500 system volts. These system design features allow for balance of systems cost savings of up to 30 per cent over competing thin film solar panels in utility-scale power plants. Nanosolar thin film solar cells are printed at the company's headquarters and manufacturing facility in San Jose, California. The Nanosolar Utility Panel can be assembled close to market demand in order to leverage local resources and minimize logistics costs.

Source: http://www.nanosolar.com/company/blog#192

Nanosolar achieves 17.1 per cent aperture efficiency through printed CIGS process

Thin film solar printing leader Nanosolar Inc. announced that the US Department of Energy's National Renewable Energy Laboratory (NREL) has certified an aperture efficiency of 17.1 per cent for a solar cell fabricated using Nanosolar's non-vacuum, low cost printing on flexible foil technology.

Nanosolar's mission is to become the lowest cost solar cell and panel manufacturer, independent of subsidies. This is possible because Nanosolar's unique thin film printing process enables significant cost savings when compared to conventional vacuum based deposition techniques. In addition, its high-throughput roll-to-roll printing method delivers a higher capital efficiency and better materials utilization. Together, these advantages can give Nanosolar a path to lower manufacturing costs than competing photovoltaic technologies.

Source: http://www.nanosolar.com/company/blog#192

Why solar wind is rhombic-shaped

With a new approach to calculating instability criteria for plasmas, Bochum researchers led by Prof. Dr Reinhard Schlickeiser (Chair for Theoretical Physics IV) have found answers to why the temperatures in the solar wind are almost the same in certain directions, and why different energy densities are practically identical. They were the first to incorporate the effects of collisions of the solar wind particles in their model. This explains experimental data significantly better than previous calculations and can also be transferred to cosmic plasmas outside our solar system.

The solar wind consists of charged particles and is permeated by a magnetic field. In the analysis of this plasma, researchers investigate two types of pressure: the magnetic pressure describes the tendency of the magnetic field lines to repel each other, the kinetic pressure results from the momentum of the particles. The ratio of kinetic to magnetic pressure is called plasma beta and is a measure of whether more energy per volume is stored in magnetic fields or in particle motion. In many cosmic sources, the plasma beta is around the value one, which is the same as energy equi-partition. Moreover, in cosmic plasmas near temperature isotropy prevails, i.e., the

temperature parallel and perpendicular to the magnetic field lines of the plasma is the same.

Explaining satellite data For over a decade, the instruments of the near-earth WIND satellite have gathered various solar wind data. When the plasma beta measured is plotted against the temperature anisotropy (the ratio of the perpendicular to the parallel temperature), the data points form a rhombic area around the value one. "If the values move out of the rhombic configuration, the plasma is unstable and the temperature anisotropy and the plasma beta quickly return to the stable region within the rhombus" says Prof. Schlickeiser. However, a specific, detailed explanation of this rhombic shape has, until now, been lacking, especially for low plasma beta.

Collisions in the solar wind In previous models it was assumed that, due to the low density, the solar wind particles do not directly collide, but only interact via electromagnetic fields. "Such assumptions are, however, no longer justified for small plasma beta, since the damping due to particle collisions needs to be taken into account" explains Dipl.-Phys. Michal Michno. Prof. Schlickeiser's group included this additional damping in their model, which led to new rhombic thresholds, i.e., new stability conditions. The Bochum model explains the solar wind data measured significantly better than previous theories.

Universally valid solution The new model can be applied to other dilute cosmic plasmas which have densities, temperatures, and magnetic field strengths similar to the solar wind. Even if the diagram of temperature anisotropy and plasma beta does not have exactly the rhombic shape that the researchers found for the solar wind, the newly discovered mechanism predicts that the values are always close to one. In this way, the theory also makes an important contribution to the explanation of the energy equipartition in cosmic plasmas outside of our solar system.

Source: http://www.sciencedaily.com/releases/2011/11/111115073934.htm

Solar concentrator increases collection with less loss

Converting sunlight into electricity is not economically attractive because of the high cost of solar cells, but a recent, purely optical approach to improving luminescent solar concentrators (LSCs) may ease the problem, according to researchers at Argonne National Laboratories and Penn State. Using concentrated sunlight reduces the cost of solar power by requiring fewer solar cells to generate a given amount of electricity. LSCs concentrate light by absorbing and re-emiting it at lower frequency within the confines of a transparent slab of material. They can not only collect direct sunlight, but on cloudy days, can collect diffused light as well. The material then guides the light to the slab's edges, where photovoltaic cells convert the energy to electricity.

LSCs can do this, potentially concentrating light to the equivalent of more than 100 suns but, in practice, their output has been limited. While LSCs work well when small, their performance deteriorates with increasing size because much of the energy is reabsorbed before reaching the photovoltaics.

The key to decreasing absorption is the microcavity effects that occur when light travels through a small structure with a size comparable to the light's wavelength. These LSCs are made of two thin films on a piece of glass. The first thin film is a luminescent layer that contains a fluorescent dye capable of absorbing and re-emitting sunlight. This sits on a low refractive index layer that looks like air from the light's point of view. This combination makes the microcavity and changing the luminescent layer's thickness across the surface changes the microcavity's resonance. This means that light emitted from one location in the concentrator does not fit back into the luminescent film anywhere else, preventing it from being reabsorbed.

The researchers do not believe that the stair step approach is the optimal design for these LSCs. A more complicated surface variation is probably even better, but designing that will take more modelling. Other approaches may also include varying the shape of the glass substrate, which would produce a similar effect and potentially be simpler to make.

Source: http://www.sciencedaily.com/releases/2011/11/111102125549.htm

Advancements in solar technology will allow more people to power their own homes

A report published in *Inorganic Chemistry* reported about the advancements that are being made in the field of solar energy production. The concept of "personalized solar energy", a model by which people power their own homes using the energy from the sun rather than rely on the power grid, is becoming more viable as scientists have discovered improved ways of storing large quantities of solar energy. The new method of energy storage is similar to plant photosynthesis. Scientists have designed a catalyst that splits water into oxygen and hydrogen that are then stored in fuel cells as fuel.

Dr Daniel Nocera, author of the report, noted that energy use is expected to increase three-fold in the next century as countries around the globe continue to industrialize. The ability to capture and store energy from the sun has the real potential to solve the world's energy and pollution crises.

He further explained that self-sustained living through personalized energy production will release many in third-world countries from poverty. Since wealth is typically scaled alongside energy use, an increase in energy availability will help to increase the standard of living for those living in the world's poorest countries.

Although the initial cost of solar equipment is typically high, the unlimited availability of free energy from the sun is an invaluable asset. Researchers recognize the potential benefits

of energy independence both for the well-being of people and the environment and they hope that the concept will become more mainstream.

Source: http://www.naturalnews.com/027816_solar_energy_homes.html

Three-dimensional solar panel

Scientists at the Georgia Tech Research Institute (GTRI) have developed a prototype of a three-dimensional solar panel that is able to capture sunlight from nearly every angle and transform it into electricity, according to a report in the journal JOM, which is published by the Minerals, Metals and Materials Society. According to researchers, the new cell should be vastly more efficient than current photovoltaic panels. Current photovoltaic cells are made in the shape of flat panels. This means that sunlight must strike the panels directly, and that light falling at the wrong angle is not collected. In addition, flat panels reflect a significant portion of the light that hits them, making it unavailable for electricity generation. The new panels make use of nanotechnology, and are shaped much like a city skyscape – a collection of tower-like structures with small spaces between them. To the naked eye or even a regular microscope, the panels still appear flat; the "towers" are on the scale of microns, or millionths of a meter. This unique shape allows the towers to collect light from nearly any angle. The towers are squares about 40 microns on a side, 100 microns tall and 10 microns apart. This unique shape increases the panels' efficiency for yet another reason. All solar panels have a coating that is designed to trap photons (light particles) rather than reflect them. The thicker the coating, the more photons trapped. However, thicker coatings also reduce the speed at which current-carrying electrons exit the panel, thus reducing its efficiency. Because the new panels capture more light, the coating can be made thinner and thus a single panel can generate more current.

