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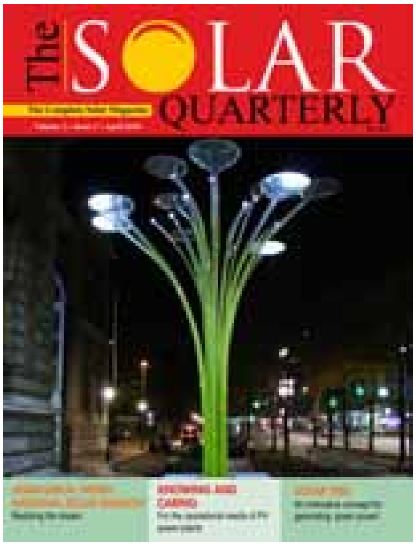
From the editor's desk...

We have added about 8 MW of grid-connected PV during the last financial year (2009/10). We have also added about 1.6 lakh solar home systems and lanterns in our list of achievements for the same period. In terms of cumulative capacity addition, 1.6 lakh small systems would not count much, but in terms of benefits, these have already touched 1.6 lakh people, mostly among the rural families who otherwise are bereft of the benefits of electricity. I do not intend to initiate the debate of MW vs access, but I certainly would like to induce some thought on the challenge that lies ahead in implementing the off-grid and decentralized solar component of the JNNSM for which the guidelines have recently been released. I want to particularly mention the three specific objectives clearly stated in the guidelines. These are to encourage innovation in addressing market needs and promoting sustainable business models; to provide support to channel partners and potential beneficiaries; and to create a paradigm shift needed for commoditization of such application. All of these objectives point at the critical requirement of *doers*, that is, those who will take up the challenge of implementation. These should not be mistaken with system suppliers and integrators who have become synonymous with project implementers, but enterprises emerging from within the government set-up, civil-society, the corporate world, and academia who will think and act innovatively. We need entrepreneurs who will try to understand the market needs, conceptualize and venture into new business models, match technological advancements with functionality to create new products and systems, and, finally, who will have the courage to take a deep breadth and dive into the sea of opportunity. We need to identify and nurture these *doers*. This is the biggest challenge.

Akanksha Chaurey
Director, TERI

Published by Dr R K Pachauri for the The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi – 110 003, Tel. +91 (11) 2468 2100 or 2468 2111, E-mail teripress@teri.res.in, Fax +91 (11) 2468 2144 or 2468 2145, Web www.teriin.org/pub, and printed at Excel Printers Pvt. Ltd., C-205, Naraina Industrial Area, Phase-I, New Delhi – 110028.



I am a regular reader of *The Solar Quarterly* magazine. I really like the content of this magazine. The articles are very interesting and informative. They help us understand varied facets of the solar energy industry. In the April issue, I was impressed with the articles on Jawaharlal Nehru National Solar Mission and solar tree. Solar tree is a very new concept and I should congratulate the editorial team for bringing out a detailed article on this concept.

Keep up the good work and all the best for the future editions.

Akash Sinha
Jharkhand

I have been reading *The Solar Quarterly* magazine for the past one year. I am a B Tech student, and I must say that this magazine has really helped me understand and clarify a lot of concepts and specifications. All the article are well researched and well written. I really like the section titled, 'university focus'. For students like us this section is very informative, as we get to know about centres, departments, institutes offering solar and renewable energy courses.

Thank you for sharing with us so much information on solar energy. All the best for the future issues of the magazine.

Prema Singh
West Bengal

I have recently started subscribing to *The Solar Quarterly* magazine. I must say that I am really impressed with the content of the magazine. I want to congratulate the editorial team for interviewing such imminent personalities. These interviews give us a complete picture of what these people, who are sitting in positions of power, are planning and how they want to implement their plans for a better tomorrow. I specially liked Shailendra Shukla's and Ajit K Gupta's interviews. The questions were well thought out and the answers were all very informative as well as elaborate.

Joyita Sarkar
Bihar

I have been reading *The Solar Quarterly* magazine since its inception in July 2008. I must say that the magazine has evolved over time. The number as well as the range of the articles have increased over time. I also like the new sections that have been added in the magazine few months back. I specially like the web update section. Though this section is small but is very informative and unique.

I want to congratulate the entire team for taking the initiative of spreading knowledge and awareness among the common people on the issue of solar energy. Solar energy is the future and we need to use this energy very prudently for a sustainable future. I hope that this magazine is able to spread this message among on and all.

Pradeep Saxena
Maharashtra

I liked the article on Jawaharlal Nehru National Solar Mission. It as very informative and gave a complete picture of varied facets of the mission. I would request the editorial team to include more articles on the various programmes and plans that the Government of India is undertaking and implementing to develop solar energy in our country.

M N Srinivasan
Delhi

Thank you very much for your encouragement. The editorial team of The Solar Quarterly will make every effort to make this magazine highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvement in terms of content and presentation.

Editor
The Solar Quarterly

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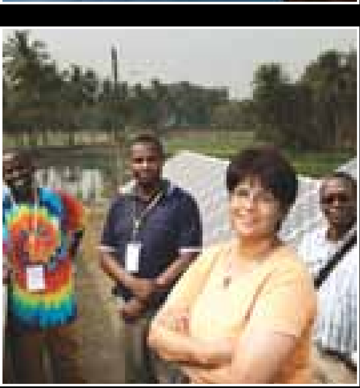

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ADB launches $9 bn solar energy initiative

The Asian Development Bank (ADB) has launched an ambitious project that it hopes will attract $6.75 billion of private investment into solar energy projects in the region over the next three years. The initiative will mark an important step towards meeting a larger portion of Asia's growing energy demand with clean energy. The Manila-based multinational lender, which unveiled the initiative at its annual meeting in the Uzbek capital, Tashkent, said that it would provide an additional $2.25 billion to support a project to generate 3000 MW of solar power by 2012. The bank did not specify target regions, but said Central Asia's growing electricity demand, as well as its abundant desert and commitments to offset high carbon emissions, made the area a strong candidate for investment. With energy demand projected to almost double in the Asia and Pacific region by 2030, there is an urgent need for innovative ways to generate power, while at the same time reduce greenhouse gas emissions.

Courtesy: United Nations

Sustainable solar energy can be the clean power of the future, if there are appropriate incentive and financing mechanisms in place. The ADB said it would set up a separate $500 million fund to help kick start the Asia solar energy initiative by covering some of the high start-up costs. ADB President, Haruhiko Kuroda, told reporters the initiative would be a "major platform for sharing information on solar technologies, projects, products and issues, and facilitate the transfer of financial resources to developing countries to reduce technology costs". Last year ADB provided nearly $1.3 billion for projects with clean energy components. From 2013, its target investment in the sector will increase to $2 billion a year.

Source: www.livemint.com

NREL to concentrate on solar thermal technology

As the market for clean solar power rapidly expands, National Renewable Energy Laboratory (NREL) researchers are investigating advanced concepts in concentrating solar power (CSP) with $5.4 million in American Recovery and Reinvestment Act funding awarded by the Department of Energy (DOE), US. The new work includes establishing two new facilities and extensive improvements to an existing third facility on the NREL's research campus. It also will include field testing of new CSP technologies at the Solar Technology Acceleration Center (SolarTAC), a new 76-acre solar test site. CSP uses mirrors to reflect sunlight onto receivers. Unlike photovoltaic cells that directly convert sunlight into electricity, this method uses the sun's heat to drive a generator to produce electricity. Key to CSP's commercial success is the development of an economical and effective energy storage capability that will hold the sun's heat to generate clean electricity during peak power demand, or during cloudy weather and at night. NREL is studying new thermal storage materials and technologies that will allow CSP plants to work at higher temperatures and greater efficiencies, while lowering the cost of energy produced by these systems. DOE's goal is to make CSP cost-competitive by 2015 and provide a sizeable amount of clean energy to the grid by 2020. CSP plants are generating about 600 MW of electricity today, mostly in the US and Spain. An additional 1000 MW are under construction by utilities in sunny regions. In the US an additional 8 GW of CSP is being planned.

Two of the NREL facilities—the Advanced Thermal Storage Process and Components Integration Laboratory and the Optical Components Characterization Laboratory—will be located in NREL's new Energy Systems Integration Facility (ESIF), which is scheduled to be completed by late 2011.

