SOLAR ENERGY: RESEARCH AND DEVELOPMENT

Dr Chetan Singh Solanki is currently Associate Professor in the Department of Energy Science and Engineering at Indian Institute of Technology (IIT)-Bombay, Mumbai, India. He is an expert in crystalline Si technology, Si-nanostructures (including quantum dots), thin film Si solar cells, PV concentrator systems, and carbon nanotubes. He received his PhD degree from the specialist silicon laboratory, Interuniversity Microelectronics Centre, Ketholik University, Leuven, Belgium.

He won the European Material Research Society Young Scientist Award in 2003 and IIT-Bombay Young Investigator Award in 2009. He has also been awarded at several international conferences for his research works. He has authored several books in the area of renewable energy, one of them is on solar PV titled *Solar Photovoltaics: fundamentals, technologies and applications*. Another book authored by him, in renewable energy sector, is titled *Renewable Energy Technologies: a practical guide for beginners*. He has also worked on several projects sponsored by the government as well as various companies. He is one of the principle investigators for the project "National Center for Photovoltaic Research and Education", sponsored by the Ministry of New and Renewable Energy (MNRE). He is currently working on projects sponsored by Applied Materials, MCIT, MNRE. He is part of the five-member national committee on Special Incentive Package Scheme of the Department of Information Technology, Government of India, for technical evaluation of solar PV projects. In an interview with Arani Sinha, Dr Chetan Singh Solanki puts forth his views on technologies, research, and development, as well as the use of solar energy in India.

Q1. The solar photovoltaic (PV) technology area has received a major boost due to the recently initiated Jawaharlal Nehru National Solar Mission (JNNSM). Could you please share your views on this development?

Solar PV technology is always considered a viable alternative to conventional power technology like coal. It is environment friendly and solar PV electricity can be generated in a distributed manner, wherever it is consumed. In this way, it can be the fastest way of providing electricity to the remote areas of the country. However, the electricity generated using solar PV technology is quite expensive. Whenever a new technology and its market grow to a level from where it can be self promoting, there is always a need for support from the government. The JNNSM has created, or will be useful in creating, the right ecosystem of solar PV technology in the country. Such an ecosystem will have appropriate industrial, financial, as well as government players at each point in the value chain of the solar PV technology, so that technology can flow from production to utilization, hopefully at grid competitive prices.

Q2. You have worked a great deal on the formation and characterization of nano silicon materials. Could you kindly tell us about their actual

The cost reduction is achieved by light concentration (2–500 times). The light concentration also poses many challenges, which are multi-dimensional in nature. There are challenges such as special solar cell design, sun tracking, and heat removal. According to me, even today, we do not have a combined and cost-effective solution for all these challenges.

commercial promise within the Indian PV industry environment?

Silicon (Si) can be used in solar cells in various forms. Currently, mono-crystalline (infinite-size grains) and multi-crystalline (millimetre centimetre size grains) Si is used in industries. The poly-crystalline Si (micrometre size grains) and nano-crystalline (nanometre size grains) Si has some potential for future use. The nano Si materials provide additional functionality, different from the thick Si, which can be useful to enhance solar cell efficiency. I have been working on Si quantum dots (QD) for tuning the band gap of Si and porous Si as seed layer for depositing epitaxial Si layers. There is one company, which is trying to promote thin film Si epitaxial solar cells at the commercial level. The Si quantum dots, which can be used to fabricate All-Si multi-junction, is in the early research phase and would require another decade or so to become viable for commercial manufacturing.

Q3. The era of megawatt-scale PV power plants has just taken off, which requires laying out of large tracts of solar modules in an open land area. To what extent would your self cleaning method of modules prove advantageous in this case?

Since solar PV technology is expensive and, therefore, every watt of installed PV module capacity should be used to generate as much electricity as possible. In India, significant amount of dust gets settled on solar PV modules, which reduces the electricity output. I have developed a cleaning-cum-tracking mechanism. Both these features are useful in harnessing more electricity per Watt of PV modules installed. Using our cleaning-cum-tracking mechanism, the generated electricity could be 20%–30% more, depending on the situation. Therefore, the developed solution can play an important role in large PV power plants. We are looking for an industrial partner to commercialize the product.

Q4. Solar PV concentrator-related research and development efforts were undertaken at several premier CSIR laboratories in the country quite early on. What, according to you, are the predominant reasons for concentrator modules still not making the desired headway in a commercial sense?

Solar PV concentrator is one of the attractive ways to bring down the cost of solar PV electricity. The cost reduction is achieved by light concentration (2–500 times). The light concentration also poses many challenges, which are multi-dimensional in nature. There are challenges such as special solar cell design, sun tracking, and heat removal. According to me, even today, we do not have a combined and cost-effective solution for all these challenges. As a result, there is no commercial success. Also, the more conventional PV technology is being used, flat plate crystalline silicon PV modules are being produced at much lower costs.

The development of any technology from the concept stage to the product state requires huge investment. I think, government should invest probably 10 to 100 times more in research and development. At the same time, industry has to also increase its share of investment in research and development.

Q5. Working partnerships between the premier research laboratories and the PV industry in India are not well established as against those witnessed in countries like the USA and Japan. How do you look at this imbalance of sorts, when such a vast pool of scientific and engineering manpower is available in the laboratories?

In India, typically, industry believes in importing technologies from outside the country due to lack of ready-to-commercialize technologies. From the perspective of academic institutes, the amount of investment in research and development is very small. The development of any technology from the concept stage to the product state requires huge investment. I think, government should invest probably 10 to 100 times more in research and development. At the same time, industry has to also increase its share of investment in research and development. These measures can increase the strength of our scientific research, improve the technology development, and can strengthen industry-academia interaction.

Q6. The capacity-building initiatives seem to revolve mainly around the short-duration training programmes and workshops. Do you think it is now time to set up exclusive regional-level PV training centres instead of fragmented efforts being made here and there?

Short-term training programmes are more suitable for giving introductory level understanding of a given subject. We need manpower in the solar area, who can contribute more intensively in research, development, and installation of PV systems. We also need a number of dedicated centres for educating and training manpower in the area. I would like to mention here that the MNRE has recently funded the National Center for Photovoltaic Research and Education (NCPRE) at IIT-Bombay. The centre will work and focus on training of human resources at various levels.

Q7. Do you have any special message to convey, especially to the young readers of *The Solar Quarterly* magazine?

I would like to ask the reducers one question, that is "are you REUSE?" If not, become one. REUSE stands for Renewable Energy USErs. The sustainability of life on earth requires all of us to be REUSE.

CONCENTRATION CUTS COSTS

Concentrating photovoltaics is booming. Energy suppliers and venture capital companies are investing heavily in this young technology. Using this fresh capital, manufacturers can finally exploit to the full the great potential capacity of light-bundling solar modules.

Written by Sascha Rentzing

A rare news item—in its fourth financing round, Solaria of the US collected more money than it expected. A developer of concentrator solar power systems, it had already announced the closing of that round in May 2010, when the kitty reached $45 million. But further investors then pressed for a share, so the company extended the investment phase until August. The operation paid off, for over the summer Solaria bagged a total of $65 million.

"We will use the capital to accelerate production," says Solaria CEO Dan Shugar. Greater output will certainly be required, for this California firm's light-bundling modules, which require tracking systems, are very much in demand. Energy supplier Enxco, for example, a subsidiary of the French EDF group located in San Diego and also an investor in Solaria, plans on expanding its solar farms in the US and Canada with the concentrators. The two parties made a five-year supply agreement to that purpose in August.

Investors are attracted by the prospect of cheap solar power. "With an efficiency of 14%, we are eye-to-eye with normal standard modules, but thanks to the savings in semiconductor material, we can produce at 15%–30% lower cost," says Philipp Kunze, Managing Director of Solaria Germany. To get that result, Solaria saws normal monocrystalline silicon cells into strips two millimetres wide and rearranges them with the same space in-between. "That way we need only half as much silicon, so we can produce two cells out of one," says Kunze. In the gaps, Solaria places V-shaped plastic light guides that bundle the light onto the silicon strips at double intensity. The modules are then fitted to trackers so they track the sun precisely.

Sawing up finished components and combining them into new cells again sounds weird, but Kunze explains that this approach saves money because the cost of plastic and additional process steps is less than that of conventional cells. The use of trackers also pays off, he says, because they help to increase energy efficiency per unit area and, thus, reduce installation costs.

Plastic replaces expensive silicon

This technique promises some relief from expensive photovoltaics (PV). Many firms are searching desperately for ways of saving on cost, and they know the existing technologies will probably be hitting their limits soon. Crystalline cells cannot be made ever more cheaply, because manufacturing the silicon and further processing the wafers is energy-intensive and laborious. Thin-film modules are already suffering problems now because of their limited capacity (new energy 4/2010). Systems that bundle light to increase its energy density for electricity production practically have unlimited development potential. Cheap optics can replace expensive absorber material, while the efficiency of multiple cells—the core component of high-concentration systems—is still capable of being markedly boosted. "This lets us look forward to dramatic price reductions," says Arnulf Jäger-Waldau of the European Commission's Joint Research Centre.

Energy suppliers and venture capital companies keen to invest are, therefore, queuing up at suppliers. US utilities are

showing the most interest. 2010 could be a breakthrough year for the solar concentrator technology. At peak times, electricity consumers in California have to pay almost half a dollar per kilowatt-hour, but solar farms can already produce electricity more cheaply.

Growing demand is increasing the number of new entrants tremendously worldwide.

''Around 50 companies now sell concentrating PV, 60% of them founded in the last five years," says Jäger-Waldau. Greater electricity yield means most developers are putting their money on a high concentration of 100 or more suns (see chart).

The Italian market promises a further boost, for a dedicated feed-in tariff ("Con-to Energia") for concentrator photovoltaics (CPY) was recently introduced. Depending on array size, up to 200 megawatts (MW) of CPV can be funded at EUR 28 to 37 cents per kilowatt-hour. This technology, still a niche phenomenon, is a hot favorite of analysts because it could cut the cost of producing electricity from the current 26 cents to eight cents as early as 2015.

Concentrix Solar of Freiburg, taken over in late 2009 by French semiconductor supplier Soitec, is among the leading suppliers of such high-concentration PV systems. It makes modules in which Fresnel lenses focus light 500-fold on tiny stacked cells with an efficiency of up to 38%. "In countries with high insolation, this technology works 10%– 20% more economically than conventional solar power systems," says Concentrix CEO Hansjörg-Lerchen muller.

Production is laborious, however, for getting each lens to focus precisely on its target cell requires the two components to be aligned with each other with millimetre precision. Concentrix can use cells smaller than a fingernail and can even afford to incorporate expensive multiple cells consisting of three absorber films stacked on top of each other. Since the lenses only work under direct insolation, they are fitted to trackers.

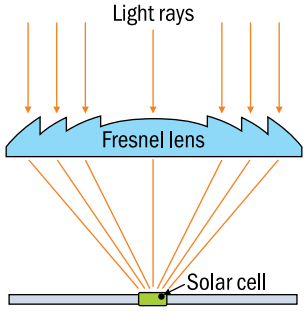
High system efficiencies justify the effort, however. Lerchenmuller says that under a southern sun, the technology converts 25% of incident light into electricity almost twice as much as common modules.