Source: http://www.naturalnews.com/021946_solar_panels_technology.html

India plugs into low-cost solar technology

India seems to excel at making things smaller and cheaper. The $2,500 car and the $35 computer are just two of the country's latest innovations. Now, India increasingly is focused on low-cost solar technology. The front lines of that effort are seen in a tiny village in the Indian state of Rajasthan called Tiloniya. In this sunlit workshop, Tenzing Chonzom solders parts onto a device that regulates electrical currents. It will eventually be connected to a solar panel, allowing it to power everything from lamps to laptops.

Low-cost solar panels Chonzom who is 50 years old, is one among the two dozen people who are being trained in the Himalayan foothills as solar engineers. Chonzom says she was chosen by her community to come here to learn about solar technology. She says she will take the knowledge back to the villages where she lives. She says many people in her region still do not have access to electricity. Most have had no formal education even. It is all part of a programme to help India's rural poor by teaching them to make and install low-cost solar panels. Then they teach others to do the same. Named the Barefoot College, it has so far trained thousands. Sanjit Bunker Roy started the programme 25 years ago. Roy is among *Time* magazine's Top 100 Most Influential People for 2010. He says grassroots solar technology is crucial for India. Nearly half the country's rural population – more than 300 million people – has either no electricity or just a few hours of it a day. The programme is spread over 450 rural villages.

Source: http://www.voanews.com/english/news/India-Plugs-into-Low-Cost-Solar-Technology-105671523.html

Arizona's largest solar project in operation

Arizona's largest commercial-scale solar power project has been completed. Located in Pinal County, the 20MW project sits on 144 acres and began operation earlier in 2011. Iberdrola Renewables will own and operate the facility with Salt River Project (SRP) purchasing the entire output of the plant under a 25- year agreement. The project, which is expected to provide enough clean energy to power 3,700 homes each year, is Iberdrola's first completed solar project in the US and adds to a portfolio of nearly 5,000MW of renewables across the country.

At the Solar Power International in Dallas, the SRP also won an award in Solar Programme Design, in partnership with Tucson Electric Power for its Community Solar programme through which more than 100 schools in 11 valley school districts are tapping into the power of the sun from the plant to offset a portion of their electric needs. In 2010 SRP, in partnership with Tessera Solar, won the Solar Partner of the Year.

The programme, which is also open to residential customers, allows customers to invest in solar energy without the upfront costs or maintenance of a rooftop system. School districts and residential customers pay a set price for 10 and five years, respectively.

The energy delivered from the plant will support SRP's Sustainable Portfolio. The SRP Board has set a goal to meet 20% of SRP's retail electricity requirements through sustainable resources by the year 2020. Currently, SRP is ahead of schedule providing a little more than 9 per cent of retail energy needs with sustainable resources, which include renewable energy, hydro power, conservation, efficiency, and pricing measures.

The facility was designed and built by California-based SunPower, in conjunction with Fluor and will feature more than 66,000 of SunPower's T0 Tracker system and E19 solar panels.

Source: http://www.pv-tech.org/news/arizonas_largest_solar_project_is_now_in_operation

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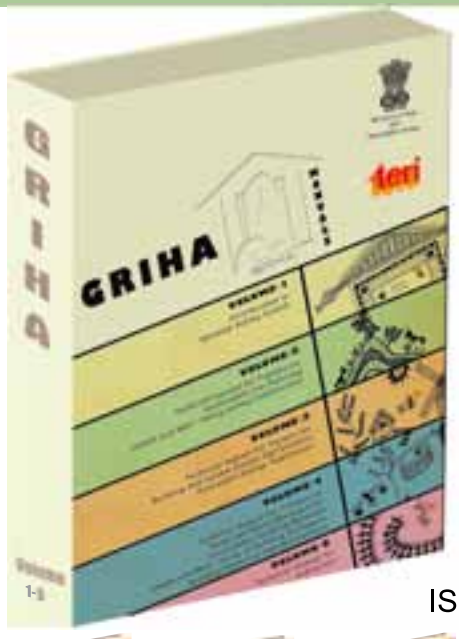

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CURRENT R&D SOLAR

Patrice Pinel, Cynthia A Cruickshank, Ian Beausoleil-Morrison, Adam Wills.2011. **A review of available methods for seasonal storage of solar thermal energy in residential applications.** *Renewable and Sustainable Energy Reviews*, 15 (7), 3341-3359

Abstract

There is generally agreement among the HVAC (Heating Ventilating and Air Conditioning) community that one of the main issues impeding solar thermal technologies from achieving their full potential for space heating and domestic hot water (DHW) production applications is the development of economically competitive and reliable means for seasonal storage of thermal energy. This is particularly true at high latitude locations, where seasonal variations of solar radiation are significant, and in cold climates, where seasonally varying space heating loads dominate residential energy consumption. This review presents the principal methods available for seasonal storage of solar thermal energy. It concentrates on residential scale systems, and particularly those currently used in practice which mostly stores energy in the form of sensible heat. Some newer methods that exhibit promise, like chemical and latent storage, are also briefly discussed and pertinent reviews are referenced.

Arif Hepbasli, Zeyad Alsuhaibani. 2011. **A key review on present status and future directions of solar energy studies and applications in Saudi Arabia.** *Renewable and Sustainable Energy Reviews,* 15 (9), 5021-5050

Abstract

Renewable energy is accepted as a key source for the future, not only for Saudi Arabia, but also for the world. Saudi Arabia has abundant potential for exploiting solar energy, which is renewable, clean, and freely available. The average annual solar radiation falling on the Arabian Peninsula is about 2,200 kWh/m2. Applications of solar energy in Saudi Arabia have been growing since 1960. Solar hydrogen production plant situated at the Solar Village, Riyadh, Saudi Arabia, could have been considered as the world's first 350 kW solar-powered hydrogen-generation plant at the time of its inception. The development of solar energy, however, has been relatively low due to several obstacles although utilization of solar energy in its various aspects is very attractive for the country. The main objectives of this study are to address current applications and future aspects of solar energy along with studies conducted in this field and to assess them in the light of available sustainable energy technologies towards establishing energy policies. The solar energy-related topics reviewed include various types of solar radiation correlations, exergetic solar radiation, solar collectors, solar photovoltaic (PV) systems, solar stills, solar-powered irrigation, solar energy-related greenhouses, solar hydrogen, solar water desalination and solar energy education. Some barriers, scenarios, and constraints are also covered. The utilization of solar energy could cover a significant part of the energy demand in the country. If a major breakthrough is achieved in the field of solar energy conversion, Saudi Arabia can be a leading producer and exporter of solar energy in the form of electricity. The geographical location of the country, its widespread unused desert land, and year-round clear skies, all make it an excellent candidate for this.