Source: www.worldofsolarthermal.com

Courtesy: DOE/NREL

Move to make solar power deals bankable delays developers' pact with NTPC arm

The power purchase agreements (PPAs) between solar power developers and the trading arm of National Thermal Power Ltd. (NTPC), NTPC Vidyut Vyapar Nigam Ltd. (NVVN), could get delayed, as the government is still working out mechanisms to make these agreements more bankable. The core committee formalizing the guidelines for calling for expression of interests (EoIs) is yet to reach a decision. Efforts are being made to make the PPAs more bankable. Elaborating this, an official said, "Certain issues like payment security mechanism need to be addressed before the guidelines for inviting EoIs are notified." It is being felt that the balance-sheet of NVVN may not by itself, lead to the bankability of PPAs. Hence, the possibility of setting up a risk guarantee fund is being considered. NVVN has been designated as the nodal agency to procure solar power from photovoltaic (PV) and thermal project developers under the National Solar Mission. NVVN, in turn, will bundle four units of thermal power with each unit of solar power to bring down the final cost of power. Once the issues are resolved, the government will notify the guidelines for the purpose. Earlier, the government was expecting to notify the guidelines by the second week of June. EoIs will be called for procuring solar power from the project developers.

The project developers offering the best discount on a tariff notified by the Central Electricity Regulatory Commission (CERC) will figure higher in the pecking order during the allocation of identified projects under the National Solar Mission programme. The tariff rates notified by the CERC for 2010/11 are Rs 17.90 a unit for PV and Rs 15.40 a unit for solar thermal. For solar power from smaller rooftop systems, the respective state utilities are the designated agency to procure and decide on the tariff. The government expects about 800 MW of PPAs to be signed during the current fiscal, under the phase I of the National Solar Mission. For solar PV, PPAs for nearly 200 MW out of the 500 MW, which are proposed in the first phase, are expected to be signed. While for solar thermal, it is expected that PPAs for all the 500 MW would be signed in the current financial year itself.

Source: www.hindubusinessline.com

New R&D initiatives at Solar Energy Centre

The Union Minister for New and Renewable Energy, Dr Farooq Abdullah, laid the foundation stone for three more technical facilities in the research and development campus of the Solar Energy Centre in the capital. The Centre is located on the Gurgaon–Faridabad Road on the outskirts of Delhi. One of the three new facilities will be the Solar Thermal Testing, Research and Simulation unit being developed by a consortium led by Indian Institute of Technology (IIT), Mumbai. The unit will have a grid-connected solar thermal power plant of 1 MW capacity. It will also have a laboratory where companies and research institutions can test the performance of different solar concentrator options, coatings and materials, and components and systems for solar thermal power plants. In addition, the consortium will develop a solar power plant simulator that simulates the performance of the actual solar thermal plant through component and system models. Members of the IIT-Mumbai led consortium include Tata Power, Tata Consulting Engineers, Larsen & Toubro, Clique, KIE Solatherm, and Solar Energy Centre. The second facility is a pilot project based on indigenously developed solar concentrator technology that will deliver low cost thermal energy. Chennai-based Megawatt Solutions has partnered with the Solar Energy Centre to demonstrate the technical and commercial viability of the technology that can harness solar energy through the thermal route for various applications, such as industrial process heating, air-conditioning, and power generation. The consortia in both these pilot projects for development of solar thermal energy represent a new model for academia, industry, and government partnership for technology development and research. Dr Abdullah also laid the foundation stone for a 20 kW solar photovoltaic (PV) power plant for validation of various design configurations. The configurations of the plant have been designed by the Solar Energy Centre. The PV plant is being installed by Solar Semiconductor Pvt Ltd. with power conditioning units supplied by Optimal Power Synergy India.

Source: www.hindubusinessline.com

BIT Mesra to collaborate with US college

In order to systematically harness solar energy, students of the Birla Institute of Technology (BIT), Mesra, along with students of Harvey Mudd College, California, have undertaken a joint project to develop a solar energy storage system. The students' team will develop a mechanical system for harnessing and storing solar energy so that this energy can be preserved for long and used when required. Today, the energy crisis is a global phenomenon. Through this project, the team of students will try to address this crisis, which will be useful to the society from the point of view of clean energy use. Exchange visits between the two institutions will form a special part of this innovative initiative.

Source: www.telegraph.com

China tops the world in solar panel manufacturing

China has for long been the world's factory for iPods, cell phones, and a host of appliances. Now, it can add solar panel manufacturing to the list of industries that it dominates. Five of the top 10 solar panel manufacturers in the world are from China, according to a report by Massachusetts-based Genentech analysts, GTM Research. "More and more consumers in the US can expect the solar modules placed on their rooftops to be

Courtesy: DOE/NREL

coming from the Chinese manufacturers," says Shyam Mehta, a senior market analyst at GTM. "The modules might have an American brand, but they will still be made in China." Suntech Power (STP) in China is in the second position on the global list. Other Chinese companies in the top 10 are Yingli Green Energy (YGE), Trina Solar (TSL), Solarfun (SOLF), and Canadian Solar (CSIQ), according to GTM Research. However, the individual crown goes to the US company, First Solar (FSLR), which grabs the laurel for the first time ever. First Solar has factories that can produce more than 1 GW of solar panels from its factories in the US, Germany, and Malaysia. One GW of solar panels could produce enough power for about 145 000 average homes and thus, save about 1 million metric tonnes of carbon dioxide emissions every year, as per the company spokeswoman Melanie Friedman.

Growing preference for solar systems

In California, the largest regional market for solar in the US, the retailers, are showing more love for panels produced by companies, such as Suntech Power, Trina Solar, Yingli, and Kyocera. This is as per Mark Bachman, a financial analyst with Auriga. Perhaps not surprisingly, these manufacturers are getting more orders because they are able to produce less expensive solar panels. Prices for solar electricity systems vary depending on location, equipment models, and labour costs. In general, a 2 kW system, suitable for a single-family home, could cost a homeowner nearly $20 000, not counting government incentives. But those government incentives have played a big role in boosting the consumer demand for solar panels, as have financing plans offered by installers. Some cities and counties have also sued bonds to fund the installation of solar electric systems for their residents and businesses. The property owners then repay their local governments over time through special fees on their property tax bills.

Germany remains the biggest market

Although 2009 was gripped by recession, solar panel production actually grew 41% to 8.9 GW. Strong demand especially in Germany led to this increase. In the fourth quarter alone, the country installed 1.3 GW. Germany is the largest solar market in the world because of a government policy that requires utilities to buy solar electricity at prices higher than they pay for power from fossil fuel-burning plants. Those prices are set to decrease this year, so many developers have been hurrying to complete projects. This rush began in the second half of last year. But earlier in 2009, solar panel makers were shutting down production lines and furloughing their workers because the recession had caused banks to slow or even stop loaning money to project developers.

Sources: www.solarplaza.com

Solarfun unveils SolarIris BIPV module

Solarfun Power Holdings Co. Ltd, a vertically integrated

manufacturer of silicon ingots, wafers and photovoltaic cells, and modules, has developed the SolarIris line of building-integrated photovoltaic (BIPV) modules. Building on the years of expertise in BIPV, Solarfun says, it integrated its high-efficiency cells into a new module that is both highly reliable and aesthetically pleasing. As with the rest of Solarfun's lineup of PV cells and modules, the SolarIris modules will also comply with the quality standards that are widely followed in the industry, including ISO 9001, TUV, CE, and UL. SolarIris improves on the typical visual trade-off of other hollow BIPV modules due to the effects of soldering on the back of a cell. The module features highly visible and visually pleasing artistic patterns and designs, Solarfun says. Built with three layers of glass, SolarIris conforms to the architectural requirements for glass thickness and strength, allowing it to be easily and safely integrated into the roof or walls of a structure. In addition, high light transmittance and insolation properties make SolarIris suitable for greenhouses, skylights, and windows.

Source: www.solarindustrymag.com

BIPV stadium listed as the world's most important sports venue

SportsPro magazine has listed the World Games Stadium in Kaohsiung, Taiwan, as the world's most important sports venue. With a capacity of 55 000, the stadium features 8844 solar panels, making it the largest solar panelled sports venue in the world. The stadium, which was designed by Toyo Ito, a Japanese architect known for creating conceptual architecture, and completed in 2009, generates enough energy to supply 75% of its power needs during an event and, when not in use, powers 80% of the surrounding area. David Cushnan, editor of SportsPro said, "The World Games Stadium might not be the largest or most-used sports venue in the world, but there can be no doubt that, thanks to the environment-friendly way it has been designed, it is amongst the most significant and could well be a model for the next generation of stadia." That guaranteed it the number one spot, even against some of the most historic sports venues in the world, such as Fenway Park, Augusta, Lord's, and the Melbourne Cricket Ground.