And the next innovation can already be foreseen, for parent company Soitec is developing a manufacturing process in which five different semiconducting connections between materials of the main chemical groups III and V—such as aluminium, gallium and indium—can be stacked on top of each other. Until now, it has only been possible to manufacture stacked cells made from three absorber films.The result is said to be an immediate 45%–50% increase in the efficiency of the multiple cells and a 35% increase in system efficiency. "The process could be industrially usable in three years," says Andreas Bett, head of the materials, solar cells and technology department at the Fraunhofer Institute for Solar Energy Systems in Freiburg.

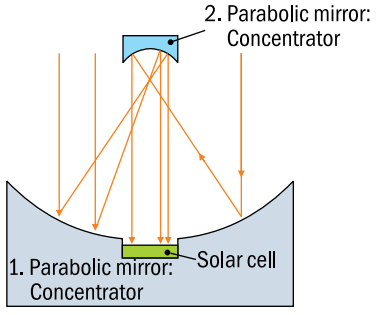
Concentrix reckons that the new "super cell" will provide good market opportunities. EU market watcher Jager-Waldau estimates that the current 50 to 100 MW of concentrator capacity installed worldwide could rise to 2000 MW by 2015. "We want a big slice of this cake," says Lerchenmuller. The firm has joined the Desertec Industry Initiative as an associated partner to smooth the way for power station projects in the Near East and North Africa. The Freiburgers already have a foothold in the US and are building a concentrator power plant with a one-megawatt

Three types of light concentration

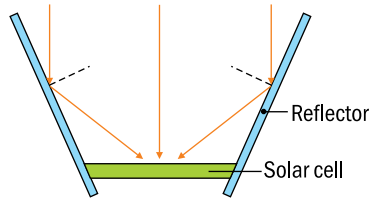
Highly-concentrated PV with fresnel lens



Highly-concentrated PV with parabolic mirror



Low-concentrated PV with simple reflectors



Concentrator photovoltaic is an alternative approach to reducing the cost of generating electricity from solar power. This technique reduces the requirement for expensive semiconductor material by bundling the light with an inexpensive optical concentrator. A small cell positioned at the focal point of the bundled light transforms the highly concentrated beam efficiently. Concentration factors now range from 2–1000. Low-concentration systems normally use simple optics, such as plastic light guides that bundle the light with doubled intensity onto a monocrystalline silicon cell. They can save up to 50% in semiconductor material. In medium and high-concentration systems, complex optics such as Fresnel lenses or parabolic mirrors bundle the light onto a multiple cell consisting of a stack of several semiconductors. The higher the concentration, the smaller the cell can be.

capacity for the Chevron oil group in New Mexico. Among Concentrix's fiercest competitors for the much sought-after desert locations are US firms Amonix and Solfocus. Amonix shares the efficiency record with Concentrix, for its systems transform 25% of light into electricity. The biggest concentrator project yet, at 59 megawatts, has now been implemented in Taiwan. The competitor there, Arima Eco, likewise relies on Fresnel technology, and uses a III-V cell with an efficiency of 36%. Solar Systems of Australia and Solfocus of California are also working with 500-fold concentration, but their system solutions trap the light with parabolic mirrors rather than lenses. They bundle solar radiation onto a stacked multiple cell positioned close to the focal point.

The energy of 1000 suns

Isofoton of Spain, Morgan Solar of Canada and Daido Steel of Japan plan to face future competition with an even higher concentration of 1000 suns. Like Concentrix, Daido uses multiple cells made by Azurspace Solar of Heilbronn, but packs them behind two lenses that concentrate the light — a Fresnel lens and a second lens — to achieve an even greater energy density. So far, says Daido, its systems only have an efficiency of 22%–23% and cost €5 per watt of installed capacity, including biaxial trackers. But Daido Steel is banking on quick progress, and a representative of the firm stated at the Valencia PV conference that improvements in its production methods would lower the system price to €3–4 per watt, the level of conventional flat plate modules, as early as 2011.

He said the firm also plans to reduce the cost of producing electricity dramatically in the coming years by boosting efficiency by more than 10%.

Morgan Solar of Canada also promises to offer a technology that, in sunny regions, will produce electricity up to 70% more cheaply than present-day standard modules. The key to greater affordability, says the firm's head Eric Morgan, is the use of inexpensive light-guide optics. A specially shaped acrylic plate five millimetres thick collects the light and directs it at a secondary glass lens inside the component. The convex glass receives the light at 50 times the sun's intensity, concentrates it to an intensity of 1000 suns, and directs it vertically onto a solar cell underneath. This technique exploits the optical phenomenon of total internal reflection, in which a light beam meeting the bounding surface of a lens at a precisely defined angle is reflected in it instead of passing through. When technically mature, such systems are expected to achieve an efficiency of 25%–30%. Morgan Solar's approach has convinced such investors as the Spanish energy group Iberdrola and the California Energy Commission, which have so far invested $11.5 million in the firm. Most of the money is going into the construction of a plant in California with 35 MW of capacity, where series production is to begin in late 2011.

Although most other firms are also developing systems with complex optics and high concentration, experts still see market opportunities for low-level concentrator systems as well. "The competition is tough," says Joachim Luther, a solar specialist who once headed the Fraunhofer Institute for Solar Energy Systems in Freiburg. Only Solaria can demonstrate progress worth mentioning, however. Despite strong competition, the firm thinks it's on the right track. "Our technology works even without direct sunlight," says Kunze. Solaria modules could, thus, be installed in regions like Germany. There are, moreover, many possibilities for optimization. Solaria's developers plan to fit future light collectors with plastics that concentrate the light not just twofold but threefold. Another option is to position the output connections of the silicon cells at the back, so they do not cast shadows. But first, however, Solaria has to achieve series production.

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SOLAR TECHNOLOGICAL UPDATE

Saint-Gobain's encapsulant is designed for flexible and lightweight solar modules

Product outline: Saint-Gobain Solar has launched a new 'LightSwitch' portfolio of solutions, including LightSwitch Frontsheet, LightSwitch Encapsulant, and LightSwitch Frontsheet Complete, as well as a design programme for photovoltaic (PV) module manufacturers. A high-performance and durable alternative to conventional materials, LightSwitch film products provide PV module manufacturers with enhanced performance, durability, and a reduction in total systems cost. The LightSwitch design programme was developed to assist module manufacturers in bringing a lightweight PV product to market.

Problem: PV module manufacturers are seeking new materials that retain performance criteria for long life and also enable new products to be developed to meet different applications.

Solution: LightSwitch Frontsheet Complete is a pre-laminate that incorporates two Saint-Gobain Solar products, LightSwitch Frontsheet ETFE and LightSwitch Encapsulant EVA, in one convenient package. Frontsheet Complete delivers on the benefits of its two components, as well as improvements in productivity, and reduced cost. LightSwitch Frontsheet is a melt processable fluoropolymer providing superior weatherability and UV resistance, ideal for flexible and lightweight solar modules. Tough and reliable, these highly transparent films offer improved resistance to chemicals and weathering, low flammability, stress crack resistance, and insulating properties. It is also surface-treated to ensure superb adhesion to LightSwitch Encapsulant. LightSwitch Encapsulant provides cushioning and structural support to solar cells and circuitry, while maximizing transmission of sunlight for energy conversion. With outstanding weathering properties, it protects the solar module throughout its lifecycle.

Applications: LightSwitch Encapsulant provides cushioning and structural support to solar cells. LifeSwitch Encapsulant is suitable for both flexible and rigid modules, with excellent adhesion to other PV module components.

Platform: The portfolio also includes the LightSwitch Module Design Programme and expert engineering design services for PV module manufacturers. Saint-Gobain Solar offers LightSwitch customers the combined experience and expertise of its design engineers and materials science experts, developing lightweight modules that meet the exact customer specifications.

http://www.pv-tech.org/product_briefings/_a/new_product_saint-gobains_encapsulant_is_designed_for_flexible_and_lightwei/

Integrated loops: a prerequisite for sustainable and environment-friendly polysilicon production

The PV market, which is dominated by polysilicon-based crystalline solar cells, has been developing rapidly, with growth rates in the double-digit range for several years. In order to meet increasing demand for hyperpure polysilicon, manufacturers need to adhere to environment-friendly production processes with low energy consumption. This article highlights the key processes needed to manufacture hyperpure polycrystalline silicon and explores the related challenges and solutions for sustainable polysilicon production. Findings prove that only an intelligent interaction of all necessary process steps fulfils the requirements for minimized production residue volumes and low energy consumption. Totally integrated production loops for all essential media are the prerequisite for reaching these targets. Once implemented, these highly efficient production processes serve as an excellent platform technology for the continued healthy growth of the PV industry.

http://www.pv-tech.org/technical_papers/_a/integrated_loops_a_prerequisite_for_sustainable_and_environmentallyfriendly/

Gas abatement for crystalline silicon solar cell production

This paper presents and discusses the merits of layout, systems, and options for exhaust treatments in PV cell production. Such treatments usually comprise of central acid scrubbing, NO_x scrubbing, Volatile Organic Compound (VOC) removal, and several local treatments for dust, silane, and VOCs, while caustic scrubbing is an option for monocrystalline PV cell production. As direct and indirect major emissions from typical production steps have already been identified, this article focuses on a full emission pattern and identifies two sectors, VOC and NO_x treatment, as most important for environment-impact analysis.

http://www.pv-tech.org/technical_papers/_a/atmospheric_deposition_techniques_for_photovoltaics/

Atmospheric deposition techniques for PV

With the never-ending need to reduce production costs, interest in atmospheric deposition techniques is steadily increasing. Even though atmospheric deposition is not new to PV, and in some cases is actually required to get the best cell performance, many of the fabrication processes for PV cells are vacuum-based. Due to the diversity in atmospheric deposition techniques available, there are opportunities for applications in thin film and patterned deposition. This paper discusses some of the deposition techniques and their applications, benefits, and drawbacks.

http://www.pv-tech.org/technical_papers/_a/atmospheric_deposition_techniques_for_photovoltaics/

Cost reduction and productivity improvement strategies for multicrystalline wafering processes

Multicrystalline wafers are the workhorse of the PV industry, with approximately 60% of crystalline silicon solar cells made from the substrate. They offer cost advantages in the form of good conversion efficiencies, which should continue to improve as cell technology advances continue. However, wafer prices were impacted by the fall in PV market demand in late 2008, which continued through most of 2009. With relatively high capital costs, continued pricing pressures and calls for greater quality and control, wafer producers are now set on a course that requires rigorous and sustainable production and cost-reduction strategies to meet customer requirements. This paper focuses on strategies that can be adopted to address this need for tighter quality specifications that reduce manufacturing costs downstream and boost cell conversion efficiencies.

http://www.pv-tech.org/technical_papers/_a/cost_reduction_and_productivity_improvement_strategies_for_multicrystalline/

Methods of emitter formation for crystalline silicon solar cells

The emitter or p-n junction is the core of crystalline silicon solar cells. The vast majority of silicon cells are produced using a simple process of high temperature diffusion of dopants into the crystal lattice. This paper takes a closer look at the characteristics of this diffusion and possible variations in the process, and asks whether this step can lead to optimal emitters or whether emitters should be made with different processes in order to obtain the highest possible efficiency.

http://www.pv-tech.org/technical_papers/_a/methods_of_emitter_formation_for_crystalline_silicon_solar_cells/

Roll-up solar panels: a startup making thin-film solar cells on flexible steel sheets

Xunlight, a startup in Toledo, Ohio, has developed a way to make large, flexible solar panels. It has developed a roll-to-roll manufacturing technique that forms thin-film amorphous silicon solar cells on thin sheets of stainless steel. Each solar module is about one metre wide and five-and-a-half metres long. As opposed to conventional silicon solar panels, which are bulky and rigid, these lightweight, flexible sheets could easily be integrated into roofs and building facades or on vehicles. Such systems could be more attractive than conventional solar panels and be incorporated more easily into irregular roof designs. They could also be rolled up and carried in a backpack, says the company's co-founder and president, Xunming Deng. "You could take it with you and charge your laptop battery," he says.