Chong W T, Naghavi M S, Poh S C, Mahlia T M I, Pan K C. 2011. **Techno-economic analysis of a wind-solar hybrid renewable energy system with rainwater collection feature for urban high-rise application.** *Applied Energy,* 88 (11), 4067-4077

Abstract

The technical and economic feasibility study of an innovative wind-solar hybrid renewable energy generation system with rainwater collection feature for electrical energy generation is presented in this paper. The power generated would supply part of the energy requirements of the high-rise building where the system is installed. The system integrates and optimizes several green technologies; including urban wind turbine, solar cell module and rain water collector. The design was conceptualized based on the experiences acquired during the development and testing of a suitable wind turbine for Malaysian applications. It is compact and can be built on top of high-rise buildings in order to provide on-site renewable power to the building. It overcomes the inferior aspect on the low wind speed by channeling and increasing the speed of the high altitude free-stream wind through the power-augmentation-guide-vane (PAGV) before it enters the wind turbine at the center portion. The shape or appearance of the PAGV that surrounds the wind turbine can be blended into the building architecture without negative visual impact (becomes part of the building). The design improves the starting behaviour of wind turbines. It is also safer to people around and reduces noise pollution. The techno-economic analysis is carried out by applying the life cycle cost (LCC) method. The LCC method takes into consideration the complete range of costs and makes cash flows time-equivalent. The evaluations show that for a

system with the PAGV (30 m diameter and 14 m high) and an H-rotor vertical axis wind turbine (17 m diameter and 9 m high) mounted on the top of a 220 m high building, the estimated annual energy savings is 195.2 MW h/year.

Veera Gnaneswar Gude, Nagamany Nirmalakhandan, Shuguang Deng, Anand Maganti**. 2012. Low temperature desalination using solar collectors augmented by thermal energy storage.** *Applied Energy*, 91 (1), 466-474

Abstract

A low temperature desalination process capable of producing 100 L/d freshwater was designed to utilize solar energy harvested from flat plate solar collectors. Since solar insolation is intermittent, a thermal energy storage system was incorporated to run the desalination process round the clock. The requirements for solar collector area as well as thermal energy storage volume were estimated based on the variations in solar insolation. Results from this theoretical study confirm that thermal energy storage is a useful component of the system for conserving thermal energy to meet the energy demand when direct solar energy resource is not available. Thermodynamic advantages of the low temperature desalination using thermal energy storage, as well as energy and environmental emissions payback period of the system powered by flat plate solar collectors are presented. It has been determined that a solar collector area of 18 m2 with a thermal energy storage volume of 3 m^3 is adequate to produce 100 L/d of freshwater round the clock considering fluctuations in the weather conditions. An economic analysis on the desalination system with thermal energy storage is also presented.

Bogdan M. Diaconu**. 2012. Energy analysis of a solar-assisted ejector cycle air conditioning system with low temperature thermal energy storage.** *Renewable Energy*, 37(1), 2012, 266-276

Abstract

Thermal energy storage is essential in solar cooling applications due to intermittent and uncontrollable availability of solar energy. Various technologies are available for low temperature energy storage. In the present work, a solar-assisted ejector cooling system with latent heat cold storage and conventional auxiliary heating was considered. The latter was applied in order to assure constant operating conditions for the ejector cycle. The analysis was carried out for an office building with cooling requirements during working hours only. The capacity of the cold storage was selected to ensure full coverage of the cooling load throughout the periods with cooling requirements. A quantitative energy analysis is presented, assessing the influence of parameters such as rated system power, ejector energy efficiency, solar collector area, ejector operating conditions and the amount of energy from the auxiliary source. Two energy efficiency parameters were defined, based on which the optimum system configuration and operating principle were identified. The advantages of each configuration were described.

Cheng-Dar Yue, Guo-Rong Huang. 2011. **An evaluation of domestic solar energy potential in Taiwan incorporating land use analysis.** *Energy Policy*, 39 (12), 7988-8002

Abstract

Solar energy is widely regarded as a major renewable energy source, which in future energy systems will be able to contribute to the security of energy supply and the reduction of CO_2 emissions. This study combined an evaluation of solar energy resources in Taiwan with land use analysis, which allows the potentials and restrictions of solar energy exploitation resulting from local land use conditions to be considered. The findings unveiled in this study indicate that photovoltaic electricity generation and solar water heating have the potential of producing 36.1 and 10.2 TWh of electricity and thermal energy annually in Taiwan, accounting for 16.3% and 127.5% of the total domestic consumption of electricity and energy for household water heating in 2009, respectively. However, the exploited solar photovoltaic power generation in 2009 accounted for only 0.02% of total potential in Taiwan, while the exploited solar water heating accounted for 11.6% of total potential. Market price and investment incentive are the dominant factors that affect market acceptance of solar energy installation in Taiwan. The administrative barriers to the purchase and transmission of electricity generated from renewable energy sources have to be removed before the potential contribution of solar energy can be realized.

Antonio Rovira, María José Montes, Manuel Valdes, José María Martínez-Val. 2011. **Energy management in solar thermal power plants with double thermal storage system and subdivided solar field.** *Applied Energy*, 88, (11), 4055-4066

Abstract

In the paper, two systems for solar thermal power plants (STPPs) are devised for improving the overall performance of the plant. Each one attempts to reduce losses coming from two respective sources. The systems are simulated and compared to a reference STPP.

They consist of: (a) a double thermal energy storage (DTS) with different functionalities for each storage and (b) the subdivision of the solar collector field (SSF) into specialized sectors, so that each sector is designed to meet a thermal requirement, usually through an intermediate heat exchanger. This subdivision reduces the losses in the solar field by means of a decrease of the temperature of the heat transfer fluid (HTF). Double thermal energy storage is intended for keeping the plant working at nominal level for many hours a day, including post-sunset hours. One of the storages gathers a fluid which is heated up to temperatures above the nominal one. In order

to make it work, the solar field must be able to overheat the fluid at peak hours. The second storage is the classical one. The combination of both allows the manager of the plant to keep the nominal of the plant for longer periods than in the case of classical thermal energy storage.

To the authors' knowledge, it is the first time that both configurations are presented and simulated for the case of parabolic through STPP with HTF technology. The results show that, if compared to the reference STPP, both configurations may raise the annual electricity generation (up to 1.7% for the DTS case and 3.9% for the SSF case).

Müjgan Çetin, Nilüfer Erican**. 2011. Employment impacts of solar energy in Turkey.***Energy Policy,* 39 (11), 7184-7190

Abstract

Solar energy is considered a key source for the future, not only for Turkey, also for all over the world. Therefore the development and usage of solar energy technologies are increasingly becoming vital for sustainable economic development. The main objective of this study is investigating the employment effects of solar energy industry in Turkey. Some independent reports and studies, which analyse the economic and employment impacts of solar energy industry in the world have been reviewed. A wide range of methods have been used in those studies in order to calculate and predict the employment effects. Using the capacity targets of the photovoltaic (PV) and concentrated solar power (CSP) plants in the Solar Roadmap of Turkey, the prediction of the direct and indirect employment impacts to Turkey's economy is possible. As a result, solar energy in Turkey would be the primary source of energy demand and would have big employment effects on the economics. That can only be achieved with the support of governmental feed-in tariff policies of solar energy and by increasing research-development funds.

J.H. Jo, T.P. Otanicar**. 2011. A hierarchical methodology for the mesoscale assessment of building integrated roof solar energy systems.** *Renewable Energy*, 36(11), 2011, 2992-3000

Abstract

Buildings and other engineered structures that form cities are responsible for a significant portion of the global and local impacts of climate change. Consequently, the installation of building integrated renewable energy sources such as photovoltaic or solar thermal systems on building rooftops is being widely investigated. Although the advantages for individual buildings have been studied, as yet there is little understanding of the potential benefits of urban scale implementation of such systems. Here we report the development of a new methodology for assessing the potential capacity and benefits of installing rooftop photovoltaic systems in an urbanized area. Object oriented image analysis and geographical information systems are combined with remote sensing image data to quantify the rooftop area available for solar energy applications and a renewable energy computer simulation is included to predict the potential benefits of urban scale photovoltaic system implementation. The new methodology predicts energy generation potential that can be utilized to meet Arizona's Renewable Portfolio Standard 2025 renewable energy generation requirements.