Source: Photovoltaics International

New product: Triulzi's glass washing and drying system reduces water consumption to save costs

Triulzi Cesare has introduced a new system for glass washing and drying that is claimed to produce higher quality PV panels and a reduced cost, using reverse osmosis water treatment. The SY.1610.6.3.4 is a horizontal solution for panel cleaning, but is also available in a vertical solution. Effective cleaning of substrates and cover glass is required to ensure solar cells can operate at maximum performance. Increasing attention to reduce water consumption is required for environmental and production cost requirements. The monitoring of the water quality feature is essential. The machine is supplied with inlet roller conveyor, prewash section, washing section with three pairs of cylindrical brushes using a reverse osmosis cascade system, and heated water system. Drying is done by four air knifes fed by high a pressure fan fitted on the top of the machine into a sound proofed box to reduce noise level and final outlet roller conveyor. The machine is equipped with energy saving system and PLC controls. A conductivimeter is used to maintain the correct water

parameters and constantly refreshes the water in the tanks throughout a cascade system. This technology can be used for glass preparation, pre-lamination, and after the process wherever required

Source: www.pvtech-org

Solar PV inverters reach 98.4% efficiency

Solar PV inverters have reached 98.4% efficiency. Siemens says its Sinvert PVS solar inverters for medium-sized and large solar photovoltaic (PV) power plants have achieved efficiencies of 98.4%. The 3-phase, transformer-less solar PV inverters have graded power outputs of 500, 1000, 1500, and 2000 kW. The Siemens compact Sinvert PVS central solar PV inverters are also available in photovoltaic containers, complete with medium-voltage components. The solar PV inverter series can be integrated into supervisory control and data acquisition systems through standardized communication interfaces.

Source: www.renewableenergyfocus.com

Solar chimneys: light at the end of the tunnel

The idea for solar updraft towers has been around for some time and small-scale pilots have come and gone. Projects are rumoured to be underway in Australia, Botswana, and Spain. However, major developments have yet to break ground. In 1982, a German engineer used sunlight to produce low-cost power, day and night, without water, mirrors, or photovoltaics. Since then, his miracle technology has been universally ignored in favour of other more costly and more complex technologies. The burning question is: why? The idea behind solar updraft towers, or solar chimneys, where hot air is trapped under a wide expanse of heat-absorbing material and then forced up a central ventilation shaft, powering a turbine in the process, has been around for over a century. According to Eduardo Lorenzo Pigueiras of the Solar Power Institute at the Polytechnic University of Madrid, the artillery colonel Isidoro Cabanyes proposed a 'solar motor' of this kind in a publication called *La Energía Electrica* in 1903. And since then, the

concept has continued to intrigue engineers, but not the investors. So far, only two fully-functioning solar updraft towers have ever been built: a 22-metre-high chimney in Botswana in 2005, and the 1982 prototype constructed by Jörg Schlaich of Schlaich Bergermann and Partners in Manzanares, Spain. Schlaich admits his pilot tower—a small-scale construction which produced up to 50 kW, had a height of 195 metres and a heat-collecting canopy measuring 46 000 sq m—"was not optimized for output, but optimized for testing." He was still impressed with the results, however. "We are absolutely convinced that the solar tower [concept] produces electricity at half the cost of trough collectors," he added.

American Capital forms venture with MSM Energy

Seeking to garner a share of the Jawaharlal Nehru Solar Mission 2020 initiative, the US-based solar energy giant, American Capital Energy, on 10 June 2010, announced joining hands with MSM Energy Ltd. to float a 50:50 joint venture company, ICE Solar, to provide photovoltaic (PV) solar engineering, procurement, and construction to the Indian markets.

Addressing a press conference, American Capital Energy CEO and President, Tom Hunton, said the new solar energy joint venture would entail an investment of Rs 2000 crore, over the next three years. The company had already bagged a 5 MW solar power project in Gujarat in the private sector and had got solicitations from a number of players wanting to venture into solar energy.

Speaking on the occasion, Walter Borden, Managing Director, of the Asia Pacific, region of American Capital Energy, said "We are proven system integrators and project developers with track record of large commercial and utility scale installations, including the largest rooftop systems in North America, and separately, one of the largest utility scale ground mounted projects in the US. We are excited to enter the Indian market and plan to install 100 MW of PV solar in the first few years of our operations."

Source: www.hindu.com

Solar energy hopefuls await the October deadline

The three-year-old Indian solar power industry is waiting with bated breath for the results of the first step under the Jawaharlal Nehru National Solar Mission, a project that can make or break the local industry.

While some players like IndoSolar have already invested hundreds of crores of rupees, others like Moser Baer PV are waiting for the initial indications from the industry before plunging into expansion mode.

The mission is one of the most ambitious solar incentive plans in the world, and targets increasing India's grid-based solar power from about 15 MW at the end of 2010 to 1 GW by March 2013.

The domestic demand for grid-connected solar power facilities, both photovoltaic or direct conversion and thermal or heat-based generation, is currently about 5 MW a year, and will jump to about 400–500 MW by end of this year, if the mission succeeds.

Source: www.dnaindia.com

LIMO develops diode laser system for solar cells

Germany-based LIMO has introduced LIMO120-F400-SL808-103, a diode laser system that generates photoluminescence and thermographic signals by asymmetric homogeneous illumination of the solar cell. The product is designed for fast in-line solar cell inspection. The 120 W fibre-coupled industrial laser system is combined with a processing head from the company's IOS00019x-series. This device generates a homogeneously illuminated field under a 35 angle of incidence that fits to solar cell sizes of up to 210 mm x 210 mm. The centre wavelength of 790–808 nm is essential for the separation of excitation source and signal light, the company notes. In addition, small bandwidth versions (<1 nm) are available as an option. Solar cell inspection tools based on the LIMO laser source operate with a single light source as compared to other inspection tools, which use two light sources. This method makes the tools more compact and reduces materials as well as assembly costs, according to LIMO.

Source: www.limo.de

Solar heat and power systems on the horizon

For the past few years, much of the innovation around solar technology has been aimed at generating more electricity from sunlight. But a new crop of entrepreneurs are working to use the sun more efficiently by using its heat, as well as its light, for individual business, factories

Courtesy: DOE/NREL

and, perhaps one day, even homes. These companies say that providing both electricity and heat reduces the amount of time it takes customers to recoup their investments. "It is a single system that provides the greatest impact on a homeowner's energy bill," says Sam Weaver, Chief Executive Officer of heat and power solar startup Cool Energy. These technologies stand to benefit if natural-gas prices rise, considering that natural gas is used, both for heating and for electricity. In general, the new combined-solar-heat-and-power systems are based on the same concentrating solar-thermal technology used by the big solar projects in the Mojave Desert. The large desert systems concentrate sunlight and use it to heat the fluid running in tubes. Then, that steam can be used to run a turbine and produce electricity. With the systems for homes and businesses, the heat would be used directly for warm air or hot water, or, although it may seem counter intuitive, could be used to run an air conditioner. Heat paired with an absorption chiller, for example, can power air conditioning. Meanwhile, some of the systems siphon a portion of the steam to make electricity, such as via a generator, while others use photovoltaic cells, and in some cases concentrators that direct sunlight to those cells, to produce electricity.

Source: www.renewableenergyworld.com

Foreign firms eye India's solar power market

India's drive to ramp up its solar capacity may trigger a stampede of firms from Asia, Europe, and North America, chasing a share of the $3.5 billion of business up for grabs by 2013 and trampling over smaller domestic players. Arizona's First Solar and China's Suntech Power Holdings are working on plans to enter the market as India commits to an ambitious $70 billion programme to build 20 GW of solar capacity by 2022. The French group Areva's renewable energy unit, it is scouting for solar project contracts in India. Foreign firms such as Suntech and First Solar, which have the scale and ability to sell cheap solar gear, are likely winners as this market grows, along with Taiwan's Motech Industries, which has signed a cell supply deal with India's Solar Semiconductor. In the near term, the Chinese and Taiwanese may well turn out to be the big beneficiaries. For now, those with advanced technology have a clear advantage. India is building an initial capacity of 1 GW by 2013, enough to power close to 1 million homes. It would then add 3–10 GW by 2017, before aiming to hit capacity of 20 GW by 2022. India hopes that international funding and technological support would help build the rest of the capacity.