Amorphous silicon thin-film solar cells can be cheaper than conventional crystalline cells because they use a fraction of the material: the cells are 1-micrometre thick, as opposed to the 150-to-200-micrometre-thick silicon layers in crystalline solar cells. But, they are also very inefficient. To boost their efficiency, Xunlight produced triple-junction cells, which use three different materials—amorphous silicon, amorphous silicon germanium, and nanocrystalline silicon—each of which is tuned to capture the energy in different parts of the solar spectrum. (Conventional solar cells use one primary material, which only captures one part of the spectrum efficiently.) Still, Xunlight's flexible PV modules are only about 8% efficient, while some crystalline silicon modules on the market are more than 20% efficient. As a result, Xunlight's large modules produce only 330 Watts, whereas an array of crystalline silicon solar panels covering the same area would produce about 740 Watts.

http://www.technologyreview.com/business/22745/

Nanopillar solar cells: new solar-cell design, suitable for large-scale flexible panels to cut costs.

Researchers at the University of California, Berkeley, have made a new kind of solar cell by growing an array of upright nanoscale

pillars on aluminium foil. They make bendable solar cells by encapsulating the entire cell inside a transparent, rubbery polymer. The design, the researchers suggest, could lead to solar cells that cost less than conventional silicon PV.

The nanopillars allow the researchers to use cheaper, lower-quality materials than those used in conventional silicon and thin-film technologies. Also, the technique used to manufacture the cells could be adapted to make rolls of flexible panels on thin aluminium foil, cutting manufacturing costs. The solar cells are made of uniform 500-nanometer-high pillars of cadmium sulfide embedded in a thin film of cadmium telluride. Both materials are semiconductors used in thin-film solar cells. The researcher showed that the cells have an efficiency of about 6% in transforming sunlight into electricity. Others have made cells with pillar designs, he says, but they used expensive methods to grow the pillars and could not get more than 2% efficiency.
The nanopillar design splits up silicon's duties, the material surrounding the pillars absorbs light, and the pillars transport them to the electrical circuit. This increases efficiency in two ways. The closely packed pillars trap light between them, helping the surrounding material to absorb more. The electrons also have a very short distance to travel through the pillars, so there are fewer chances of their getting trapped at defects.

http://www.technologyreview.com/computing/22958/?mod=related

More AC power from solar panels

There is more to solar power than the blue glassy panels shimmering on rooftops. Just as important are the inverters that convert DC power created by the solar panels into grid-ready AC power. Typically, the panels on a rooftop PV system are connected to one large inverter mounted on the side of a house.

Startup Enphase Energy of Petaluma, California, is now manufacturing the first micro-inverters. These smaller inverters can be bolted to the racking under each solar panel, to convert DC power into AC for each panel, individually. The company claims that the devices will increase a PV system's efficiency by 5%–25% and decrease the cost of solar power.

In addition to DC-to-AC conversion, inverters are in charge of getting maximum power from solar modules. They have a logic circuit that constantly searches for the best voltage and current levels at which the panels can operate. (Power is the product of voltage and current.)

In a conventional PV system, solar panels are wired together in series, and their combined high-voltage DC power is fed to an inverter. Therefore, the inverter's logic circuit optimizes the total current and voltage levels. But, if one panel's current drops, it limits the overall output of the system. Micro-inverters optimize the voltage-current levels at each panel individually. This squeezes the most power from each panel and then adds it together, increasing the system's efficiency. In addition, the equipment cost for micro-inverters is about 15% less than the cost for a traditional system, she says, because expensive DC components, such as signal combiners and disconnects, can be replaced with off-the-shelf AC parts.

http://www.technologyreview.com/energy/22661/?mod=related

Ink-jet printing cheaper solar cells

A new printing method could cut costs and produce more-precise features. An improved process for making solar cells could allow manufacturers to cut the amount of silicon needed to half. Since, silicon can account for about three-quarters of the cost of conventional solar cells; this could significantly lower the price of solar power. The technique can reduce the amount of other materials used and improve solar-cell performance.

The process uses ink-jet printing to make electrical connections within a solar cell, replacing the existing screen-printing process. Because the ink-jet method is more precise, it can use less material for these connections. Also, because the print heads do not make any contact with the silicon, the method works with thinner silicon wafers. The process uses an ink-jet printer built by iTi Solar, based in Boulder, USA, that was originally designed for printing electronics, such as the contacts on touch screens.

The National Renewable Energy Laboratory (NREL), in Golden, USA, which helped direct the design of the device, is now starting to produce solar-cell prototypes using the technology. Since the ink-jet printer can be dropped into existing solar-cell manufacturing lines, it could be used in commercial production within a year.

One of the first applications could be in the manufacture of silicon solar cells, the most common type of solar cell sold today. Silicon absorbs light and converts it into electrons, and then an array of silver lines printed on the silicon collects these electrons, creating an electrical current. In conventional manufacturing, these silver lines are printed using screen printing. The silver ink used in the new process is much more conductive than the silver paste used in screen printing, and ink-jet printing is more precise. As a result, much thinner lines can be printed—35–40 micrometres wide, compared to 100–125 micrometres wide with screen printing. Using less silver saves money and improves the performance of the solar cell, since,the thinner lines shade less of the active material.

http://www.technologyreview.com/energy/22599/?mod=related

Printing cheap chips: Kovio's system for printing inorganic transistors lead to large-area displays and cheap smart cards

After years in "stealth mode," a company founded to commercialize technology originally developed at Massachusetts Institute of Technology's (MIT) Media Laboratory has announced a new process for printing transistors for memory and logic chips, and analog devices for radio. Since,

the technology uses commercial printing equipment such as inkjet printers; it could be a cheap and easy way to make high-performance microchips.

Kovio is one of the companies developing ultracheap alternatives to conventional microchips by replacing conventional photolithography methods with printing techniques. Such processes produce larger transistors rather than conventional chip-making methods—a printed chip might have a thousand transistors, rather than hundreds of millions—and will not compete with the microchips used in computing or consumer electronics. But, because, printed electronics are cheap to make, they could lead to the use of microchips in a large range of common objects, as well as large displays that cover, for example, an entire wall.

What sets Kovio apart from most printed electronics companies is that it uses inorganic semiconducting materials, such as silicon, rather than organic materials such as conducting polymers. Although they cost a bit more, the inorganic transistors give 100–1000 times better performance than organic transistors. Organic materials are cheaper and can be easier to work with, but inorganic materials, and the processing techniques that Kovio has developed, make it possible, for example, to produce radio devices that switch at speeds fast enough to meet current Radio-frequency identification (RFID) standards.

http://www.technologyreview.com/business/19746/?mod=related

Better solar for big buildings: startup selling cylindrical solar cells that can generate more power than conventional panels.

Solyndra, a startup based in Fremont, USA, has developed a novel type of solar panel that is cheaper to install and produces more power than conventional panels. Unlike conventional solar panels, which are made of flat solar cells, the new panels comprise rows of cylindrical solar cells made of a thin film of semiconductor material. The material is made of copper, indium, gallium, and selenium. To make the cells, the company deposits the semiconductor material on a glass tube. This is then encapsulated within another glass tube with electrical connections, which resembles those on fluorescent lightbulbs. The new shape allows the system to absorb more light over the course of a day than conventional solar panels do, and, therefore, generate more power. Also, arrays of these tubes offer less wind resistance than conventional flat solar panels, which makes them easier and cheaper to mount on roofs, the company says.

The company has raised $600 million in venture funding and has orders for $1.2 billion worth of solar panels, which it sells through installers, exclusively for commercial rooftops. It started shipping its products earlier this year and is now ramping up production at its factory, which will eventually produce enough solar panels every year to generate 110 MW of electricity. The company soon plans to start construction on a 420-MW-capacity factory.

Solyndra is one of the several companies that have recently received hundreds of millions of dollars to develop thin-film solar cells. Miguel Contreras, a senior scientist at the NREL, which developed the semiconductor deposition method used by Solyndra, notes that several other companies have developed solar cells based on thin films using the same combination of semiconductors. These thin films are helping in manufacturing a wide range of new forms for solar cells, including flexible solar cells and solar roofing materials. "There is a lot more flexibility with thin films than there is with [conventional silicon] wafer technologies," Contreras says.

The cylindrical solar-cell design has a number of advantages for generating solar power on the flat rooftops of big-box stores, warehouses, and other commercial buildings. Ordinary flat solar panels can catch the wind, so they must be bolted or weighed down with ballast. Solyndra's panels consist of rows of cylindrical tubes with spaces between them that allow the wind to pass through, decreasing wind loads and making it unnecessary to bolt or weigh down the panels, even with winds up to 130 miles per hour, the company says.

http://www.technologyreview.com/energy/21473/

Ultra-lightweight, affordable solar panel technology uses 1/100 of silicon in conventional solar cells

Researchers develop solar panel technology that allows for cheaper, lighter, and easier-to-install solar PV panels. A team of researchers at the California Institute of Technology in Pasadena, USA, have developed a method for producing flexible solar cells using just 1% of the material in conventional solar cells. The initial purpose of the study was to discover ways in which thin, light solar panels could be incorporated into clothing, but the study's immediate benefits are in the manufacture of cheaper, lighter, easier-to-install solar PV panels.