Marcos J D, Izquierdo D M, Parra D. 2011. **Solar space heating and cooling for Spanish housing: Potential energy savings and emissions reduction.** *Solar Energy,* 85(11), 2011, 2622-2641

Abstract

An experimental solar energy facility was designed to meet as much of the heating demand in a typical Spanish dwelling as possible. With a view to using the facility during summers and preventing overheating-induced deterioration of the solar collectors in that season of the year, an absorption chiller was fitted to the system to produce solar-powered air conditioning. The facility operated in solar space heating mode in the winter of 2008–2009 and in cooling mode during the summer of 2008. The design was based on a new type of flat plate vacuum solar collectors that delivered higher efficiency than conventional panels. This type of collectors can reach temperatures of up to 110 °C in the summer and up to 70 °C on the coldest winter days. The solar facility comprised a 48-m^2 (with a net area of 42 m^2) solar collector field, a 25-kW plate heat exchanger, a 1500-l storage tank, a 4.5-kW (Rotartica) air-cooled absorption chiller and several fan coils. The facility was tested by using it to heat and cool an 80-m^2 laboratory located in Madrid. As the average area of Spanish homes is 80 m^2, the findings were generally applicable to national housing. The solar facility was observed to be able to meet 65.3% of the space heating demand. For air conditioning, the system covered 46% of the demand, but with high indoor temperatures. In other words, the collector field was found to be able to air condition only half of the home (40 m^2). Lastly, the savings in CO_2 emissions afforded by the use of this facility compared to conventional air conditioning were calculated, along with its amortisation period. These results have been extrapolated calculating the potential energy savings and emissions reduction for all the Spanish households.

Takahiko Miyazaki, Atsushi Akisawa, Isao Nikai.2011. **The cooling performance of a building integrated evaporative cooling system driven by solar energy.** *Energy and Buildings, 43* (9), 2011, 2211-2218

Abstract

The solar chimney is a passive cooling technique to enhance the natural ventilation of buildings. The effect is, however, limited under hot and humid climatic conditions. In the study, the solar chimney was accompanied by a dew-point evaporative cooler.

The dew-point evaporative cooler was integrated with the ceiling of a building. The air flow induced by the solar chimney was predicted by simulation, and the cooling effect of the dew-point evaporative cooler was also analysed by heat and mass transfer simulation. The results showed that the system was capable of coping with internal heat gains of an ordinary office building. In addition, the optimal geometry of the evaporative cooling channel was revealed.

Calvin Lee Kwan, Timothy J Kwan**. 2011. The financials of constructing a solar PV for net-zero energy operations on college campuses.** *Utilities Policy*, 19 (4), 226-234

Abstract

The LACCD has a goal of establishing net-zero energy operations across its nine campuses. The project faces many challenges, including limited open areas for installing solar PV, increasing energy consumption challenges associated with campus energy growth and the high cost of installing solar PV. A previous study found that the LACCD would need to install a 9.5 MW solar PV array in order to meet total campus energy demand on a college campus through the year 2020. This paper attempts to evaluate the financial feasibility of such a project, taking into account the current local, state and federal renewable energy incentives available. We find that despite the availability of financial incentives by local municipal utility companies including installation rebates and net metering, the cost of electricity generated by solar PV still remains approximately 30% higher than the electricity generated by fossil fuels. We also find that the optimal solar PV array size from a financial standpoint is one that is sized to generate and meet all electrical demand during sunlight hours. Finally our analysis examined the influence of per kW installation cost and found that only when prices dropped to $3.00 per installed watt did a net-zero energy solar PV array have an NPV of 0.

Ghaffour N, Reddy V K, Abu-Arabi M. 2011. **Technology development and application of solar energy in desalination: MEDRC contribution**. *Renewable and Sustainable Energy Reviews,* 15 (9), 4410-4415

Abstract

Desalination has become one of the sources for water supply in several countries especially in the Middle East and the North Africa region. There is a great potential to develop solar desalination technologies especially in this region where solar source is abundantly available. The success in implementing solar technologies in desalination at a commercial scale depends on the improvements to convert solar energy into electrical and/or thermal energies economically as desalination processes need these types of energies. Since desalination is energy intensive, the wider use of solar technologies in desalination will eventually increase the demand on these technologies, making it possible to go for mass production of photovoltaic (PV) cells, collectors and solar thermal power plants. In the objective to promote solar desalination in MENA, the Middle East Desalination Research Center has concentrated on various aspects of solar desalination in the last twelve years by sponsoring 17 research projects on different technologies and software packages development for coupling desalination and renewable energy systems to address the limitations of solar desalination and develop new desalination technologies and hybrid systems suitable for remote areas. A brief description of some of these projects is highlighted in this paper. The full details of all these projects are available at the Center's website.

Ershu Xu, Zhifeng Wang, Gao Wei, Jiayan Zhuang. **2012. Dynamic simulation of thermal energy storage system of Badaling 1 MW solar power tower plant.** *Renewable Energy*, 39 (1), 2012, 455-462

Abstract

In this paper, the thermal energy storage system of Badaling 1 MW solar power tower plant is modelled from mathematical models for whole of the working conditions using the modular modelling method. This model can accurately simulate the recharge and discharge processes of thermal energy storage system. The dynamic and static characteristics of the thermal energy storage system are analyzed based on the model response curves of the system state parameters that are obtained from different steam flow disturbances.

Maria La Gennusa, Giovanni Lascari, Gianfranco Rizzo, Gianluca Scaccianoce, Giancarlo Sorrentino. 2011. **A model for predicting the potential diffusion of solar energy systems in complex urban environments.** *Energy Policy,* 39 (9), 2011, 5335-5343

Abstract

The necessity to reduce greenhouse gas emissions produced by energy building consumptions and to cut the energy bill (mainly due to the use of fossil sources) leads to the employment of renewable energy sources in new planned scenarios. In particular, more and more often municipal energy and environmental plans pay great attention to the possibilities of employment of the solar technologies at urban scale.

Solar thermal and photovoltaic (PV) systems are, by far, the most suitable tools to be utilized in urban areas. Obviously, the proper adoption of such systems in buildings does call for the availability of calculation methods suitable to provide the actual level of exploitation of solar energy in urban layouts.

In this work, a procedure for evaluating the geographical energy potential of building roofs in urban areas is proposed; in particular, the amount of surface on the roof that could be used for the installation of systems able to capture solar radiation for the energy production is investigated. The proposed procedure is based on the use of the GIS technology and 3D cartography. The effectiveness of the proposed method is assessed by means of an application to the town of Palermo (Italy). ■

OREGON INSTITUTE OF TECHNOLOGY'S RENEWABLE ENERGY CENTRE

Located in the highly picturesque mountain town of Klamath Falls, Oregon; the Oregon Institute of Technology (OIT) is the only public institute of technology in the north-western United States. The college was founded in 1947 and focuses exclusively on engineering and technology education, offering courses in Civil, Mechanical, Computer Systems and Electrical Engineering. OIT was the first college in the United States to offer a full-time degree in Renewable Energy Engineering, and is currently a prominent centre in Renewable Energy Research. Due to its proximity to a geothermal spring system, OIT is the only university in the United States to exclusively use geothermal-heating for all campus heating purposes. OIT is host to the Geo-Heat Centre, an American national resource for geothermal development.

Oregon Renewable Energy Centre (OREC)

The Oregon Institute of Technology is home to the Oregon Renewable Energy Centre (OREC), which focuses on providing practical solutions to the problems of energy conservation and renewable energy by integrating renewable energy technologies into existing energy systems. The centre conducts applied research and provides education and training in fields of study such as photovoltaic power systems, ground-source heating systems, fuel-cell technologies, and wind and biomass technology. Both the Geo-Heat Centre (GHC) and the Oregon Renewable Energy Centre (OREC) are supported by the Department of Energy by the US Government.