Source: www.economictimes.com

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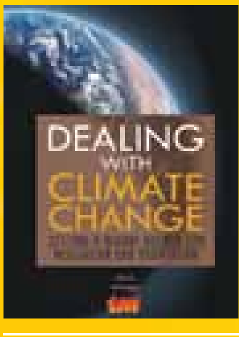
NEW RELEASES

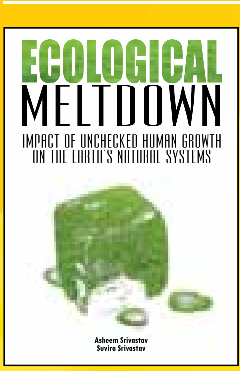


Dealing with Climate Change: setting a global agenda for mitigation and adaptation

R K Pachauri, Director-General, TERI, and Chairman, IPCC

Climate change is the most important existential threat that humanity faces at the moment. There is an urgent need for a framework for international cooperation, research and development, technology, finance, market mechanisms, as well as consensus on the role of business in addressing the issue. In this book, seven authoritative contributions from international experts lay out the issues, the options, and the prospects of mitigation and adaptation.

9788179932773 • 300 pages • Hardbound • Rs 695 • 2010 • TERI Press

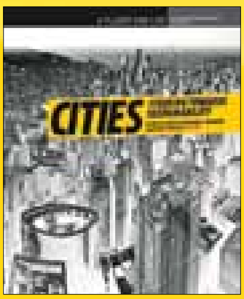


Ecological Meltdown: Impact of unchecked human growth on the earth's natural system

Asheem Kumar Srivastav and Suvira Srivastav

Ecological Meltdown is a thought-provoking book that documents the destruction of biodiversity and ecosystems due to human actions. It warns of an impending ecological meltdown and analyses the causes behind it. These include unprecedented growth in human population, diversion and degradation of natural ecosystems, changing consumption patterns and survival strategies, sinking conservation funding, ineffective management, weak international biodiversity-related conventions, and never-ending conflicts. It also looks at solutions that need to be urgently adopted by the global civil society and national governments. The book is an invaluable resource for policy-makers and institutions in the forestry, wildlife, energy, rural development, environment sectors, conservationists, scientists, researchers, and students of environmental science.

9788179932780 • 256 pages • Hard bound • Rs 495 • 2010 • TERI Press

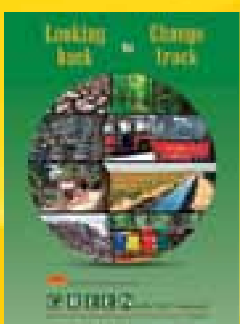


CITIES: steering towards sustainability

Pierre Jacquet, Rajendra K Pachauri, and Laurence Tubiana

Today's urban actors, both citizens and their leaders, have a major responsibility as trustees of the future: their present actions will influence the shape and structure of cities, so that the generation to come may live healthy and contended lives. This volume takes the reader straight to the heart of how cities work, and identifies contemporary trends, mechanism and tools that can influence current strategies and choices. The authors show that urbanization is not a problem per se for sustainable development, but rather that cities, in all their diversity and complexity, offer solutions as well as challenges.

9788179931318 • 272 pages • Soft bound • Rs 595 • 2010 • TERI Press



Looking back to change track

Divya Datt and Shilpa Nischal (eds)

The present study picks up the thread from 1997, when TERI's study Growth with Resource Enhancement of Environment and Nature (GREEN) India 2047 was undertaken. The book examines environmental trends in the last decade, isolating underlying priority issues and identifying strategies that are needed to prevent or ameliorate environmental damage. The mandate of the present study, thus, is to go beyond reporting the state of India's environment. Through an evaluation of the major factors that are responsible for the present state and the characteristics of resulting impacts, the study provides an agenda for action.

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Illuminating darkness

The second solar lanterns survey in India

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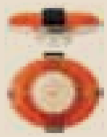
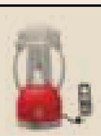
A survey on solar lanterns was earlier published in the October 2008 issue of *The Solar Quarterly* magazine. However, considering the dynamism in the field of solar lighting and the recent advancements in the field of light-emitting diode (LEDs), a fresh survey was recently undertaken, the results of which are being presented in this article. This article gathers information on several solar lantern manufacturers from all across India and puts them forward on a common platform for the benefit of common people.

The survey involved about 100 solar lantern manufacturers in India, eliciting specific information from them about their lanterns, covering all important and critical aspects of a solar lantern. Survey questionnaires were accordingly prepared and sent out to a list of solar lantern manufacturers all across India. The list was received from the Solar Energy Centre, a unit of the Ministry of New and Renewable Energy (MNRE) for development and promotion of solar energy technologies. Also, the list of solar lantern manufacturers approved by the Global Approval Programme for Photovoltaic (PV GAP) was taken into account. The Energy and Resources Institute (TERI's) own internal resources were utilized along with the medium of Internet for identifying solar lantern manufacturers in India. However, during the process, some suppliers might have been missed out inadvertently.

In response to the survey conducted, about 16 odd responses were received on 39 solar lantern models. Based on these 16 responses for the time period of 1989–2010, a comprehensive information table (Table 1A and 1B) has been prepared on different solar lantern models available in the market.

For the benefit of our readers, we have made some preliminary observations regarding the development of new trends in solar lantern market in comparison to the results of the 2008 survey.

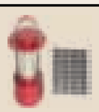
Table 1A LED lanterns (in ascending order of LED wattage)

S. No	Lantern manufacturer	Lantern model	Photograph of the lantern model	Luminous efficacy (Lumen/ Watt)	Light distribution (in Degrees)	Illuminance (Lux output at 1 feet from the centre of the base of the lantern)	Lantern housing material	Height and weight of the lantern	Lantern type (CFL/ LED/ both)	Wattage of CFL/ LED (Watts)	Lumen output (Lumens)	CFL/LED make	Battery capacity (V,Ah)
1	Greenlight Planet India Pvt. Ltd	Sun King		90	220	*	PC, Rubber and ABS with a nylon strap	30 cm, 0.3 Kgs	LED	0.66 (rated)	59.40	_	3.7 V, 0.75 Ah (Lithium-Ion battery)
2	Global Telelinks Ltd.	SHL1	–	100	120	101 lux at 1 feet horizontal distance 400; lux at 1 feet vertical distance	ABS	0.251 Kgs	LED	1.00	100.00	Tk	3.7 V 1400 mAh (Lithium-Ion battery)
3	Global Telelinks Ltd.	SHL 2	–	100	120	101 lux at 1 feet horizontal distance 400 lux at 1 feet vertical distance	ABS	0.271 Kgs	LED	1.00	100.00	Tk	Two 3.7 V 1400 mAh (Lithium Ion battery)
4	Ritika Systems Pvt. Ltd	KIRANDEEP		110	180	*	ABS/PC	26 cm, 1.1 Kgs	LED	1.00	110.00	OSRAM/ CREE	6V, 4.5 Ah (Lead Acid battery)
5	Solid Solar	SS-1007		100	_	_	ABS and PC	20 cm, 1.3 Kgs	LED	1.00	100.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah (Lead Acid battery)
6	Solid Solar	SS-1009		100	_	_	ABS and PC	20 cm, 1.4 Kgs	LED	1.00	100.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah (Lead Acid battery)
7	Avni Energy Solutions Pvt Ltd	ELECTRA		120	360	50 lux at 1 feet horizontal distance; 118 lux at 1 feet vertical distance	ABS	26 cm, 1.25 Kgs	LED	1.50	180.00	NICHIA	6V, 4.5 Ah (Lead Acid battery)
8	Solid Solar	SS-1008		100	_	_	ABS and PC	20 cm, 1.5 Kgs	LED	1.50	150.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah (Lead Acid battery)