The new material is composed of silicon micron-sized wires, as opposed to the brittle silicon wafers that comprise of current solar PV panels. These wires are woven into a flexible polymer sheet that can be rolled or bent. Because this new solar panel technology uses only 1/100 of the silicon in conventional solar cells, this research has been touted as a means to bring down the costs associated with solar alternatives to oil and gas energy. Further reducing the cost is the fact that the flexible polymer is also much more durable than silicon wafers, which are typically quite fragile and, thus, require a lot of time, energy, and money to manufacture solar panels. Testing indicated that Kelzenberg's polymer sheet achieved about 15%–20% efficiency, which is standard for the solar PV panels available in the market today. It remains unclear as to when this technology will hit the market in the form of real, tangible, and cheaper solar panels.

http://buildaroo.com/news/article/ultra-lightweight-affordable-solar-panel-technology-in-development/

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CURRENT R&D SOLAR

Chen Y, Athienitis K A, Galal K. 2010. **Modelling, design, and thermal performance of a BIPV/T system thermally coupled with a ventilated concrete slab in a low energy solar house: Part 1, BIPV/T system and house energy concept.** *Solar Energy* **84**(11): 1892–1907

Abstract

This paper is the first of two papers that describe the modelling, design, and performance assessment based on monitored data of "a building-integrated photovoltaic-thermal (BIPV/T) system", thermally coupled with a ventilated concrete slab (VCS) in a prefabricated, two-storey detached, low-energy solar house. This house, with a design goal of near net-zero annual energy consumption, was constructed in 2007 in Eastman, Québec, Canada—a cold climate area. Several novel solar technologies are integrated into the house along with passive solar design to reach this goal. An air-based open-loop BIPV/T system produces electricity and collects heat, simultaneously. Building-integrated thermal mass is utilized, both in passive and active forms. Distributed thermal mass in the direct gain area and relatively large, south-facing triple-glazed windows (about 9% of floor area) are employed to collect and store passive solar gains. An active thermal energy storage system (TES) stores part of the collected thermal energy from the BIPV/T system, thus, reducing the energy consumption of the house's ground source heat pump heating system. This paper focuses on the BIPV/T system and the integrated energy concept of the house. Monitored data indicates that the BIPV/T system has a typical efficiency of about 20% for thermal energy collection, and the annual space heating energy consumption of the house is about 5% of the national average. A thermal model of the BIPV/T system, suitable for preliminary design and control of the airflow, is developed and verified with monitored data.

Martín L, Zarzalejo F L, Polo J, Navarro A, Marchante R, Cony M. 2010. **Prediction of global solar irradiance based on time series analysis: application to solar thermal power plants energy production planning.** *Solar Energy* **84**(10): 1772–1781

Abstract

Due to a rise in the generation of solar power, the predictions for incoming solar energy are acquiring more importance. Photovoltaic and solar thermal are the main sources of electricity generation from solar energy. In the case of solar thermal energy plants with storage energy system, its management and operation need reliable predictions of solar irradiance with the same temporal resolution as the temporal capacity of the back-up system. These plants can work like a conventional power plant and compete in the energy stock market avoiding intermittence in electricity production.

This work presents a comparison of statistical models, based on time series and applied to predict half daily values of global solar irradiance with a temporal horizon of three days. Half daily values consist of accumulated hourly global solar irradiance from solar raise to solar noon and from noon until dawn for each day. The dataset of ground solar radiation used belongs to stations of the Spanish National Weather Service (AEMet). The models tested are autoregressive, neural networks, and fuzzy logic models. Due to the fact that half daily solar irradiance time series is non-stationary, it has been necessary to transform it to two new stationary variables (clearness index and lost component), which are used as input of the predictive models. Improvement in terms of RMSD of the models essayed is compared against the model based on persistence. The validation process shows that all models essayed improve persistence. The best approach to forecast half daily values of solar irradiance are neural network models with lost component as input, except the Lerida station where models based on the clearness index have less uncertainty because this magnitude has a linear behaviour, and it is easier to simulate by models.

Baetens R, Jelle B P, Gustavsen A. 2010. **Properties, requirements, and possibilities of smart windows for dynamic daylight and solar energy control in buildings: a state-of-the-art review**. *Solar Energy Materials and Solar Cells* **94**(2): 87–105

Abstract

A survey on prototype and currently commercial, dynamic tintable smart windows has been carried out. The technologies of electrochromic, gasochromic, liquid crystal, and electrophoretic or suspended-particle devices were examined and compared for dynamic daylight and solar energy control in buildings. Presently, the state-of-the art, commercial electrochromic windows seem most promising to reduce cooling loads, heating loads, and lighting energy in buildings where they have been found most reliable and able to modulate the transmittance up to 68% of the total solar spectrum. Their efficiency has already been proven in hot Californian climates, but more research is necessary to validate the products for colder climates, and to improve, furthermore, the commercial products in order to

control the indoor climate in a more energy efficient way by reducing both heating and cooling loads.

Calise F, Dentice d'Accadia M, Palombo A. 2010. **Transient analysis and energy optimization of solar heating and cooling systems in various configurations.** *Solar Energy* **84**(3): 432–449

Abstract

In this paper, a transient simulation model of solar-assisted heating and cooling systems (SHC) is presented. A detailed case study is also discussed, in which three different configurations are considered. In all cases, the SHC system is based on the coupling of evacuated solar collectors with a single-stage LiBr–H_2O absorption chiller, and a gas-fired boiler is also included for auxiliary heating, only during the winter season. In the first configuration, the cooling capacity of the absorption chiller and the solar collector area are designed on the basis of the maximum cooling load, and an electric chiller is used as the auxiliary cooling system. The second layout is similar to the first one, but, in this case, the absorption chiller and the solar collector area are sized in order to balance only a fraction of the maximum cooling load. Finally, in the third configuration, there is no electric chiller, and the auxiliary gas-fired boiler is also used in summer to feed the absorption chiller, in case of scarce solar irradiation.

The simulation model was developed using the TRNSYS software, and included the analysis of the dynamic behaviour of the building in which the SHC systems were supposed to be installed. The building was simulated using a single-lumped capacitance model. An economic model was also developed, in order to assess the operating and capital costs of the systems under analysis. Furthermore, a mixed heuristic-deterministic optimization algorithm was implemented, in order to determine the set of the synthesis/design variables that maximize the energy efficiency of each configuration under analysis.

The results of the case study were analysed on monthly and weekly basis, paying special attention to the energy and monetary flows of the standard and optimized configurations. The results are encouraging as far as the potential of energy saving is concerned. On the contrary, the SHC systems appear still far from the economic profitability: however, this is notoriously true for the great majority of the renewable energy systems.

Philipps S P, Peharz G, Hoheisel R, Hornung T, N M Al-Abbadi M N, Dimroth F, Bett WA. 2010. **Energy harvesting efficiency of III–V triple-junction concentrator solar cells under realistic spectral conditions.** *Solar Energy Materials and Solar Cells* **94**(5): 869–877

Abstract

In this paper, we present a methodology that uses the detailed balance method to determine the optimum bandgap combination of III–V triple-junction solar cells for the highest yearly energy production. As an example of the methodology, we analyse two geographical locations on the earth with distinct spectral conditions. For these places, the monthly average of the measured aerosol optical depth and the precipitable water are used to calculate direct solar spectra with a discretization of one spectrum per hour. The model is used to analyse the spectral sensitivity of the bandgap design of four practical III–V triple-junction solar cell structures. Furthermore, the ideal bandgap combination for a maximal energy harvest is calculated for each location. It is shown that the metamorphic solar cell structure of Ga0.35In0.65P/Ga0.83In0.17As/Ge with transparencies optimized for the standard AM1.5d reference spectrum leads to the highest energy harvesting efficiencies and shows the lowest spectral sensitivity. The standard lattice-matched structure of Ga0.50In0.50P/Ga0.99In0.01As/Ge shows the highest spectral sensitivity with up to 10% relative difference in the yearly energy harvesting.

Rizwan M, Jamil M, Kothari D P. 2010. **Solar energy estimation using REST model for PV-ECS based distributed power generating system.** *Solar Energy Materials and Solar Cells* **94**(8): 1324–1328

Abstract

The effect of two important atmospheric factors, variation of turbidity and NO_2 absorbance, is proposed in estimating the solar irradiance. Reference evaluation of solar transmittance (REST), a broadband model for the solar irradiance, is used to estimate the solar irradiance. After estimating the solar irradiance for the distributed power-generating system, the photovoltaic (PV) solar output power is calculated. Instead of conventional batteries, use of a new storage device called energy capacitor system (ECS) is proposed because of its various advantages.

Li Yutong, Lu Lin, Hongxing Y. 2010. **Energy and economic performance analysis of an open-cycle solar desiccant dehumidification air-conditioning system for application in Hong Kong.** *Solar Energy* **84**(12): 2085–2095

Abstract

In this article, a transient simulation model and the EnergyPlus were used to study the energy performance and economical feasibility for integrating a solar liquid desiccant dehumidification system with a conventional vapour compression air-conditioning system for the weather condition of Hong Kong. The vapour compression system capacity in the solar-assisted air-conditioning system can be reduced to 19 kW from the original 28 kW of a conventional air-conditioning system as a case study, due to the solar desiccant cooling. The economical performance of the solar desiccant dehumidification system is compared with that of the conventional air-conditioning system. The results show that the energy saving potentials, due to incorporation of the solar desiccant dehumidification system in a traditional air-conditioning system, is significant for the hot wet weather in Hong Kong, due to higher COP resulting from higher supply of chilled water temperature from chiller plants. The annual

operation energy savings for the hybrid system is 6760 kWh and the payback period of the hybrid system is about seven years. The study shows that the solar assisted air-conditioning is a viable technology for utilizations in subtropical areas.

Shrestha S K, Aliberti P, Conibeer G J. 2010. **Energy selective contacts for hot carrier solar cells.** *Solar Energy Materials and Solar Cells* **94**(9): 1546–1550

Abstract

Double barrier resonant tunnelling structures consisting of silicon quantum dots (QDs) in silicon dioxide ($SiO_{2)}$ matrix have been studied for Energy Selective Contacts for Hot Carrier solar cell. A single layer of silicon QDs has been fabricated by high temperature annealing of SiO_2/ Si-rich oxide (SRO)/SiO_2 layers deposited by RF magnetron sputtering. Compositional analysis of SRO films obtained with different sputtering targets has been accurately measured with Rutherford backscattering spectroscopy. Size-controlled growth of SiQDs has been studied with photoluminescence measurements, which demonstrate that QD sizes can be controlled with SRO layer thickness. In addition, resonant tunnelling behaviour of SiO_2/ Si QD/SiO_2 structures has been investigated.

Yang Z, Garimella S V. 2010. **Thermal analysis of solar thermal energy storage in a molten-salt thermocline** *Solar Energy* **84**(6): 974–985

Abstract

A comprehensive, two-temperature model is developed to investigate energy storage in a molten-salt thermocline. The commercially available molten salt HITEC is considered for illustration with quartzite rocks as fillers. Heat transfer between the molten salt and quartzite rock is represented by an interstitial heat transfer coefficient. Volume-averaged mass and momentum equations are employed, with the Brinkman–Forchheimer extension to the Darcy law used to model the porous-medium resistance. The governing equations are solved using a finite-volume approach. The model is first validated against experiments from the literature and then used to systematically study the discharge behaviour of thermocline thermal storage systems. Thermal characteristics, including temperature profiles and discharge efficiency, are explored. Guidelines are developed for designing solar thermocline systems. The filler particle size strongly influences the interstitial heat transfer rate and, thus, the discharge efficiency.