Examples of the work done at the OREC and GHC include:

Energy-efficient homes

- OREC faculty and students designed data acquisition and controls system to monitor the operating energy systems for two Net Zero energy homes in Oregon, i.e.; the Rose House (an 800 ft2 "green" cottage), and the Cannon Beach Cottage (a 2,268 ft^2 custom home).
- The Rose House is one of Oregon Department of Energy's (ODOE) demonstration homes in Portland, Oregon. The Cannon Beach cottage has won the National Association of Home Builder's 2005 "National Green Builder of the Year" award.

Waste heat recovery

- OREC staff and students designed and built a system with bi-facial solar cells on a parabolic solar concentrator. The system demonstrated 80-90% recovery of solar energy that is rejected from the solar cell which can be used in a heating process.
- The system also improved the electrical efficiency of the solar cells by lowering the cell temperature.

Transportation

- OREC's staff and students built a single person fuel cell powered car. This system utilizes a Proton Exchange Membrane Ballard 1.2 KW Hydrogen fuel cell as its sole power source that is capable of driving the 130-kg vehicle at 85 KPH.

OREC's portable photovoltaic array tester

- OREC's faculty and students designed and built a portable PV array tester capable of measuring I-V characteristics of up to 5KW Photovoltaic systems.
- The tester's compact design makes it quite easy to operate for a measurement equipment tool, and also makes it easy to transport to field sites. The university believes it has the potential to become a standard tool for PV array installers and inspectors across the world.

Courses offered at OIT

- **Bachelor of Science in Renewable Energy Engineering**
  The course established a strong foundation in Physics, Chemistry, and Mathematics which is followed by coursework in Electrical and Mechanical Engineering. Elective courses in renewable-energy specific streams include photovoltaics, wind power, biofuels, energy management and auditing, renewable-energy transportation systems, green building, and fuel cells.

Graduates will

- Be prepared for an engineering career in the energy sector in general, and the renewable energy sector in particular.
- Be employable in the roles of field engineers, energy auditors, renewable energy system integrators, and local and state government renewable-energy inspectors.
- Be adequately knowledgeable and prepared for pursuing graduate study in renewable energy from the world's top universities.

People

President: Chris Maples

Provost: Brad Burda

Program Director (Renewable Energy Engineering): Frank Rytkonen

Director of Oregon Renewable Energy Centre (OREC): Tom Chester

SOLAR PV SIMULATION SOFTWARES AT A GLANCE

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

Introduction

Solar energy technologies are used to meet a variety of end-use applications. These mainly include lighting, water pumping, cooking, water heating, and battery charging for multiple uses. Currently, a large number of products and systems are available in the marketplace, each with its physical and technical specifications. Perhaps there is nothing new about these uses. However, what is certainly unique is that these use free flowing solar energy as a basic fuel for their day to day operation. There are a few more distinguishing facts too. The most important being the day long variability of the solar radiation being received by us on earth. Solar radiation varies throughout the day, which has a definite effect on the amount of electricity produced by a solar module for example. It is this very change that a system designer tries to investigate while designing an efficient solar system. There are several procedures available to design a system via a host of manual and standardized computer simulation based methods. We have included several of the well accepted procedures for system sizing in various issues of this solar magazine, *The Solar Quarterly*.

In this article, we present a quick glimpse of such softwares along with a few more for ready reference for our readers.

Solar system design software

Currently, a large number of system simulation software is available both in a free to download form as well as against subscriptions. These can be listed as follows.

- HOMER
- RETSCREEN
- F-Chart
- TRNSYS
- PVSYST
- NSOL
- SolarPro

HOMER

The HOMER model was initially developed at the National Renewable Energy Laboratory (NREL), a premier research facility of the US Department of Energy, for the village power programme. It was then licensed to Homer Energy. Homer energy model software is a very innovative tool for the design cum analysis of a wide range of hybrid power systems. Homer is a very quick and an easy to learn programme as expressed by many users. The Homer 2.81 version was released in November 2010 with a facility to download the trial version. Presently version 2.68 of Homer is available. It is capable of carrying out the following three primary types of analysis:

- Sensitivity analysis
- Optimization
- Simulation

In all, Homer has an ease of convenience as far as evaluating the design choices for remote, standalone, and distributed generation applications are concerned.

RETSCREEN

The RETSCREEN (4.0 version) clean project analysis software is a unique decision support tool. It has been developed with an active involvement of personnel drawn up from the government, industry, and academia. Importantly, it is available at no cost from the government of Canada keeping in view its strong commitment to reduce the greenhouse gas emissions the world over. Retscreen can be put to a global use for evaluating the following:

- Energy production and savings
- Emission reductions
- Cost
- Financial viability
- Risk for technologies involved

RETSCREEN is currently available in about 35 languages (including Hindi) with facilities of databases related to project, product, and climate.

PV F-Chart

This software has been developed at the University of Wisconsin. It is regarded as a comprehensive system analysis and design program. It performs monthly-average performance calculations for each hour of the day. The design methods utilized for the purpose elucidate reveal the statistical changes in the incoming solar radiation along with the load. F-chart has weather data pertaining to more than 300 locations and is programmed to take in some extra weather related data too. It is quite possible to obtain the following set of parameters via an efficient use of this simulation software:

- Energy production and accompanying savings
- System performance results
- Efficiency values
- Life cycle costs

- Cost of the equipment
- Solar fraction costs
- GHG emission reductions

PVSYST

This specific simulation software has been developed by the Institute of Environmental Sciences (IES) at the University of Geneva, Switzerland. It is quite suitable for Standalone, grid connected, DC grid systems and water pumping systems, etc. The software allows a user to study, size, simulate and analyse the data with an improved reliability (version 5.0). It gives quick estimates of the generation values. In addition, it has specific pedagogic tools and import of measured results for a close comparison with the simulated values. Thus to put it in perspective, it has a direct link of importing a very wide range of solar modules, inverters, solar batteries and water pumps. PVSYST is capable of giving the graphical representations in terms of the following few elements:

- PV Array characteristics (under the conditions of partial shading)
- Quick meteo calculations (on tilted planes)
- Clear sky irradiation yields on tilted planes
- Hourly meter plots

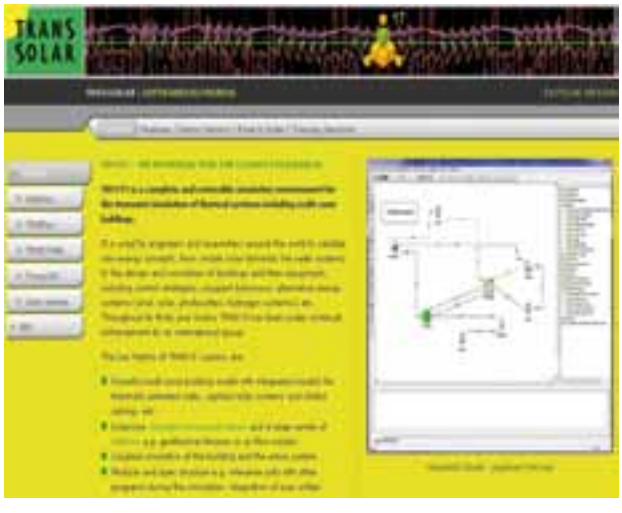
TRNSYS

It is also known as the TRANsient Systems simulation or simply TRNSYS. Its origin dates back to 1975 with initial efforts having been made in countries like the United States, France and Germany. It is one of the most workable energy simulation software packages. TRNSYS is made of two main parts (I & II). Part I is an engine which reads and processes the input file, solves the system, determines convergence and traces the system variables. In contrast, Part II possesses a wide library of components. Each such component models the performance of one part of the system. Within this library are the following few elements:

- Wind turbines
- Electrolysers
- Pumps
- Multi-zone buildings
- Weather data processors
- Basic HVAC equipment and much more