Standard/ certification of battery	Duration/ hours of operation (Hours) [considering fully charged battery)	Input charging option (Solar, AC, non -rechargeable batteries, manually operated)	Size of solar PV panel	Is the SPV module certified? (yes/no)	IEC standard number that the SPV module conforms to	Certifying authority of solar module	Is lantern certified? (yes/no)	Certifying authority of the lantern	Market introduction of the model (Year)	Price of the lantern without solar module (Rs)	Price of the lantern with module (Rs)	Average number of systems sold in a year	Additional remarks/other provisions in the lantern
ROHS Certified	16 Hours	Both Solar and AC (AC charging via standard Nokia charger)	700 mWp	No	–	–	Yes	CE	2009	–	850	–	Could be floor lamp/table top/ wall mounted; most portable 1 year warranty; Digital chip to maintain steady
–	4 -30 Hours	Solar Rechargeable Mobile charger community charger	3 Wp	Yes	–	–	–	–	2009	1100	1500	1000	–
–	8 -60 Hours	Solar Rechargeable Mobile charger community charger	5 Wp	Yes	–	–	–	–	2009	1300	2000	1000	–
–	5 - 6 Hours	Both Solar and AC	2Wp	Yes	IEC 61215	STQC	Yes	MNRE	2010	900	1200	3200	–
–	7-8 Hours	Both Solar and AC	2 Wp	Yes	–	MNRE	Yes	–	–	1616	2457	15 000	–
–	6-7 Hours in full brightness mode 12-14 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	–	MNRE	Yes	–	–	1710	2549	15 000	Mobile charging; different illumination modes in the lanterns
CE Certified	12 Hours	Both Solar and AC	3 Wp	Yes	IEC 61215	TUV Rheinland	No	–	2009	975	1500	10 000	Efficiency: 85% protections; low battery voltage cutoff; over voltage protection; no load protection sufficient indicators
–	6–7 Hours in full brightness mode 12–14 Hours in low brightness mode	Both Solar and AC	5 Wp	Yes	–	MNRE	Yes	–	–	1710	2549	12 000	Mobile charging; different illumination modes in the lanterns

Contd...

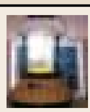
Table 1A LED lanterns (in ascending order of LED wattage) *(contd...)*

S. No	Lantern manufacturer	Lantern model	Photograph of the lantern model	Luminous efficacy (Lumen/ Watt)	Light distribution (in Degrees)	Illuminance (Lux output at 1 feet from the centre of the base of the lantern)	Lantern housing material	Height and weight of the lantern	Lantern type (CFL/ LED/ both)	Wattage of CFL/ LED (Watts)	Lumen output (Lumens)	CFL/LED make	Battery capacity (V,Ah)
9	Solid Solar	SS–1001		80	_	_	ABS and PC	37 cm, 1.6 Kgs	LED	1.50	120.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah (Lead Acid battery)
10	Solid Solar	SS–1002		80	_	_	ABS and PC	20 cm, 1.2 Kgs	LED	1.50	120.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah (Lead Acid battery)
11	Solid Solar	SS–1003		80	_	_	ABS and PC	27 cm, 1.55 Kgs	LED	1.50	120.00	OSRAM/ CREE/ NICHIA	6 V, 4.5 Ah
12	Moser Baer India Ltd	SL03–SL05	_	80	360	55 lux at 1 feet horizontal distance; 120 lux at 1 feet vertical distance	PC and ABS	24.5 cm, 1.6 Kgs	LED	1.60	128.00	SEOUL / EVERLIGHT	6V, 4.2 Ah (Lead Acid battery)
13	Solkar Solar Industry Ltd	WONDERLITE	_	*	180	20 lux at 1 feet horizontal distance; 2000 lux at 1 feet vertical distance	ABS	20 cm, 1.2 Kgs	LED	1.70	*	Brightness opto	6V, 4.5 Ah (Lead Acid battery)
14	Bhambri Enterprises	KSSL 09 a/b		*	*	52 lux at 1 feet horizontal distance	ABS/ Acrylic	20.3 cm, 1.0 Kgs	LED	2.00	_	*	6V, 4.5 Ah

Standard/ certification of battery	Duration/ Hours of operation (Hours) [considering fully charged battery)	Input charging option (Solar, AC, non-rechargeable batteries, manually operated)	Size of solar PV panel	Is the SPV module certified? (yes/no)	IEC Standard number that the SPV module conforms to	Certifying authority of solar module	Is lantern certified? (yes/no)	Certifying authority of the lantern	Market introduction of the model (Year)	Price of the lantern without solar module (Rs)	Price of the lantern with module (Rs)	Average number of systems sold in a year	Additional remarks/other provisions in the lantern
_	6–7 Hours in full brightness mode 12–14 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	_	_	_	_	_	1558	2808	10 000	Big study light; Different illumination modes in the lanterns
_	6 Hours in full brightness mode 12 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	_	_	_	_	_	1706	2955	13 000	General light
_	6 Hours in full brightness mode 12 Hours in low brightness mode	Both Solar and AC	3Wp	Yes	_	_	_	_	_	1867	3116	12 600	Big general light
MNRE Approved	6 Hours in full brightness mode 12 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	IEC 61215, IEC 61646	MNRE	_	_	2010	2000	2500	_	Solar and AC charging; mobile charging FM; different illumination modes in the lanterns
CE Certified	7 Hours in full brightness mode 13 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	IEC 61215, IEC 61646	MNRE	Yes	MNRE	2009	1300	2000	20 000	Different illumination modes in the lanterns
_	5 - 6 Hours	Both Solar and AC	3Wp	Yes	IEC 61215, IEC 61730-1, IEC 61730-2, TUV Safety Class 11	_	No	_	2007	1050	1600	1000	_

Contd...

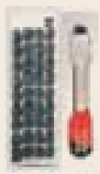
Table 1A LED lanterns (in ascending order of LED wattage) *(contd...)*

S. No	Lantern manufacturer	Lantern model	Photograph of the lantern model	Luminous efficacy (Lumen/ Watt)	Light distribution (in Degrees)	Illuminance (Lux output at 1 feet from the centre of the base of the lantern)	Lantern housing material	Height and weight of the lantern	Lantern type (CFL/ LED/ both)	Wattage of CFL/ LED (Watts)	Lumen output (Lumens)	CFL/LED make	Battery capacity (V,Ah)
15	Reliance Industries Ltd	Arushi	_	100	360	105 lux at 1 feet vertical distance	PC	26.5 cm, 1.25 Kgs	LED	2.00	200.00	CREE	6V, 4.5 Ah (Lead Acid battery)
16	Ritika Systems Pvt. Ltd	HUTLITE-006E		140	360	*	ABS/PC	23 cm, 1.2 Kgs	LED	2.00	280.00	NICHIA	6V, 4.5Ah (Lead Acid battery)
17	Solkar Solar Industry Ltd	SUNSHINE	_	*	360	70 lux at 1 feet horizontal distance 300 lux at 1 feet vertical distance	ABS	26 cm, 1.5 Kgs	LED	2.00	*	OSRAM	6V, 4.5 Ah (Lead Acid battery)
18	Suraj Solar System	SL01N Indoor		120	360 (Top covered)	_	ABS	27.9 cm, 0.7 Kgs	LED	2.00	240.00	NICHIA	6 V, 4.5 Ah (Lead Acid battery)
19	Suraj Solar System	SLOIN Outdoor		120	360 (Top illuminated)	_	ABS	27.9 cm, 0.7 Kg	LED	2.00	240.00	NICHIA	6 V, 4.5 Ah (Lead Acid battery)
20	Ritika Systems Pvt. Ltd	HUTLITE-006A		80	360	*	ABS/PC	23 cm, 1.2 Kgs	LED	2.25	180.00	WAHWANG	6V, 4.5 Ah (Lead Acid battery)
21	Halonix Ltd	PRISM lantern		90	360	120 lux at 1 feet horizontal distance 250 lux at 1 feet vertical distance	PC	29 cm, 1.3Kgs	LED	2.50	225.00	OSRAM	6V, 4.5Ah (Lead Acid battery)