Naspolini F H, Militão G S H, Rüther R. 2010. **The role and benefits of solar water heating in the energy demands of low-income dwellings in Brazil.** *Energy Conversion and Management* **51**(12): 2835–2845

Abstract

In Brazil, the widespread use of electrical showerheads for providing hot water for domestic consumption contributes to a load curve that peaks in the early evening, imposing a considerable burden to generation, transmission, and distribution utilities. On an average, over 73% of Brazilian households use these 3–8 kW electrical resistance showerheads. In some of the more temperate climate regions in the south of the country, where most of the Brazilian population is concentrated, electrical showers are present in over 90% of the residential buildings. For the residential consumer, while these high-power heating devices are the least-cost investment alternative, they lead to high running energy costs. Furthermore, due to their very low load factor (typically below 2%), each of these high-power showerheads results in considerably low returns on the high investment costs in terms of infrastructure for the electricity sector. Particularly in low-income dwellings, electrical showerheads represent, by far, the highest electrical loads, resulting in their becoming a major component in the monthly energy bill. On the other hand, Brazil is one of the sunniest countries in the world, and solar water heating technologies have demonstrated large financial benefits and short payback times. Due to their comparatively higher initial investment costs, however, domestic solar water heaters are used mostly in higher income residences. In this work, we present the potential of a low-cost version of the typical domestic solar water heating system for low-income dwellings, where the electrical resistance, which is normally installed inside the hot water tank, is replaced by a variable power electrical showerhead. This design avoids the use of electrical power as auxiliary heating for the whole of the boiler volume, since only the water, which passes through the showerhead might be heated by the electrical resistance. This system configuration is a commercially available low-cost solar water heater option. .

Alzoubi H H, Alshboul A A. 2010. **Low energy architecture and solar rights: Restructuring urban regulations, view from Jordan.** *Renewable Energy* **35**(2): 333–342

Abstract

The concept of solar energy-conscious design has emerged worldwide with the growing number of high-rise apartment buildings. It is important to think of maximizing solar energy utilization in buildings through architectural design strategies. This should lead to the setting-up of mandatory regulations on both urban and building design levels. This study analyses the current building regulations of Greater Amman Municipality (GAM) from the standpoint of solar accessibility. It suggests new regulations that ensure adequate solar accessibility in new constructions of residential apartments in Amman, Jordan. Computer simulations associated with sun mask analysis have been conducted to obtain a firm judgment towards setting up new dimensions of setbacks and building heights for apartment blocks in Amman. The study gives clear and flexible guidelines for urban and architectural designers to determine the number of sunlit floors, based on the desired distances between apartment blocks. To achieve the goals of this study, the authors suggest that the current urban regulations in Jordan be modified on energy-based design strategies.

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EXPERT SPEAK

Answers to questions on solar energy

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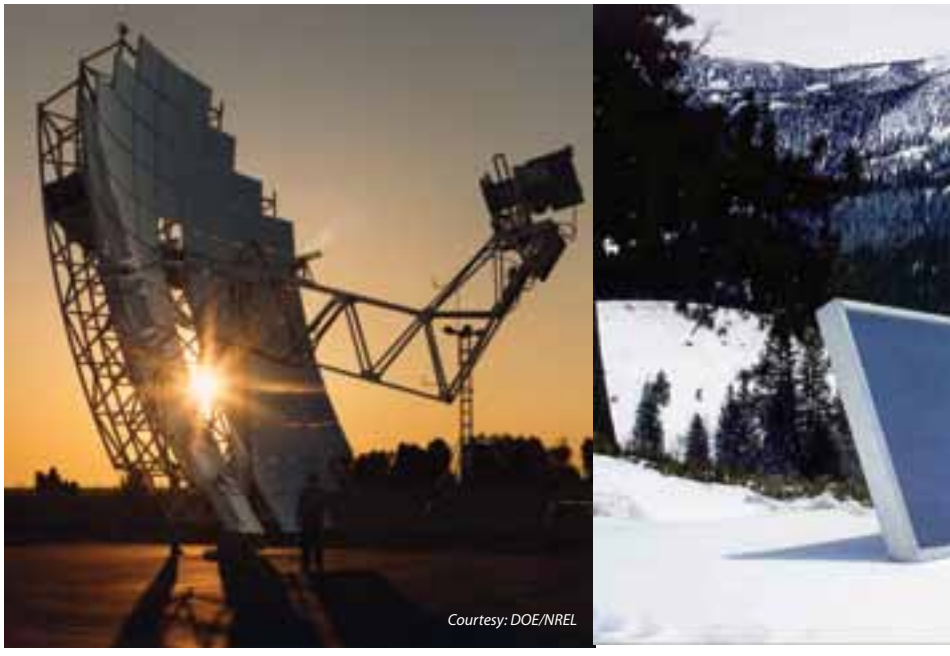
Solar energy is a promising source for future energy supplies because not only is it clean, but also remarkably abundant. Not only is the potential of solar power enormous, we also have the technologies to take advantage of it. We can design our homes to take the maximum benefit of solar energy. Solar water heaters can reduce our electricity bills and solar electricity can power our homes, and even our cars. Solar energy technologies are, sooner or later, going to take everyone by sheer surprise. Sizeable numbers can come through by opening up new commercial vistas for applications, alongside an increased market deployment of traditional uses. PVT collector use is one such novel application with a ready ability to fulfil multiple energy needs. It can also ensure maximum possible use of the available roof space. All we have to do is start using it on a wider scale. However, there are many questions in the minds of a consumer who wants to use solar energy in his day-to-day life. This section attempts to answer some such questions, however basic they may be. Dr R L Sawhney, Professor, TERI University fields questions on solar thermal and PV (photovoltaics).

Q. Can we build solar panels on our own?

Solar photovoltaic (PV) panels are normally constituted of series and/or parallel solar cells. The solar cells used in these panels are generally made from highly pure silicon, which can be either single crystalline or polycrystalline. Of course, these solar cells can be made from other materials besides silicon. In each case, the process of making solar cells is quite complex and, hence, it is not possible to make these cells on our own. But, if solar cells are bought or made available to us, it is possible to make a solar panel (also known as solar module) by connecting these cells parallely in a series. The voltage provided by each solar cell generally ranges between 1–2 Volts, where the maximum current provided by each solar cell under bright sunlight, ranges between 1–2 Amps. Depending on the application, these cells are connected in series or parallel. For meeting the higher voltage requirements, the cells are connected in series, while for meeting higher current requirements, these cells are parallely connected. For protecting these cells from hostile weather conditions, they need to be covered by a transparent sheet on the top and some opaque sheet at the back.



Courtesy: DOE/NREL

Q. Could you please enlighten us about the history of solar energy?

The history of solar energy is as old as humanity itself. There are enough examples of the use of solar energy in ancient times, in several parts of the world. As we begin to trace the history of solar energy use, it may be worthwhile to mention a bit about the early Greek and Roman cultures. In fact, energy problems date back to these civilizations. The climate in the coastal areas of Greece, 2500 years back, was marked by warm summers and cool winters. The primary source of energy then was wood. However, by 5th century BC, fuel shortages became rampant. It was around that time that the Greeks started using solar energy for various purposes, primarily heating. Also, their homes were designed to derive maximum possible advantage of solar energy during winters.

The Romans made use of glass windows to enhance solar heating. Thus, the practice of using greenhouses to raise food during winters came into being. These are a few classic examples of the use of solar energy in history. In recent times, one can list out the following developments.

- Augusta Mouchout developed a steam engine in 1861, which was powered by the sun.

Courtesy: DOE/NREL

- John Eriksson designed the parabolic trough collector a century back.
- Albert Einstein proposed the basic photo-electron emission process, that is, emission of electrons by light in the 20th century.
- Gerald Pearson, Daryl Chapin, and Calvin Fuller (all from Bell Laboratories) developed the first silicon solar cell in 1953.

Q. Could you give us an overview of the current uses of solar energy?

It is well-known that energy contained in all the fossil fuels, that is, coal, oil, natural gas, and other conventional fuels, such as wood, has actually come from the sun through the process of photosynthesis. Hence, solar energy is capable of doing what conventional energy has been doing for a long time now.

Solar energy can be converted into thermal energy for thermal applications and electrical energy for electrical applications. The process for direct conversion of solar energy into thermal energy is simpler and is achieved through various devices, such as solar cookers, solar dryers, solar water heaters, solar steam generators, and so on. The direct conversion of solar energy into electrical energy is achieved through solar cells. Solar cells provide DC power, which can then be converted into AC power through inverters. Solar energy can also be indirectly converted to electrical energy by first converting it to thermal energy, and then into mechanical energy through conventional external combustion engines, and finally converting it to electrical energy through electrical generators, and this route will soon achieve its maturity.

Solar energy is now commonly being used for various thermal applications such as the following.

a) For heating domestic and commercial interior spaces in cold climates
b) For cooking food, making use of various gadgets like box type solar cookers and SK-14 type concentrating solar cookers for domestic use and Scheffler concentrating solar cookers (both for direct cooking and steam cooking) for both domestic and community use
c) For meeting hot water requirements of households, hotels, hospitals and nursing homes, commercial buildings, and industries
d) For drying perishable food products
e) For generating saturated steam for various industrial processes and superheated steam for captive power generation
f) For vapour absorption air conditioning and refrigeration systems for providing required hot water/steam,though these uses are not yet common.

Solar energy is now being commonly used for various electrical applications such as the following.

a) For meeting domestic and street lighting requirements; for operating fans, television, other music systems; for mobile charging stations, especially in villages and remote areas, where regular grid electricity is not available.
b) For agricultural water pumping
c) For reliable railway line and street signalling in conjunction with LEDs
d) For providing reliable AC power for essential services like telephone exchanges, mobile towers
e) Now, with special incentives being provided by the government for generating electricity through solar routes (either photovoltaic or thermal), under the National Solar Mission, solar plants generating power in the range of 5 MW have started coming up in the country.

It is clear from the discussion that the current energy needs could be easily met with the help of dual use of the technologies already mentioned. Our domestic, commercial, institutional, industrial, and agriculture sectors are already reaping benefits of the efficient use of solar energy technologies. The Ministry of New and Renewable Energy (MNRE) is constantly encouraging an enhanced utilization of the available range of solar energy technologies, both in the rural and urban areas.

AN INTRODUCTION TO PHOTOVOLTAIC SYSTEM

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Background

The demand for solar photovoltaic (PV) is constantly increasing all over the world. In turn, it has led to a changing array of software available for those who intend to install PV systems for domestic, institutional, commercial, and industrial purposes. Today, there is a wide range of analysis and design tools. Their primary objective is to enable calculation programmes, analysis and simulation programmes, data collection programmes, and design and service programmes. Also, few of these also make available print-worthy reports for potential project developers. In totality, these types of analysis programmes are largely deemed to be time-saving measures (tools), more so when put into action in the early stages of a project. Photovoltaic System (PVSYST) is one such programme with an increasing market acceptance.

The origin

PVSYST 5.31 is a simulation software, the latest version of which was released on 14 December 2010. This simulation software has been developed and updated through years of intensive effort by the Institute of Environmental Sciences of the University of Geneva. It happens to be a widely used energy software to undertake sizing, simulation, and data analysis of the complete PV systems. Beside academicians, the other main beneficiaries of this important software are researchers, engineers, and architects. One of its key features is that it provides extensive contextual help. It is used to investigate at length the techniques and the models used for the purpose. In fact, the new PVSYST version 5.0 showcases a major updation of the software. Following few are amongst its latest features.

- Possibility to define multi-PV field
- Improved definition of the inverters (thus, enabling it to consider multi-maximum power point tracking (MPPT)
- Simulation of PV systems with heterogeneous orientations
- A multi-language interface (at present English, German, French, Spanish, and Italian)

PVSYST is quite often used to study a PV system. This software is used for the following types of systems in particular.