Table 1 Important solar system simulation software: a quick glance

S.No.	Software	Origin/Commercial entity	Approximate Sourcing Cost	Related Website
1.	HOMER	National Renewable Energy Laboratory (USA)	Nil	www.nrel.gov/homer
2.	PV-F Chart	University of Wisconsin, USA	$ 400-600	www.fchart.com
3.	TRNSYS	University of Wisconsin, USA	$ 2100 (related to educational use)	http://sel.me.wisc.edu/trnsys
4.	PVSYST	Institute of Environmental Sciences, University of Geneva, Switzerland	950 CHF for single machine license	www.pvsyst.com
5.	RETSCREEN	Natural Resources Canada	Nil	www.retscreen.net
6.	SolarPro	Laplace Systems Company Limited	$1950 (related to educational use)	www.lapsys.co
7.	PV Sol Express	Solar Design Company	166.26 Pounds	www.solardesign.co.uk



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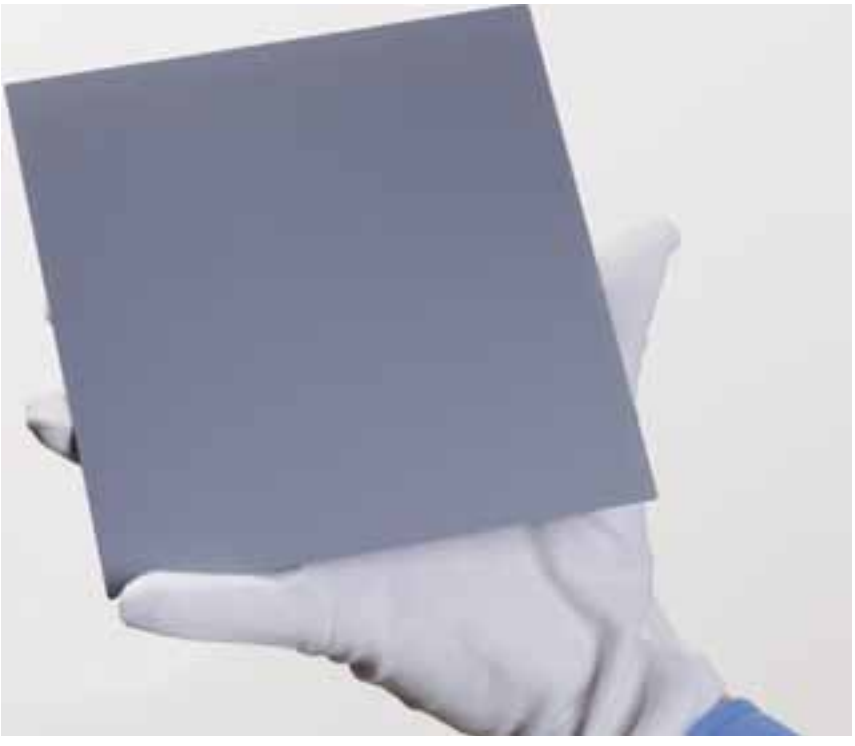
KNOWLEDGE BOOKS ON ENVIRONMENT, WHICH SUPPLEMENT THE ENVIRONMENT EDUCATION CURRICULUM

MULTICRYSTALLINE SOLAR CELL



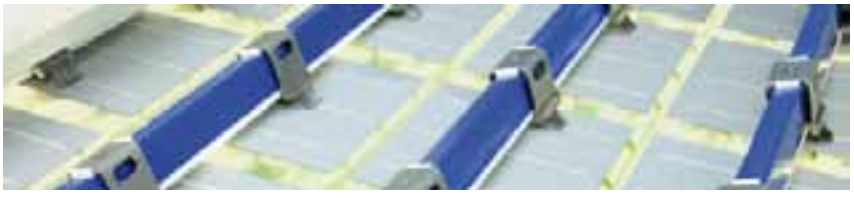
SCHOTT Solar AG and its project partners have reached an important milestone in the research project Las VeGaS in only six months: a solar cell metalized with copper achieved an efficiency of 18.0 per cent. A multicrystalline wafer from SCHOTT Solar AG that features standard screen-printed backside metallization serves as the basis. The goal of the Las VeGaS project is to largely replace the silver contacts that are commonly used on the front side of solar cells with less expensive nickel-copper plating. This would lower the manufacturing costs of front side metallization by more than half.

The special challenge involved in metalizing with nickel-copper plating is to prevent diffusion of the copper into the silicon solar cell, as this would reduce the carrier lifetime of the electrons and thus reduce the efficiency of the cell. For this reason, the project team has developed an electroplated nickel layer that serves as a diffusion barrier as well as the appropriate manufacturing techniques for applying both then nickel barrier and the copper contacts to the cell.

These solar cells will now be used to fabricate test modules so that they can demonstrate their long-term stability in reliability tests. Furthermore, the project team is working on transferring these development successes to monocrystalline cells. Efficiency that exceeds 19 per cent are expected.

The Las VeGaS method offers yet another advantage besides the lower costs for the raw material copper: the electroplated layers are environmentally friendly because they are free from both lead and solvents and thus meet the requirements of the European Union's RoHS Directive. This places restrictions on the use of hazardous substances in electrical and electronic devices. It is now no longer necessary to use large amounts of expensive silver paste, because only a very thin electroplated silver layer is needed to solder the cells to the copper tabs to make a module. This, in turn, lowers the consumption of silver by at least 95 per cent.

SCHOTT Solar, with its high-quality products, enables the potential of the sun as a nearly inexhaustible source of energy to be utilized. And it's for exactly that reason that SCHOTT Solar produces important components for photovoltaic applications and solar energy plants. In the photovoltaic industry, the company is one of the few integrated manufacturers of crystalline silicon wafers, cells and modules. In thin-film technology, SCHOTT Solar also describes itself as an advanced supplier due to having over twenty years of experience. And in the production of receivers for solar power plants, SCHOTT Solar sees itself as a market and technology leader. ■



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- ☐ Interviews
- ☐ Technical corner
- ☐ Current research and development
- ☐ University focus
- ☐ Learning Package
- ☐ Others (please specify)

5. What do you think about the new look and feel of *The Solar Quarterly*?
- ☐ Brilliant
- ☐ The previous look was better
- ☐ Needs more work
- ☐ Design is not a priority, content is
- ☐ Others (please specify)

6. How do you rate the magazine overall?
- ☐ Best in the business
- ☐ Informative and interesting
- ☐ Marginally useful
- ☐ Not useful at all
- ☐ Others (please specify)

7. Which other solar based/renewable energy based magazine do you read?
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ None

8. What issues would you like *The Solar Quarterly* to cover?
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

9. Any other suggestion?

_____
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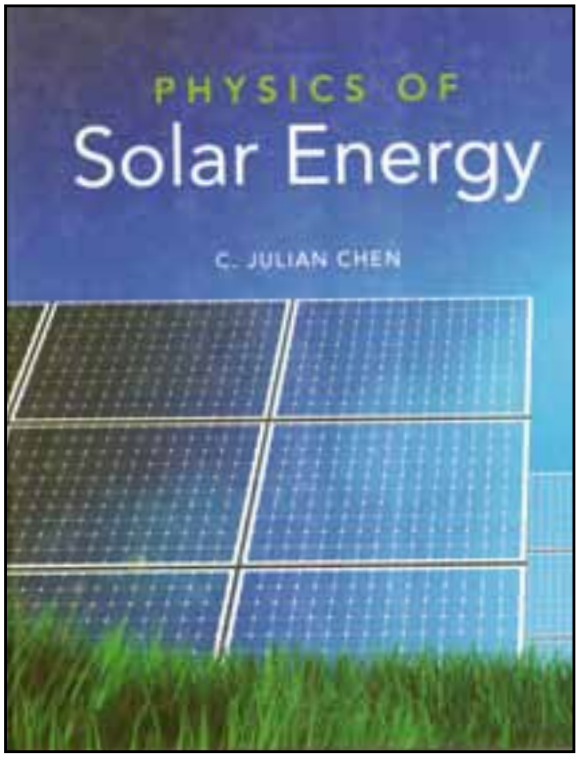
teri
The Energy and Resources Institute