Standard/ certification of battery	Duration/ Hours of operation (Hours) [considering fully charged battery)	Input charging option (Solar, AC, non-rechargeable batteries, manually operated)	Size of solar PV panel	Is the SPV module certified? (yes/no)	IEC Standard number that the SPV module conforms to	Certifying authority of solar module	Is lantern certified? (yes/no)	Certifying authority of the lantern	Market introduction of the model (Year)	Price of the lantern without solar module (Rs)	Price of the lantern with module (Rs)	Average number of systems sold in a year	Additional remarks/other provisions in the lantern
_	12 Hours	Solar	3.3 Wp	Yes	IEC 61215, EN 61730	TUV, Japan	_	_	2008	_	3200	_	_
_	4–5 Hours	Both Solar and AC	3Wp	Yes	IEC 61215	STQC	Yes	MNRE	2007	1200	1800	10 000	_
CE Certified	6 Hours in full brightness mode 12 Hours in low brightness mode	Both Solar and AC	3 Wp	Yes	IEC 61215, IEC 61646	MNRE	Yes	MNRE	2010	1400	2100	_	Different illumination modes in the lanterns
*	5–6 Hours	Both Solar and AC	3Wp	_	_	_	Yes	MNRE, ERTL, NTH	2007	900	1350	6000	Intelligent charge conroller; PWM mode charge controller;high charge cut off low voltage load cut off. Fully micro controller based;. Step-less intensity control; optional mobile charger
*	5–6 Hours	Both Solar and AC	3Wp	_	_	_	Yes	MNRE, ERTL, NTH	2007	900	1350	4000	Intelligent charge conroller. PWM mode charge controller high charge cut off low voltage load cut off. Fully Micro controller based. Step less intensity control. Optional mobile charger
_	3–4 Hours	Both Solar and AC	3Wp	Yes	IEC 61215	STQC	Yes	MNRE	2007	1000	1600	10 000	_
MNRE, Euro Tech, ERTL Certified	6–8 Hours (in Full brightness mode) 10–14 Hours (in low brightnessmode) 16–20 Hours in night lamp mode	Both Solar and AC	5Wp	Yes	IEC 61215	_	_	_	2009	1500	2500	_	Prism Lantern gives 360° light spread for better illumination in any area; lantern has unique features like; battery status indicator, low battery Indicator mobile charging socket; different illumination modes in the lanterns

Contd...

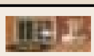
Table 1A LED lanterns (in ascending order of LED wattage) *(contd...)*

S. No	Lantern manufacturer	Lantern model	Photograph of the lantern model	Luminous efficacy (Lumen/ Watt)	Light distribution (in Degrees)	Illuminance (Lux output at 1 feet from the centre of the base of the lantern)	Lantern housing material	Height and weight of the lantern	Lantern type (CFL/ LED/ both)	Wattage of CFL/ LED (Watts)	Lumen Output (Lumens)	CFL/LED Make	Battery capacity (V,Ah)
22	Ritika Systems Pvt. Ltd	HUTLITE-006F		140	360	*	ABS/PC	23 cm, 1.2 Kgs	LED	2.50	350.00	NICHIA	6V, 4.5 Ah (Lead Acid battery)
23	Arsh Electronics Pvt. Ltd.	ALL3DC		30	360	55 lux at 1 feet horizontal distance 15 lux at 1 feet vertical distance	ABS and PC	24 cm, 1.2 Kgs	LED	3.00	90.00	KWALITY	6 V, 4.5 Ah
24	Avni Energy Solutions Pvt Ltd	ELECTRA-BIG		120	360	120 lux at 1 feet horizontal distance 223 lux at 1 feet vertical distance	ABS	34.5 cm, 3 Kgs	LED	3.00	360.00	NICHIA	12V, 7.2 Ah (Lead Acid battery)
25	Freeplay Energy India Pvt. Ltd	VII	–	80	360	*	ABS	34.5 cm, 1.2 Kgs	LED	3.00	240.00	NICHIA	6V, 4Ah (NiMH Battery)
26	Geetanjali Solar Enterprises	Sourapam - 3		*	*	_	PC and Nylon	22.8 cm, 1.090 Kgs	LED	3.00	*	PHILIPS / OSRAM	6 V, 4 Ah (Lead Acid battery)
27	Ritika Systems Pvt. Ltd	HUTLITE-006G		110	360	*	ABS/PC	23 cm, 1.2 Kgs	LED	3.00	330.00	NICHIA	6V, 4.5 Ah (Lead Acid battery)
28	Jain Irrigation Systems Ltd	JJLL-1	–	95	360	112.5 lux at 1 feet horizontal distance 171.6 lux at 1 feet vertical distance	ABS	32 cm, 4 Kgs	LED	4.50	427.50	CREE	12V, 7.5 Ah

*Data Unauthenticated

Standard/ Certification of battery	Duration/ Hours of operation (Hours) [considering fully charged battery)	Input charging option (Solar, AC, non-rechargeable batteries, manually operated)	Size of solar PV panel	Is the SPV module certified? (yes/no)	IEC Standard number that the SPV module conforms to	Certifying authority of solar module	Is lantern certified? (yes/no)	Certifying authority of the lantern	Market introduction of the model (Year)	Price of the lantern without solar module (Rs)	Price of the lantern with module (Rs)	Average number of systems sold in a year	Additional remarks/other provisions in the lantern
_	3.5 Hours	Both Solar and AC	3Wp	Yes	IEC 61215	STQC	Yes	MNRE	2008	1400	2000	10 000	_
MNRE Approved	8 - 9 Hours	Both Solar and AC	5 Wp	Yes	_	MNRE	Yes	MNRE, PVGAP	2007	950	1950	1500	_
CE Certified	12 Hours	Both Solar and AC	8 Wp	Yes	IEC 61215	TUV Rheinland	No	_	2009	1600	2500	5000	Efficiency: 85% Protections: low battery voltage cutoff; over voltage protection; no load protection sufficient indicators
CE Certified	5 Hours	Solar, AC, Manually operated	6Wp	*	_	_	_	–	_	1650	_		Additional options such as mobile charging and battery status indicator
*	4 – 8 Hours	Both Solar and AC	*	Yes	_	ERTL	Yes	MNRE	2006	1000	1500	3500	Provision for high /low switching and Mobile charging
_	3 Hours	Both Solar and AC	3Wp	Yes	IEC 61215	STQC	Yes	MNRE	2008	1540	2140	10 000	_
DGS&D Approved	4-5 Hours	Solar	5 Wp	Yes	IEC 61215	TUV	_	In process	2009	1100	1800	_	_

Table 1B CFL lanterns (in ascending order of CFL wattage)

S. No	Lantern Manufacturer	Lantern Model	Photograph of the Lantern Model	Luminous Efficacy (Lumen/ Watt)	Light Distribution (in Degrees)	Illuminance (Lux output at 1 feet from the centre of base of the lantern)	Lantern housing material	Height and weight of the lantern	Lantern type(CFL/ LED/both)	Wattage of CFL/ LED (Watts)	Lumen Output (Lumens)	CFL/LED Make	Battery Capacity (V,Ah)
1	Ritika Systems Pvt. Ltd	HUTLITE-954-A		50	360	*	ABS/PC	23 cm, 1.2 Kgs	CFL	5.00	250.00	OSRAM	6V, 4.5 Ah (Lead Acid battery)
2	Solid Solar	SS-1011	–	–	–	–	ABS and PC	33 cm, 2.2 Kgs	CFL	5.00	_	OSRAM	6V, 4.5Ah (Lead Acid battery)
3	Arsh Electronics Pvt. Ltd.	ALC7DC		60	360	_	ABS and PC	35 cm, 3 Kgs	CFL	7.00	420.00	OSRAM	12 V, 7 Ah
4	Geetanjali Solar Enterprises	Sourapam – 10		53	360	_	PC and Nylon	35.5 cm, 3.335 Kgs	CFL	7.00	371.00	PHILIPS / OSRAM	12 V, 7 Ah (Lead Acid battery)
5	Jain Irrigation Systems Ltd	JJL–2		53	360	_	ABS	32 cm, 3.9 Kgs	CFL	7.00	371.00	OSRAM	12 V, 7.5 Ah
6	Reliance Industries Ltd	CFL Lantern	–	53	360	_	ABS	36 cm, 3.5 Kgs	CFL	7.00	371.00	OSRAM	12V, 7Ah (Lead Acid battery)
7	Ritika Systems Pvt. Ltd	HUTLITE–952-A		61	360	*	ABS/PC	35 cm, 1.2 Kgs	CFL	7.00	427.00	OSRAM	12V, 7Ah (Lead Acid battery)
8	Solid Solar	SS–1010	_	_	_	_	ABS and PC	34 cm, 2.1 Kgs	CFL	7.00	_	OSRAM	6V, 9 Ah (Lead Acid battery)
9	Suntechnics Energy Systems Pvt Ltd	IIA	_	53	360	_	ABS	35 cm, 3.5 Kgs	CFL	7.00	371.00	OSRAM	12V, 7Ah
10	Jain Irrigation Systems Ltd	JJL–3		62	360	_	ABS	32 cm, 3.9 Kgs	CFL	9.00	558.00	OSRAM	12V, 7.5 Ah
11	Solid Solar	SS–004	_	_	_	_	ABS and PC	34 cm, 2.2 Kgs	CFL	9.00/7.00	_	OSRAM	*