- Standalone
- Grid connected
- Water pumping
- DC grid connected

Categorization

It is essentially categorized in three distinct parts—preliminary design, project design, and tools. Brief details of each of these are given below.

Preliminary design

Under this, pre-sizing is undertaken in respect of the standalone, grid-connected, and water pumping system. The immediate purpose is to carry out initial designing of the system, as the name of this activity suggests.

Project design

In this specific stage, simulation is done using some of the data available from the preliminary design. Further on, detailed project report is initiated.

Tools

Important tools like the solar geometry are available to undertake the project design exercise.

Understanding few important steps

a. Parameters for a geographical site

Let us choose a geographical site, say Delhi, where we intend to put up a SPV system. It is located at an altitude of 215 m from the mean sea level. Further, the latitude of Delhi is 28.2 °North and longitude is 77.2.

b. Using the meteorological database

Meteonorm is basically an effective tool, which will generate climatic data from almost anywhere in the world. It basically uses a combination of measured data, along with models of solar geometry and climate types, to produce a range of

climatic data. This is then used as an input to the building models. The final product, normally available from the tool, is an ASCii text file. It contains columns of data sought by developing the project essentials from several end-use considerations. Following which, it can be manipulated with the help of a spreadsheet package (Excel) or text editor (Notepad) or a word processing software (Word). Such a data may be provided at hourly intervals or simply averaged over a month. Following few are some of the monthly Meteo values that it calculates.

- Hourly global radiation
- Hourly diffuse radiation
- Extraterrestrial radiation
- Clearness index
- Ambient temperature
- Wind velocity

Solar paths, corresponding to different durations, can also be calculated for easy understanding of the end-user. Let us now consider the application of the software to grid-connected systems. The geographical site data is fed into the system file. Here, one has to choose the collector plane orientation, which is normally 30° in case of Delhi. The main features of the PV installation recorded by the PVSYST are as follows.

- Type of solar module
- Type of technology
- Technique for mounting of panels
- Back ventilation properties

As far as the system characteristics are concerned, following elements is of immediate significance.

- PV field nominal power
- Collector area
- Annual energy yield
- Specific energy yield

The simulation exercise through PVSYST now helps to work out the system output in kWh corresponding to each month of the year. Thus, the collective units to be generated on an annual basis are known. Thereafter, one can progress to a more detailed worksheet, for example, specific to a grid-connected solar PV system. PVSYT makes it possible to determine a wide range of parameters. These mainly include the PV array loss factors, annual system production, performance ratio (PR), annual cost, energy cost, and most importantly, the running cost during the active life of a PV facility, in this case a grid connected power plant. Further, the gross investments minus any financial and fiscal incentives, as may be available under the purview of both national and international programmes/schemes, are also evaluated using this simulation software. As has been already mentioned, PVSYST can also be used quite conveniently to work out the techno-economic details of the standalone systems as well. So, both the grid connected and non-grid connected system sizing/costing needs can be known in a clear and reliable manner.

PVSYST proving powerful

Solar modules as well as arrays remain vulnerable to local weather conditions, both during the day and night. Any amount of dust present on the glass surface reduces the amount of incident sunlight passing through it and, thereby the useful power output available from an array. This problem is more severe where the dust content in the neighbourhood of a solar installation is quite high. PV Tracker is a company, which specializes in the production of solar trackers. It regularly monitors the array power generation performance by taking recourse to PVSYST package. The company has recently made a startling revelation that regular cleaning of power at few sites has increased the PV power production by as much as 4%–9%, month-after-month. A washing process has been put in place for the trackers using PVSYST package. Is this not the best example of a software going hand-in-hand with the hardware to lend more power to the system? In India, too, a small town located on the southern Coromandel Coast has been equipped with a solar facility and a PVSYST designed solar tracker is in operation to optimize the power production.

Country specific initiative

The recently launched Jawaharlal Nehru National Solar Mission (JNNSM) has provided a heightened impetus to the conceptualization/initiation of large-scale PV power generation. Softwares like the PVSYST are, thus, being seen as systems that could lend reliable estimations of both the technology-oriented and cost-driven parameters. Selected few organizations in India have already started imparting training to PV system designers and engineers. Under one such programme, participants were given a demonstration of PVSYST at the Engineering Staff College of India, Hyderabad. It is important to mention here that few more softwares like RETSCREEN, NSOL, HOMER, and are also finding an increasing use across several categories of energy use considerations.

Software availability

You may download a trial version of this PV simulation package from www.pvsyst.com. However, it will be valid for a period of 15 days only. Following which, a licensed version can be requested from admin@pvsyst.com.

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IIT-Bombay, was established in 1958 through an Act of Parliament, at Powai, a northern suburb of Mumbai. Today, the Institute is recognized as one of the centres of academic excellence in the country. Over the years, IIT-Bombay has made tremendous progress in all academic and research activities. Institutes in positions of excellence grow with time. The ideas and ideals on which such institutes are built evolve and change with national aspirations, national perspectives, and trends worldwide. IIT-Bombay, too, is one such institution.

Department of Energy Science and Engineering

Energy Science and Engineering (ESE) was founded in 1981 as an inter-disciplinary group at IIT-Bombay. The department offers MTech and PhD programmes. In 2007, the Board of Governors of IIT-Bombay approved the growth of Energy Systems Engineering into a Department of Energy Science and Engineering (DESE). The new department is expected to provide manpower and research inputs that are critical for the growth of India's energy sector and provide innovative energy technologies and systems to mitigate the global problem of climate change. DESE has started an integrated MSc- PhD programme in energy from 2007 and a dual degree (BTech–MTech) programme in Energy Systems Engineering from 2008. The projected student strength of the department is about 300 (in 2013) with a core faculty of 15–20 and another 30–40 associated from other departments in the institute. The department's research activities focus on developing cost effective renewables (for example, thin film photovoltaics, low cost solar thermal industrial heating, microbial fuel cells, bio-refinery) and energy-efficient devices and systems (process integration, benchmarking, heat pumps, trigeneration, controllers, power electronics). The department will have a combination of fundamental experimental work on new materials (nanomaterials for fuel cell, battery, hydrogen storage applications) and system simulation and analysis capabilities. The department is in the process of strengthening the existing research groups, catalysing new research groups, and building new research facilities.

Research

As the name suggest, the activities at DESE presents a unique combination of science and engineering in the field of energy.Research in this area at IIT-Bombay encompasses of various aspects of energy, cutting across a variety of science and engineering fields.Technological and policy issues related to energy efficiency and conservation in various applications are also addressed. With a strong focus on renewable energy alternatives, work related to development, testing, and commercialization of various renewable energy technologies utilizing biomass, solar, and wind energy are being pursued. Further, both fundamental and applied issues related to nuclear energy usage are also under exploration. Currently, several mega scale projects that are being implemented by the department, which includes setting up of a national solar thermal power testing, simulation and research facility, setting up of a National Centre for Photovoltaic Research and Education (NCPRE), developing a 100 kg/day biomass vacuum pyrolyser, and so on.

Research areas

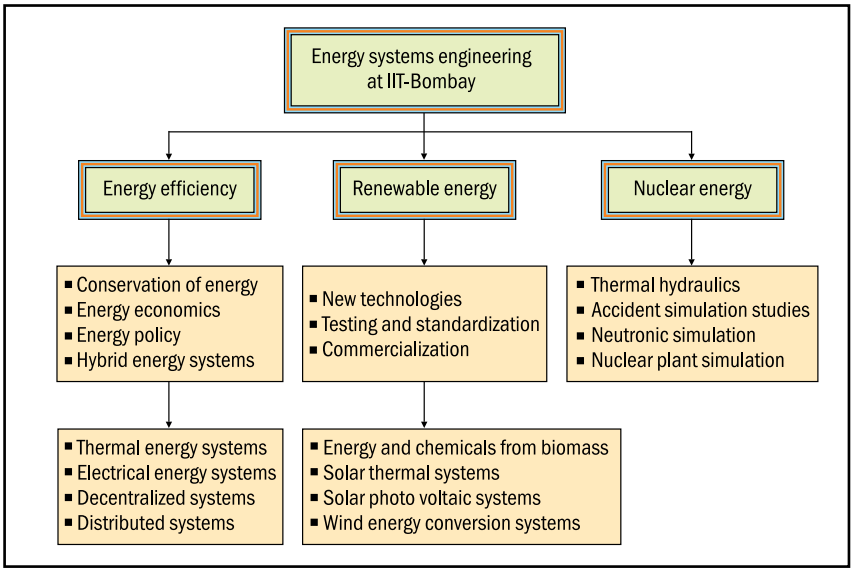
Research activities at the Department of Energy Science and Engineering aim at generating clean energy and developing energy systems to meet the future energy demands.

The research activities of the department can be grouped into three distinct areas.

Energy efficiency

The need for saving energy in every sphere is well known to all, especially due to increase in energy costs. The department has been developing sustainable energy solutions with a clear focus on energy saving strategies.

Energy Efficiency Testing of Motor



Courses taught at the Department of Energy Science and Engineering

in the field of energy (leading to MTech or PhD degree). The DESE is inter-disciplinary in nature and has the following areas of research.

- Energy efficiency/Improvements in conventional supply systems
- Renewable energy systems
- Nuclear energy

Renewable energy systems

Due to the depletion of conventional energy sources, various forms of renewable energy have attracted attention. Active research in areas such as solar thermal, solar photovoltaics, solar photovoltaic concentrator, biomass, wind, and so on is being pursued.

Nuclear energy

There is a strong need for developing technologies for fast breeder reactor and advanced heavy water reactor. The research activities in nuclear energy are geared towards thermal hydraulics, stability of flows, safety aspects, space-time kinetics for neutronic simulation, and so on.

Academics

The Department of Energy Science and Engineering offers graduate courses in mechanical, chemical, electrical engineering, and other allied engineering disciplines. It gives an opportunity to specialize

Zero energy building

The department will have a new zero energy building. This zero energy building will have the following features.

- Solar passive architecture
- Ventilation (natural and induced)
- Shading
- Daylight
- Energy efficient appliances
- Integration of renewable energy
- Building integrated PV
- Gasifier-based power
- Solar hot water
- Water harvesting
- Intelligent control and management

Source http://www.ese.iitb.ac.in/aboutus/Energy_Science_Engineering.pdf

Future scenario 2013

Output
- BTech 30
- MTech 55
- MSc 12
- PhD 20

Total: 117
UG:PG 42 :75 (1:1.8)
Faculty: student 1: 12
Student population
DD 150
MSc–PhD 60
PhD 30
MTech 50
Total: 290
Core faculty 18
Associated 30
20% of time six equivalent
Total equivalent: 24

Source http://www.ese.iitb.ac.in/aboutus/IITBadvcom07.pdf

The DESE faculty have developed strong linkages with government organizations like the Ministry of New and Renewable Energy, Atomic Energy Regulatory Board, Department of Atomic Energy and several industrial organizations (like Forbes Marshall, Maharashtra Electricity Regulatory Commission, International Energy Initiative). The department provides the facilities, atmosphere, and experience that can help engineers and researchers to develop sustainable energy systems and solutions for the future.

Solar Photovoltaic Panel: It is used for operating solar powered water pump (experimental set-up).