PHYSICS OF SOLAR ENERGY



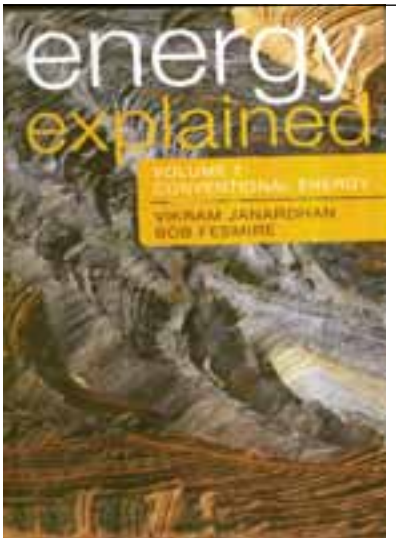
Editors: Julian Chen C
Year: 2011
Pages: 326 pp.
Publisher: John Wiley and Sons, New Jersey

One of the greatest challenges facing mankind in the twenty-first century is energy. Starting with the industrial revolution in the eighteenth century, fossil fuels such as coal, petroleum, and natural gas have been the main energy resources for human society: from steam engines to Otto and diesel engines, from electricity to heating and cooling of buildings, from cooking and hot-water making, from lighting to various electric and electronic gadgets, as well as for most of the transportation means. However, fossil fuel resources as stored solar energy accumulated during hundreds of millions of years are being rapidly depleted by excessive exploration. In addition, the burning of fossil fuels has caused and is causing damage to the environment.

The basic design of the book is as follows. The first chapter summarizes the energy problem and compares various types of renewable energy resources, including hydropower and wind energy, with solar energy. Chapter 2, "Nature of Solar Radiation," presents the electromagnetic wave theory of Maxwell as well as the photon theory of Einstein. Understanding blackbody radiation is crucial to the understanding of solar radiation, which is described in detail. Chapter 3, "Origin of Solar Energy," summarizes the astrophysics of solar energy, including the basic parameters and structure of the Sun. The gravitational contraction theory of Lord Kelvin and the nuclear fusion theory of Hans Bethe for the origin of stellar energy are presented. Chapter 4, "Tracking Sunlight," is a self-contained but elementary treatment of the positional astronomy of the Sun for non-astronomy majors. It includes an elementary derivation of the coordinate transformation formulas. It also includes a transparent derivation of the equation of time, the difference of solar time and civil time, as the basis for tracking sunlight based on time as we know it. This chapter is supplemented with a brief summary of spherical trigonometry in Appendix B. The accumulated daily direct solar radiation on various types of surfaces over a year is analysed with graphics. Chapter 5, "Interaction of Sunlight with Earth" presents both the effect of the atmosphere and the storage of solar energy in the ground, the basis for the so-called shallow geothermal energy. A simplified model for scattered or diffuse sunlight is presented. Chapter 6, "Thermodynamics of Solar Energy," starts with a summary of the basics of thermodynamics followed by several problems of the application of solar energy, including basics of heat pump and refrigeration. Chapters 7–10 deal with basic physics of solar photovoltaic and solar photochemistry. Chapter 7, "Quantum Transition," presents basic concepts of quantum mechanics in Dirac's format, with examples of organic molecules and semiconductors, with a full derivation of the golden rule and the principle of detailed balance. Chapter 8 is dedicated to the essential concept in solar cells, the pn-junction. Chapter 9 deals with semiconductor solar cells, including a full derivation of the Shockley–Queisser limit, with descriptions of the detailed structures of crystalline, thin-film, and tandem solar cells. Chapter 10, "Solar Photochemistry," presents an analysis of photosynthesis in plants as well as research in artificial photosynthesis. Various organic solar cells are described, including dye-sensitized solar cells and bilayer organic solar cells. Chapter 11 deals with solar thermal applications, including solar water heaters and solar thermal electricity generators. The vacuum tube collector and the thermal-cipher solar heat collectors are emphasized. Concentrate solar energy is also presented, with four types of optical concentrators: through, parabolic dish, heliostat, and especially the compact linear Fresnel concentrator. Chapter 12 deals with energy storage, including sensible and phase-change thermal energy storage systems and rechargeable batteries, especially lithium ion batteries. The last chapter, "Building with Sunshine," introduces architectural principles of solar energy utilization together with civil engineering elements.

The book is designed with this in mind. For example, background knowledge in positional astronomy, thermodynamics, and quantum mechanics is included. For students who have already taken these courses, the background material serves as a quick review and as a reference for the terminology and symbols used in this book. ■

NEW BOOK INFORMATION



Janardhan V and Fesmire B
Rowman and Littlefield Publishers, Inc: Plymouth, UK
270 pp. • 2011

Energy Explained, Vol.1: Conventional Energy

Energy is undoubtedly the world's most vital commodity. It makes modern societies possible, and the decisions made regarding it have far-reaching repercussions. Every day, stories about the price of oil, the resurgence of nuclear power, or the latest clean energy alternative appear in mainstream news outlets across the country.

Yet despite its high profile, energy remains largely misunderstood. People are confused, and generally discouraged from learning about energy, partly because the topic is so large and opaque but also because the resources that do exist fail to provide an overall picture the average reader can understand.

Here, in an easy to understand language accompanied with simple illustrations of difficult concepts, the authors have laid out the basics of energy in a refreshing manner. Readers are treated to a vivid presentation of the basics of energy science, alongside the politics, economics, and social issues that impact its production, distribution, and use.

Volume 1 of this book examines non-renewable energy sources, which for all practical considerations are limited in supply on earth. The chapters in this column provide an overview of renewable sources of energy that are essentially inexhaustible.

Energy Explained, Vol.2: Alternate Energy

As a society, we have a fascination with the weather. El Nino, Katrina, a killer heat wave- weather extremes capture headlines and the popular imagination. But aside from the spectacle of a natural disaster, there is an undeniable connection between humanity and elements. This book is divided into 24 chapters which are further classified into five parts. Part I focusses on Renewable Energy and covers all the different aspects of renewable energy and technologies. Part II, dedicated to Energy and Transportation, covers the fossil fuels and alternative fuels which are currently popular in the market and an intensive research is carried out at various levels such as biodiesel, ethanol, hybrid electrical vehicles, and fuel cells technology. The Part III of the book discusses critical issues relevant in today's context and throws light on topics like energy security, geopolitics of oil, nuclear energy programme and policies, etc. Part IV of the book deals with energy efficiency. The topic on reducing energy wastage has also been dealt with in detail in the book. The last section, Part V of the book, mentions that the world is heading towards new energy economy. This section also discusses cleantech investments and forthcoming energy revolution among various other topics of importance.

Janardhan V and Fesmire B
Rowman and Littlefield Publishers, Inc.: Plymouth, UK
253 pp • 2011

SolarTotal

SolarTotal is Europe's leading provider of photovoltaic (PV) solar panels to homeowners, businesses and government organizations. SolarTotal delivers a complete service to its customers – from the tailored solar PV system design, installation and monitoring through to the financing of the project; all with Carefree Warranty for 20 years or more.

Founded in 2006 with the mission to create a new customer experience for the supply of clean, sustainable local solar energy, SolarTotal is helping thousands of homeowners and businesses to adopt solar power, protecting customers from rising electricity costs and the environment from polluting power sources. As a SolarTotal customer you become your own in-house green energy producer with the possibility to sell electricity surplus to your own needs into the wider electricity grid.

http://www.solartotal.com

Go Solar California Campaign

The Go Solar California campaign is a joint effort of the California Energy Commission and the California Public Utilities Commission. The goal is to encourage Californians to install 3,000 megawatts of solar energy systems on homes and businesses by the end of 2016, making renewable energy an everyday reality. The program also has a goal to install 585 million therms of gas-displacing solar hot water systems by the end of 2017.