Standard/ Certification of battery	Duration/ Hours of operation (Hours)	Input charging option (Solar, AC, non-rechargeable batteries, manually operated)	Size of Solar PV Panel	Is the SPV module certified? (yes/no)	IEC Standard number that the SPV module conforms to	Certifying authority of solar module	Is lantern certified? (yes/no)	Certifying authority of lantern	Market introduction of the model (Year)	Price of the lantern without solar module (Rs)	Price of the lantern with module (Rs)	Average number of systems sold in a year	Additional remarks/ other provisions in the lantern
_	2 Hours	Both Solar and AC	5 Wp	Yes	IEC 61215	STQC	Yes	MNRE	1995	700	1400	10 000	_
_	2.5 Hours	Both Solar and AC	5Wp	Yes	_	_	_	_	_	1039	1929	10 000	_
MNRE Approved	4–5 Hours	Both Solar and AC	10 Wp	Yes	_	MNRE	Yes	MNRE, PVGAP	1994	1300	3100	3000	Night lamp, mobile charging on optional basis
*	4–5 Hours	Both Solar and AC	*	Yes	_	ERTL	Yes	MNRE	1989	2500	4000	1250	Provision for mobile charging
DGS&D Approved	4–5 Hours	Solar	10 Wp	Yes	IEC 61215	TUV	Yes	_	2003	3050	4150	20 000	LEDs for night mode
_	10 Hours	Solar	10 Wp	Yes	IEC 61215, EN 61730	TUV, Japan	Yes	CPRI	2008	_	4470	_	_
_	3–4 Hours	Both Solar and AC	10 Wp	Yes	IEC 61215	STQC	Yes	MNRE	1995	1250	2600	10 000	_
_	3–4 Hours	Both Solar and AC	8Wp	Yes	_	_	_	_	_	926	1816	9000	_
MNRE/CPRI Approved	3 Hours	Solar	10/12 Wp	Yes	IEC 61215	IEC and MNRE	Yes	MNRE	2010	1500	2700	15 000	_
DGS&D Approved	2.5–3 Hours	Solar	10 Wp	Yes	IEC 61215	TUV	Yes	MNRE	2003	3250	4350	1000	LEDs for night mode
_	3–4 Hours	Both Solar and AC	10Wp	Yes	_	_	_	_	_	1858	4257	13 000	Clear Top

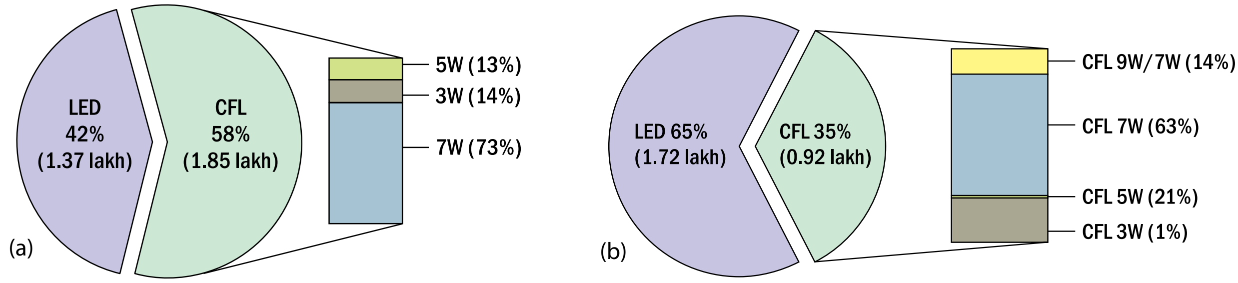


Figure 1 (a) Annual dissemination of CFL and LED lanterns (survey results 2008); (b) Annual dissemination of CFL and LED lanterns (survey results 2010)

To begin with, the survey traces back the 2008 survey[1] results regarding the categories of the most popular solar lanterns in the market. Unlike the 2008 survey results, which indicated sales of compact fluorescent lamp (CFL) lanterns forming the majority in the market, this year's survey indicates that 65% of the 2.66 lakh (based on average sales in a year as reported by 2010 survey) solar lanterns sold were LED, while the remaining 35% were CFL-based lanterns. Refer to Figure 1.

While the survey did not find any major deviation in trends in the compact fluorescent lamp (CFL) category, there are some interesting developments in the LED lanterns category as compared to 2008 survey results. This year's survey indicates emergence of ultra-bright LED lanterns whose illumination is equivalent or even higher than CFL lanterns. As reported by Jain Irrigation Systems Pvt. Ltd, its JJL-I model has illumination of 427.5 lumens with 4.5W LEDs in the lantern. This also indicates the ongoing developments in the LED industry with lantern manufacturers making use of LEDs with luminous efficacy as high as 140 lumens/watt in the lanterns. This value stands significantly higher as compared to the results of 2008 where the highest luminous efficacy reported was about 95 lumens/ watt.

There are some interesting developments in storage technology area. The survey shows that many lantern manufacturers are opting for small sized but highly efficient NiMh and Li-ion batteries. Talking about certifications of LED lanterns, it is interesting to note that as reported in the 2008 survey, only one LED lantern model was certified. However, this year's survey indicates that most of the LED lanterns have got ERTL, CE, CPRI, or MNRE certifications. In the 2010 survey, a large number of LED lantern manufacturers had mentioned that their LED lanterns had certification from MNRE. However, the MNRE website lists only five approved LED lantern vendors.

An interesting observation common to both CFL and LED lantern models in the 2008 and 2010 survey is, that most of the solar lanterns resemble traditional lanterns. This is in line with the field findings of GTZ in Africa with regard to the end users' preference of lantern designs that resemble traditional lighting devices [Presentation by GTZ on consumer preferences and impacts, delivered in Lighting Africa conference, 2010]. Table 2 presents a comparison of major observations between 2008 and 2010 survey.

It is worth noting that despite being present in the market for more then 20 years; there is not much variation within the category of CFL lanterns. However, there are significant variations within the category of LED lanterns, for instance, there is a lot of variation in terms of LED wattage (0.66–4.5 watt), lumen output (59.4–427.5 lumens), prices (Rs 850–Rs 3200), services provided by the lanterns, and so on.

[1] About 20 lantern manufacturers with 39 solar lantern models participated, in the 2008 survey,.

Table 2 Comparison of major observations between 2008 and 2010 survey

S.No	Parameters	2008 Survey	2010 Survey
1	Number of lantern manufacturers participated	20	16
2	Total number of lantern models	39	39
3	CFL models	24	11
4	LED models	13	28
5	Models with combination of CFL and LED/ both CFL and LED	2	0
6	Percentage of CFL lantern models sold annually (based on average annual sales as reported by 20 respondents)	58% of the 3.21 lakh models	35% of the 2.66 lakh models
7	Percentage of LED lantern models sold annually (based on average annual sales as reported by 20 respondents)	42% of the 3.21 lakh models	65% of the 2.66 lakh models
8	Highest illumination of LED lantern model, as reported in the survey	240 lumens	427.5 lumens
9	Highest luminous efficacy in LED lanterns, as reported in the survey	95 lumens/ watt	140 lumens/ watt
10	Number of certified LED lantern models	1	15

As can be effortlessly deciphered from this survey and analysis of the current trend, the LED lantern market is fast expanding and evolving. In the backdrop of this scenario, there is an urgent need for testing, certification, and recommendation centres. The lanterns are currently being manufactured by various manufacturers worldwide, and their prices vary widely. Some lanterns are not very expensive, but the quality of the product is unreliable, while others are of better quality but expensive. Basically, there is lack of data characterizing the quality and performance of LED-based solar lanterns, which may hamper its efficient marketing.

In addition to the survey results, as is discussed in another article from the LaBL[2] campaign[3], 'it is observed that out of about 45 LED lanterns tested in the LaBL lab at TERI, India, the efficacy of the LED varied from 20 lumen/watt to 110 lumen/watt. Similarly, out of the total LED lantern samples tested in the lab, the illuminance of the lanterns also vary widely, and in more than 50% of the cases, it reduced drastically with time and was not uniform throughout its duration of operation. In some samples, the optics was not efficiently designed to provide uniform distribution of light. Similarly, the performance of electronic circuits differs widely in terms of their charging efficiency, driver efficiency, type of protections, and indications present. Such examples reveal the variation in the quality and performance of the LED lanterns.'