Courses

Core courses

- Non-conventional energy sources
- Foundation for energy engineering
- Energy resources, economics, and environment
- Energy management
- Energy systems modelling and analysis
- Power generation and systems planning
- Energy systems laboratory
- Non-conventional energy systems lab
- Mathematical foundation for energy science
- Electrical energy systems
- Introduction to transport phenomena
- Thermodynamics and energy conversion
- Combustion engineering
- Direct energy conversion systems
- Material science for energy applications
- Computational laboratory

The department also offers a number of elective courses.

Core faculties (energy)

S Bandyopadhyay: Industrial energy conservation, process integration

R Banerjee: Energy efficiency and management, Energy modelling, Hydrogen energy

A Ganesh: Energy and chemicals from biomass and coal, IC engines, Alternate fuel

P C Ghosh: Polymer electrolyte fuel cell, Hydrogen generation and storage

J K Nayak: Solar thermal, Energy conscious buildings, Solar passive architecture

M Neergat: Electrocatalysis, Fuel cell, Bio-fuel cells

P Sharma: Thin films, Amorphous semiconductors, IChalcogenides on irradiation, Hydrogen storage

C S Solanki: Solar photovoltaics, Thin-film organic solar cells, Carbon nano tubes, PV concentrator

S B Kedare (Adjunct): Concentrating solar collectors, Industrial thermal hybrid systems

R Shah (Adjuct): Fuel cells, Hydrogen, Compact heat exchangers, Automotive air-conditioning

The department also has a number of associate faculty members.

For more details contact
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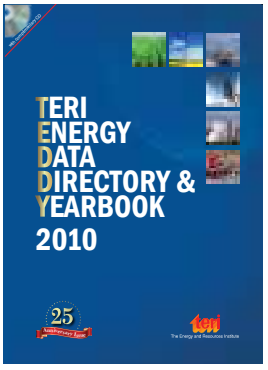

TERI Energy Data Directory & Yearbook 2010

Description

TERI Energy Data Directory & Yearbook, or TEDDY, is an annual publication brought out by TERI since 1986. *TEDDY* is often used as a reference in other peer-reviewed books and journals for energy and environment-related data. It gives an annual overview of the developments in the energy supplying and consuming sectors as well as the environment sector. It also provides a review of the government policies that have implications for these sectors of the Indian economy.

The book provides extensive data, collated from various government ministries, on the energy supply sectors, including coal and lignite, oil and gas, power, and renewable energy sources and technologies; energy demand sectors, namely, agriculture, industry, transport, and domestic; along with information related to environment and climate change. Graphs and maps have been used extensively to explain facts, which makes the book an interesting read. Besides, detailed tables have been provided at the end of each chapter, making *TEDDY* a comprehensive data book.

Each edition of *TEDDY* contains India's commercial energy balances for the past four years. These energy balances provide comprehensive information on energy flows within different sectors of the economy and how they have been changing over time. They are valuable ready reckoners for anybody working in energy and related sectors.

This is the 25th anniversary edition of the book and a number of refinements have been made in the content and presentation to reflect the changing needs of the readers. At the same time, care has been taken to ensure that continuity of information is preserved so that researchers can study the trends over time in the energy sector.

Key features

- An exhaustive compilation of data from energy supply and demand sectors.
- Recent data along with data for the past years is presented in the form of structured and easy-to-understand tables.
- Recent advances made in the energy sectors are presented in the book.
- Self explanatory figures showing the latest trends in various sectors are also part of each chapter.
- The "in focus" section in every chapter highlights a topical issue.
- The book comes with a complimentary CD that contains all the chapters and additional tables.

Table of contents

ISBN 9788179933930 • 464 pages • Size 280 mm x 216 mm • Hardback • ₹1500 • 2011

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SOLAR EDUCATION KIT

Solar energy utilization is growing by the day. New types of products and systems are making their way into the Indian market. Lighting products, in the form of solar lantern and indoor and outdoor lighting systems, are amongst the most preferred solar products, today. Alongside these, there are a few products, which have been around for a reasonably good period of time. One such product is "Solar Education Kit", which was developed during the earlier stages of the photovoltaic (PV) programme by the Bengaluru-based Tata BP Solar.

Why is it relevant even today?

You may have read about the salient features of the recently launched Jawaharlal Nehru National Solar Mission (JNNSM) in a few previous issues of *The Solar Quarterly* magazine. Under this mission, a large number of installations, both in the off-grid and on-grid modes, is expected to come up across the length and breadth of our country. It would also mean that we need to have trained manpower at various levels to give shape to this massive programme, quite convincingly. To begin with, those aspiring to get involved in this exercise need to be made aware about the basic concepts of solar PV technology. PV education and training is going to be one of the major components of this programme ranging from students, to educators and technicians. In this context, the Solar Education Kit is the best product to demonstrate the basic concepts of solar technologies. It was primarily intended for students to make them familiar with the solar-to-electric conversion process.

Key features of the education kit

At a glance, this product, neatly fitted in a suitcase enclosure, would seem to be no different from the suitcase in your home. This suitcase, however, contains solar appliances and few current and voltage measuring instruments. It is made of a compact housing with screen -printed polycarbonate for the module and aluminium plate for the switches and meters. The unit is portable and light weight. The following are the important components of this educative product.

- Solar module
- Battery
- Ammeter
- Voltmeter
- Loads (optional)
- Transistor
- Interconnecting wires
- Switch (to select the mode of operation)

In addition, it also has very low power consuming items like alarm clock, musical chime bell, calculator, and compact torch.

The simple experimentation

Both the ammeter and voltmeter is of an analog type, along with a potentiometer. The simple, but important, idea is to know the variation of current (I) and voltage (V) values as a function of the incoming solar radiation. This way, one can record the I and V values during different time periods of the day. It is important to mention here that I-V characteristics of a module form the backbone of any solar power producing component. It is also possible to derive a few more parameters like Imax, Vmax, and Pmax from the I-V plot. Any change in the load value will change the current and voltage values. The potentiometer can change the load resistance. In all, the solar education kit provides a glimpse into the solar-to-electric conversion process, besides providing the space for some basic experimentation. The portable nature of this product easily allows a field demonstration under the morning and afternoon sun (when the solar insolation generally peaks).

This education kit is of immediate relevance to schools, colleges, vocational centres, Industrial Training Institutes (ITIs), and so on.

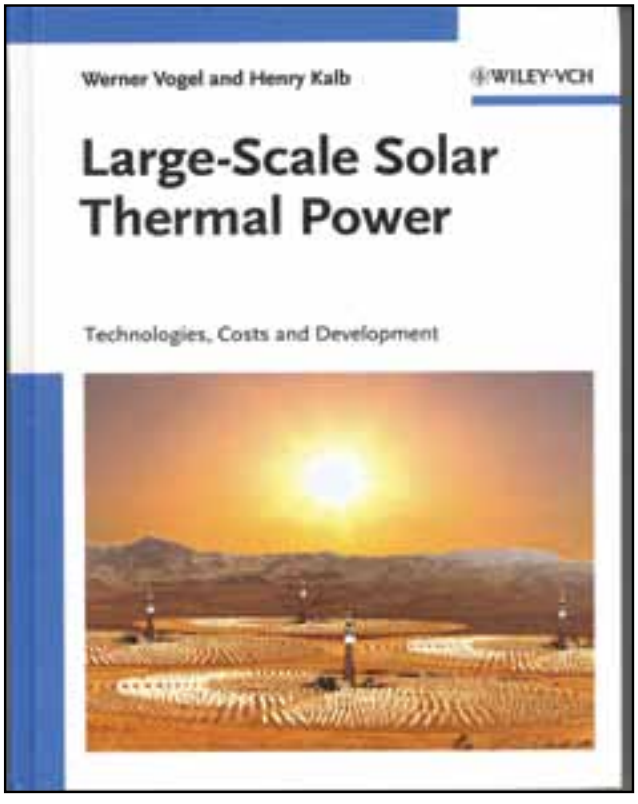
Features and benefits of the solar education kit

Features	Benefits
Compact housing with screen printed polycarbonate for module and aluminium plate for switches and metres	The design is integrated with solar module, battery, ammeter and voltmeter, which automatically increases the life for the system
Analog ammeter and voltmeter with potentiometer	This gives the user control over the resistance
Switch to select mode of operation	This allows the user to power the load through a solar cell or battery
Portable and light weight	This makes it ideal for training purposes
Aluminium anodized frame	This gives the system strong corrosion-free structural support
Simple to operate with clear instructions	It is easy for the user to 'do it yourself'

Source http://www.tatabpsolar.com/products_view.php?pr_id=Educational_Kit
Photo credit http://www.tatabpsolar.com/products_view.php?pr_id=Educational_Kit

Large-Scale Solar Thermal Power

Technologies, Costs and Development



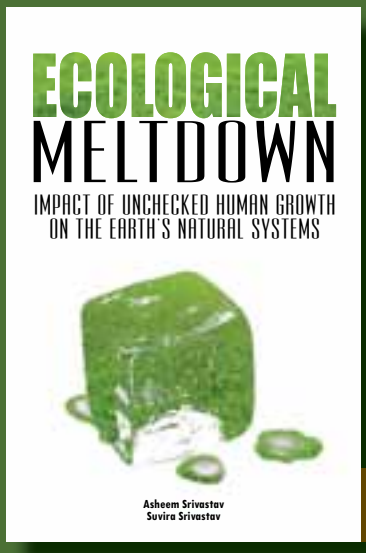
Editor: Vogel Werner and Kalb Henry
Year: 2010
Pages: 508
Price: ₹6309 (approx.)
Publisher: Wiley-VCH

This book is based on the work done by the authors that began in the mid-1970s on the topics of solar thermal power plants, long-distance power transmission, and solar hydrogen, for a study for the European Association for Renewable Energy (Eurosolar), carried out from 1996–1998. In the face of considerable resistance from the scientific and political communities, since the early 1980s, the authors have attempted to introduce the concept of importing solar thermal generated electrical energy.

In this book, all the variants of solar thermal technology are described. The main emphasis is, however, on the cost considerations related to mass production, applied, in particular, to solar tower power plants, and to a lesser extent to parabolic-trough and chimney plants. For each topic, open questions and concrete research approaches are discussed. In the appendix, among other things, the relevant energy-statistical data are presented in a clear form. This book not only intends to provide the necessary knowledge for a comprehensive estimate of the economic outlook for solar thermal power plants and the related concrete developmental requirements and possible courses of action but also provides the information needed to rank this new energy technology within the greater energy-political context.

Given the relative cost differences with other conceivable energy supply routes, the authors also talk about the CO_2 free coal-fired power plants as well as modern nuclear plants. In case of the latter, in particular, the author discusses the costs to be expected under mass production. And to complete the discussion, they summarize the situation concerning uranium reserves. This book also contains information on goal gasification and methanol production. In the appendix, the relevant energy-statistical data are presented in a clear form. This book, thus, intends not only to provide the necessary knowledge for a comprehensive estimate of the economic outlook for solar thermal power plants and the related concrete developmental requirements and possible courses of action, but it also provides the information needed to rank this new energy technology within the greater energy-political context. Thus, along with the specialized topics related to solar energy, the general question of the fastest possible conversion from oil to other; more secure future energy sources (and the associated costs) as a whole is discussed. In this connection, the most important elements of the necessary development programme are described. The book sketches an overall plan for a rapid turnaround of the energy supply, beginning as soon as possible, and is, therefore, directed not only at readers interested in solar energy, but also at all those who are asking themselves what are the options available in view of increasing oil prices, and in the face of the increasingly pressing questions of environmental protection and climate change.