The Go Solar California website provides California consumers a "one-stop shop" for information on solar programs, rebates, tax credits, and information on installing and interconnecting solar electric and solar thermal systems. The site has information on program rules, including eligible equipment and standards, as well as information on how to find an eligible, licensed solar contractor.

http://www.gosolarcalifornia.org/about/index.php

AMECO SOLAR

AMECO SOLAR is one of the oldest established solar companies in California. As a pioneer in the solar field, the company has been installing solar systems for its residential, commercial, and municipal clients since 1974. With "hands-on" experience in applications that are truly cost effective and long lasting, it has experimented with different system designs as well as a myriad of different solar collectors, controls, pumps, and storage media. AMECO SOLAR specializes in solar system services including design, installation, and repair.

http://www.amecosolar.com/about-us/index.html

ANNOUNCEMENT

The Product Update section

The Solar Quarterly magazine invites updates and information on all new products in the solar energy sector. The update and information provided will be featured in the 'Product Update' section of the magazine.

Send in your write ups to

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IHC Complex
Lodhi Road
New Delhi 110 003
Tel: +91 11 2468 2100 / 2468 2111
E-mail: roshnis@teri.res.in

NATIONAL AND INTERNATIONAL EVENTS

National

The Solar Future: India II
29 February –1 March, 2012
Jaipur, India
Tel: +31 (0) 10 280 9198
Email: p.vanderlinden@solarplaza.com
Website: http://www.thesolarfuture.in/

International Conference on Renewable Energy Utilization (ICREU-2012)
4 – 6 January, 2012
Coimbatore Institute of Technology, Coimbatore, India
Tel: +91 9629283060, +91 9942029372,
Email: secretary@icreu2012.com
Website: http://www.icreu2012.com/

5th National Conference on Advances in Energy Conversion Technologies
2– 4 February, 2012
Manipal Institute of Technology, Manipal University, Manipal, Karnataka, India
Tel: +91 0820-2925121, +91 9480289614
Email: aect2012@maipal.edu, aect2012@gmail.com
Website: http://conference.manipal.edu/aect2012

Conference on Advances in Solar Energy and Material Research (ASEMR)
3 March, 2012
Manav Rachna International University, Faridabad, Haryana, India
Tel: +91-129-4198100 (Ext: 8261)
Email: asemr.fet@gmail.com
Website: http://info.mriu.edu.in/

Energize Talent: International Conclave on Talent Management in Energy Sector
9–10 January, 2012
New Delhi, India
Tel: +91-11-41003224
Email: sharmistha@itourz.in
Website: http://www.energizetalent.org/

International Multi-Disciplinary Conference on Solar Energy
1 – 3 February, 2012
Chennai, India
Tel: +91 44 2480 1636
Email: convener@imdcse.org
Website: http://www.imdcse.org/

International

PHOTON's Solar Terawatt-hours Conference Series 2012 USA
1–2 February, 2012
San Francisco, California, USA
Tel: +49-241-4003-5233
Email: info@photon.info
Website: www.photon.info

Solar Maghreb 2012: Developing Large Scale North African Solar Markets
22– 23 May, 2012
Casablanca, Morocco
Tel: +44 (0)207 099 0600
Email: info@greenpowerconferences.com
Website: http://www.greenpowerconferences.com

CSP Today South Africa 2012: 1st Concentrated Solar Thermal Power Conference and Expo
7–8 February, 2012
Hilton Sandton Hotel, Johannesburg, South Africa
Tel: +44 (0) 207 375 7206
Email: heidi@csptoday.com
Website: http://www.csptoday.com/southafrica

SNEC 6th (2012) International Photovoltaic Power Generation Conference & Exhibition
16–18 May, 2012
Shanghai, China
Tel: +86 21 33561099
Email: office@sneia.org

SolarTech Bangladesh
16–18 February, 2012
Dhaka, Bangladesh
Tel: +88 2 8321726
Email: info@solartechbd.com

6th Photovoltaic Fab Managers Forum
25–27 March, 2012
Berlin, Germany
Tel: +49 30 303080770
Email: sraithel@semi.org
Website: http://www.pvgroup.org/Events/p040664

4th Hybrid and Organic Photovoltaics Conference
6–9 May, 2012
Uppsala, Sweden
Tel: +34 964 387539
Email: ConfOrg@ nanoge.org
Website: http://www.enf.cn/expo/529x.html

4th Solar Sri Lanka 2012 International Expo
14–16 June, 2012
Colombo, Sri Lanka
Tel: +94 11 2591750-2
Email: contact@cems-solarexpo.com
Website: www.cems-solarexpo.com

4th International Conference on Thin-Film Photovoltaics
12 June, 2012
Munich, Germany
Tel: +49 941 29688-24
Email: leonore.nanko@otti.de
Website: www.otti.de/en/events/id/fourth-international-conference-thin-film-photovotlaics.html

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2012 China International Solar Photovoltaic Industry Fair
20–22 June, 2012
Shenzhen, China
Tel: +86 20 39571950
Email: trade-ok.2009@163.com
Website: www.china-pv.org

INDUSTRY REGISTRY

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China
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RENEWABLE ENERGY AT A GLANCE

S.No.	Source/system	Estimated potential	Achievement as on 31 August 2011
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45,195	14,989.10
2	Bio power (agro residues and plantations)	16,881	1,083.60
3	Bagasse cogeneration	5,000	1,779.03
4	Small hydro power (up to 25 MW)	15,000	3,153.93
5	Energy recovery from waste (MW)	2,700	73.46
6	Solar photovoltaic power	—	46.16
	Sub total (A)	**84,776**	**21,125.38**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	327.95
8	Biomass gasifier	—	141.43
9	Energy recovery from waste	—	75.80
10	Aero generator/hybrid systems		1.24
11	Water mills/micro hydel	—	1818 nos.
12	Solar PV power plants and street lights (>1 kW)	—	72.50
	Sub total (B)	**—**	**618.92**
	Total (A+B)	**—**	**21744.30**
II	**Remote village electrification**	—	8,846 villages/hamlets
III	**Decentralized energy systems**		
13	Family-type biogas plants	1.20 million	4.31 million
14	Solar photovoltaic systems		
	i. Solar street lighting system	—	1,22,697 nos
	ii. Home lighting system	—	6,56,707 nos
	iii. Solar lantern	—	8,17,369 nos
	iv. Solar power plants	—	2.92 MW_p
	v. Solar photovoltaic pumps		7,495 nos
15	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	4.67 million m^2 collector area
	ii. Solar cookers		.66 million
16	Wind pumps		1,352 nos
IV	**Awareness programmes**		
17	Energy parks	—	511 nos
18	Aditya solar shops	—	302 nos
19	Renewable energy clubs	—	521 nos
20	District advisory committees	—	560 nos

MW – megawatt; kW – kilowatt; MW_p – megawatt peak; m^2 – square metre; km^2 – kilometre square

Source www.mnre.gov.in

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- Monthly
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- Matte paper
- Number of pages: 56

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Finished size:	20.5 cm × 26.5 cm
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Twelve issues	684,000	570,000	570,000	342,000	205,200

Subscription

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THE SOLAR QUARTERLY

Circulation information

Solar Industries, Ministries, PSUs, Corporates, Multi and Bilateral Agencies, Universities, Educational Institutions, and Research professionals. Readership of 25,000.

General information

- Quarterly
- All colour
- Matte paper
- Number of pages: 76

Technical specifications

Finished size:	20.5 cm × 26.5 cm
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