This book, which can be seen as an important contribution to the issue of renewable energy, describes the technical and economical requirements of mass-produced solar thermal power plants, from the different types of power plants to the development needs and a massive development programme. The book is written by renowned and experienced experts in the field of renewable energy. And they show that solar thermal power plants, because of their simple technology, are easy to build with high production rates and, therefore, can play a substantial role in the rapid substitution of fossil fuels. On the basis of solar thermal power (using long distance transmission) and coal from substituted coal plants, a future energy system is described supplying gas and liquid fuels. This book gives a comprehensive picture of renewable energy and of crash-strategy, for the partial replacement of oil and natural gas.



The Ecological Meltdown

impact of unchecked human growth on the earth's natural systems

By
Asheem Kumar Srivastav, Indian Forest Service
Suvira Srivastav, Development communicator and Journalist

ISBN 9788179932780 • 256 pages • Hardbound • Rs 495 • 2010
TERI Press

Description

The book rings alarm bells of the ecological meltdown, footsteps of which are getting louder with every passing day. The difference between the current recession, and the one mentioned in the book is that there are ways and means to recover from a financial crisis. However, the picture that emerges from the exhaustive analysis of international data drawn from the most reliable sources clearly indicates that we have reached a point of no return: humanity has gained access to the gateway of extinction where the other biological species will disappear first followed by humans.

The book reinforces the key findings of the millennium ecosystem assessment report of the UN that humans have made unprecedented changes to the ecosystems and this pressure will increase globally, in coming decades, unless human attitudes and actions change.

Features

- Thoroughly researched and analytical
- Authoritative and up-to-date data from the most authentic sources
- Scientific data supported by graphs, figures, and tables
- Offers a global as well as Indian perspective on the issues
- A must read for all those who are concerned for the planet's future

Contents

- Humanity's ecological footprints: the ecological meltdown
- Earth's carrying capacity; co-relation between population dynamics and biodiversity; India in 2050
- State of global forests; Global wood fuel analysis; grazing impact in India
- Global Protected area assessment
- Wild species and challenges of illegal trade
- Conservation funds, impact of wars and civil strife; Global military budget
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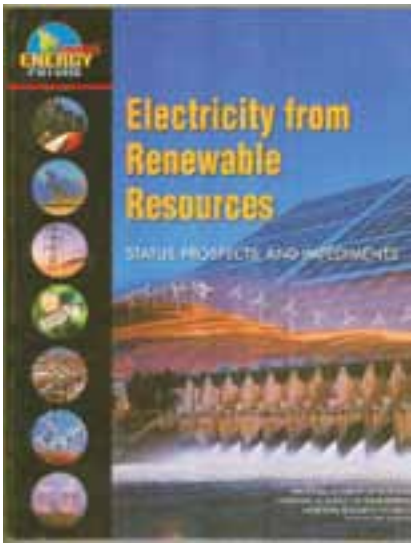

Electricity from renewable resources: status, prospects, and impediments

America's Energy Future Panel on Electricity from Renewable Resources and National Research Council and National Academy of Sciences

This book examines the technical potential of wind, solar photovoltaic, geothermal, solar thermal, hydroelectric, and other renewable resources for generating electric power. The book focuses on those renewable electricity technologies that show maximum promise for initial commercial deployment within 10–25 years and could have a substantial positive impact on the US energy system.

Along with offering a quantitative characterization of costs, performance, and impact of renewable electricity technologies, this book discusses barriers in the implementation process and describes research and development needs. It also addresses the challenges of incorporating renewable electricity technologies into the power grid, as well as potential improvements in the electricity system that could enable better and more extensive utilization of wind, solar thermal, solar photovoltaic, and other renewable resources

National Academies Press,
Washington, 367 pp.
Year: 2010

Renewable Energy: the facts

Interest in renewable energy has never been greater, but much uncertainty remains regarding the role that various technologies will play in the transition to a low-carbon future. This book sets out the facts—how the technologies work, where and to what extent they are currently employed, and where the greatest potential lies. Covering all the geothermal, hydropower, as well as new energy technologies, it also includes sections on how to best to promote the uptake of renewable and answers the common questions and opposition. The authors provide a number of German-sourced, yet internationally relevant, examples and strategies that have become increasingly significant in the promotion of renewable energy in recent years. The convenient layout mixes detailed explanation with clear takeaway facts and messages on each double-page spread. This straight talking, information-filled guide is the perfect primer for anyone who wants to better understand and promote renewable energy, whether in industry, study, policy of campaigns.

Seifried D and Witzel W
London: Earthscan, 251 pp.
Year: 2010

SPI powered by cooler planet

This website has all the information about solar panel. Visit this website if you want to find out how much you can save with solar panels. This website contains information regarding what are solar panels, solar panel inverter, solar panel installation, environmental information, passive solar energy, hot water panels, solar panels for your homes, and so on. It has a separate section, which contains news on solar gadgets and solar projects.

http://www.solarpanelinfo.com/

SolarPowerBeginners.com

One problem with solar information is that it can often get a little technical. Another issue is the blatant exaggerations that some people make vis-à-vis solar and also other forms of renewable energy sources. This website contains interviews and information from experts that aims to solve the above problems. The SolarPowerBeginner.com aims to bring various solar experts on a common platform and let them give all the answers that people need. The website contains a separate section, solar quotes, which gives information on how much solar panels cost.

http://www.solarpowerbeginner.com/solar-power-information.html

Solar DIY INFO

Solar DIY INFO is all about bringing you simple, practical solar energy solutions. If you have been looking for solar DIY (do it yourself) information, check out the growing list of articles and hints on solar applications on this website. If you need to know or are looking for ways to apply solar solutions to your home, cabin, farm or business, there may well be suggestion on this website that can assist you. The website has separate sections on wiring solar panels, troubleshoot solar panels, equipment solar power, do it yourself solar, solar panel tracking, solar panel orientation, passive solar home design, and so on. The website also contains a number of articles on solar DIY INFO. One can download free solar e-book for quick guidance on solar energy issues.

http://www.solardiyinfo.com/

totalsolarenergy.co.uk

In the face of ever increasing energy bills and global warming, the aim of this website is to give its viewers the information required to make ones mind up whether solar energy is the right choice. Whether you want to go the DIY way and cut costs dramatically or just want to have a system fitted by a reputable company, all the information you need is contained in this website. The good news is that the site is not about facts and figures on solar energy that only researchers and scientists can understand. It is about simple facts and figures that a layman can understand and use them to lower carbon emissions and fuel bills. The website has different sections on DIY solar heating, solar PV, solar toys, solar products, green electricity, solar power news, solar blog, and so on.

http://www.totalsolarenergy.co.uk/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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NATIONAL AND INTERNATIONAL EVENTS

National

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E-mail efyenq@efyindia.com
Website www.efyexpo.com

Renewtech India 2011
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Mumbai, India
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E-mail sales@renewtechindiacom
Website www.renewtechindia.com

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Mumbai, India
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Website www.electronicstoday.org

International

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Fax 86 10 63107703
E-mail zhouyangcnecc.org.cn
Website www.neforum.cn/2010/cn/

EXPO Solar/PV Korea 2011
16–18 February 2011
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Fax 82 2 71-58245
E-mail interexpo@infothe.com
Website www.exposolar.org

World Future Energy Summit 2011
17–20 January 2011
Abu Dhabi, United Arab Emirates
Tel 44 208 271 2134
Fax 44 208 910 7823
E-mail rxinfo@reedexpo.co.uk
Website www.worldfutureenergysummit.com

Solar Power Australia 2011
22–23 February 2011
Melbourne, Australia
Tel 61 2 9223 2700
Fax 61 2 9223 2622
E-mail info@iqpc.com.au
Website www.solarpoweraus.com.au

SNEC PV Power Expo 2011
22–24 February 2011
Shanghai, China
Tel 86 15821149946
Fax 86 21 64642653
E-mail teresa.wen@snec.org.cn
Website www.snec.org.cn

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Tel 49 307 26296-326
Fax 49 307 26296-309
E-mail Severine.Schniepp@solarpraxis.de
Website www.solarpraxis.de

4th International Photovoltaic Power Generation Expo
2 –3 March 2011
Tokyo, Japan
Tel 81 3 334985-76
Fax 81 3 334985-35
E-mail pv@reedexpo.co.jp
Website www.pvexpo.jp

26th Photovoltaic Symposium
3–5 March 2011
Bad Staffelstein, Germany
Tel 49 941 29688-39
Fax 49 941 29688-17
E-mail irene.eckhardt@otti.de
Website www.otti.de

Intersolar China / Solarcon China 2011
15–17 March 2011
Shanghai, China
Tel 49 (0) 723158598207
Fax 49 (0) 72315859828
E-mail engelhard@solarpromotion.com
Website www.intersolar.asia

Impianti Solari Expo
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E-mail info@senaf.it
Website www.senaf.it

Solar World Africa 2011
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Fax 27 11 4636000
E-mail brendan.harington@terrapinn.co.za
Website www.terrapinn.com/2011/solarafrica

PV America
3–5 April 2011
Pennsylvania, USA
Tel 1 202 628 7745
Fax 1 202 628 7779
E-mail info@seia.org
Website events.jspargo.com/seia09/public/enter.aspx

PV Korea 2011
6–8 April 2011
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Fax 82 53 601 5372
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Website www.energyexpo.co.kr

Energethica
7–9 April 2011
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RENEWABLE ENERGY AT A GLANCE

S.No.	Source/system	Estimated potential	Achievement as on 30 June 2010
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	12 009.48
2	Bio power (agro residues and plantations)	16 881	901.10
3	Bagasse cogeneration	5 000	1 411.53
4	Small hydro power (up to 25 MW)	15 000	2 767.05
5	Energy recovery from waste (MW)	2 700	72.46
6	Solar photovoltaic power	—	12.28
	Sub total (A)	**84 776**	**17 173.90**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	238.17
8	Biomass gasifier	—	125.44
9	Energy recovery from waste	—	52.72
10	Aero generator/hybrid systems		1.07
	Sub total (B)	**—**	**417.40**
	Total (A+B)	**—**	**17591.30**
II	**Remote village electrification**	—	6867 villages/hamlets
III	**Decentralized energy systems**		
11	Family-type biogas plants	120 lakh	42.60 lakh
12	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting system	—	119 634 nos
	ii. Home lighting system	—	603 307 nos
	iii. Solar lantern	—	797 344 nos
	iv. Solar power plants	—	2.92 MW$_p$
	v. Solar photovoltaic pumps		7334 nos
13	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	3.53 million m^2 collector area
	ii. Solar cookers		6.72 lakh
14	Wind pumps		1347 nos
IV	**Awareness programmes**		
15	Energy parks	—	511 nos
16	Aditya Solar Shops	—	302 nos
17	Renewable energy clubs	—	521 nos
18	District Advisory Committees	—	560 nos

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

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