The main parameters that require testing, validation, and rating are the quality, reliability, and durability of the white LED based solar lantern. Thus, the need for standardization of the LED lantern as a consumer product requires dedicated testing laboratories. An article by Parimita Mohanty in this issue argues that the quality of the products can be determined based on the following basic minimum parameters.

- Luminous efficacy
- Illuminance and glare
- Lighting distribution characteristics
- Light output over a single discharge cycle
- Hours of useful illuminance delivered from a fully charged battery
- Persistence of battery capacity
- Performance of charging circuit and charging efficiency
- Overall system efficiency

In order to gain an overview of the test and validation facilities available, some of the test methodology and technical documents of the major test centres were surveyed. Based on the available information, Table 3 has been developed that lists the main tests and quality pointers and the laboratories across the globe that conduct such testing. Though the table is been meticulous, some minor human error might have happened inadvertently. Also, this list is not an exhaustive database of all the existing laboratories and their capabilities. As is clearly observed, a handful of highly equipped and efficient laboratories have already been established with variations in their test capabilities. Considering the growing solar lantern market, India and the international fraternity, in general, requires expansion of the existing laboratories and creation of many more accredited laboratories covering most of the required testing and validation capabilities.

[2] Lighting a Billion Lives (LaBL) is TERI's flagship programme on providing basic illumination through clean technologies to one billion lives across the world who do not have access to electricity.

[3] Mohanty, P, 'LED Solar Lanterns: Critical Quality Aspects'. This article features in the May/June 2010 issue of the *Lighting India* magazine and in the present issue of *The Solar Quarterly* magazine.

Table 3 Test parameters and testing laboratories for solar lantern[1]

Test category	Parameters evaluated	LaBL, TERI[2]	SEC (MNRE), India[3]	Fraunhofer ISE[4]	PV GAP[5]	Lighting research centre[6]
Visual inspection and mechanical stability						
	Size and weight	√		√	√	
	Internal and external quality of workmanship	√		√	√	
	Components properly fixed and ideally screwed	√		√	√	
	Corrosion, discolouration of metals			√	√	
	Printed circuit board and solder joints	√	√	√	√	
	Proper housing including optics for focusing light	√	√		√	
Lighting services					CFL	
	Illuminance (instantaneous)	√	√	√	√	
	Lighting distribution characteristics			√	√	√
	Variation of illuminance through lamp operating hours	√		√	√	√
	Colorimetry (CRI/CCT/Chromaticity)				√	√
	Total luminous flux			√		√
Usability of the system						
	Daily burn time/duty cycle	√		√		
	Solar charging time	√		√		
	Cable length	√		√	√	
	Indicators (Charge status)	√		√	√	
	User manual & data sheet for LED, PV module, battery, charge controller	√	√	√	√	
Durability of the system						
	Charge controller (influencing life of the rechargeable device)			√		
	Fixing of parts (shaking/vibration test)			√	√	
	Robustness (Drop test)	√		√		
	Switches and connectors			√	√	
	Protections against environmental impacts[7]			√		
System component testing						
	Check all certificates	√	√	√	√	
	Solar module				√	
	Electrical parameters (and comparison for discrepancy against data provided by manufacturer)	√	√	√	√	
	Check certification				√	
	Outdoor exposure test				√	
	Damp heat test				√	
	Robustness of terminals				√	
	Battery					
	Capacity of the battery as per standard specifications[8]		√	√	√	
	Battery efficiency (Ah , Wh)			√	√	

Test category	Parameters evaluated	LaBL,TERI	SEC (MNRE), India	Fraunhofer ISE	PV GAP	Lighting research centre
	Shipping vibration test				√	
	Protections					
	Deep discharge protection	√	√	√		
	Overcharge protection	√	√	√		
	Open-circuit protection				√(CFL)	
	Reverse flow protection	√	√			
	Load reconnect	√	√			
	Temperature compensation		√			
	Short-circuit protection	√	√		√	
	No load protection	√	√			
	Battery reverse polarity protection	√	√		√	
	Reverse polarity protection at PV terminals	√			√	
	Inverter/driver/charge controller					
	Charge controller-efficiency test , driver efficiency test	√	√			
	Lamp ballast operating temperature measurement					√
Long-term tests						
	Lumen degradation test			√		
	Battery capacity degradation test					

[1] This chart has been compiled by the technical support unit of TERI's LaBL campaign team.
[2] LaBL is TERI's flagship programme: Two labs in New Delhi, India are functional that carry out testing of solar lights.
[3] Solar Energy Centre, Ministry of New and Renewable Energy, Govt. of India.
[4] For Lighting Africa (a World Bank Group initiative), Fraunhofer ISE has developed test protocols and methodologies for testing of solar lighting products. Lab: NLTC, Beijing
[5] PV GAP (Global Approval programme) Labs: PWQTC, China and TUV Rheinland, Germany
[6] Lighting Research Centre (ASSIST), USA: for luminaries (not particularly PV based systems)
[7] IP protection classes – DIN EN 60529/IEC 529. Protection of the lights under IP41 is recommended.
[8] (as per the standard), Lead Acid-IEC 62257-8-1; NiMH-DIN EN 61951; Li-ion-DIN EN 61960 are recommended.

Solar charge controller

changing dimensions

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Introduction

Solar power has gained substantial ground in the developing countries. Also, the biggest potential for solar markets lies in these regions. However, according to the American Council on Renewable Energy (ACRE), only about 1% of the global solar panel production has been installed in the developing world so far. The solar market in Africa, Asia, and Latin America is quite huge as nearly 44% of the population of the developing world lacks basic access to electricity even today. So, it is obligatory upon all the stakeholders to solarize such communities by offering them smooth functioning off-grid solar systems at comparatively cheap rates. The simplest of these systems would make use of a small photovoltaic (PV) module, battery, and associated electronics. However, there is more to it than what meets the eye in the first instance.

Is charge controller a privileged link?

Solar power is produced during daytime. Thus, power generated is stored in a battery for use at night with the simplest of the applications being a solar lantern. Normally, a battery used for this purpose is at some variance with that used in automobiles, for example. These have come to be known as solar batteries and work fine as long as these are maintained properly. However, it is equally true that the lifespan of a battery (3–4 years) is quite small in comparison to an extended life span of a module (20–25 years). That simply means setting aside some amount for timely replacement of the battery. This calls for an innovative business model as is being implemented in some cases. The cost of grid-connected PV systems continues to come down mainly due to the decreasing price of a solar module. However, the same is not quite true with an off-grid system, in which a battery alone costs as much as 40% of the total system cost. Now, that being the case, it is all the more necessary to take the best possible care of these batteries. Well, to do so, solar charge controller is the designated piece of equipment. This article will focus on the charge controllers to begin with, in our series of dealing with similar other vital system components, such as inverters.

Knowing the charge controller

Solar insolation varies throughout the day, being brighter at times and dull in-between. Obviously, brighter the sunlight, the more voltage a solar cell is going to produce. Such an excessive voltage may lead to battery damage, which needs to be avoided at all costs. This state of charging is usually referred to as overcharging. So, as the input voltage from the array increases, the charge controller regulates the charge to the batteries, thus, preventing any overcharging of the batteries. That is not all as it also stops the battery from getting excessively deep discharged. Thus, a simple yet critical function of the charge controller is to keep the battery safe, both against overcharging and deep discharging.

Charge controllers: then and now

Solar lighting systems have been around for a long time now and so have been the charge controllers. It is not a misperception though that majority of the PV systems working in the field today are of the off-grid type. These add to vast numbers, but not in terms of the actual capacity deployed, mainly due to involvement of minuscule capacities. It is equally true that a large number of these are installed in rural remote environs, which calls for a very high degree of field performance reliability. The moot question is—can we avoid the use of a solar charge controller in the first instance? That is not the case, as it is needed in almost all the power systems that have batteries. A solar charge controller regulates the power that goes from the solar panels to the batteries. In case you overcharge the batteries, following few changes may take place.

- battery life may reduce
- battery may be damaged

The simplest version of a charge controller will monitor the battery voltage and open the circuit. It will stop the charge the moment battery voltage increases to a certain level. In the old designs of charge controllers, a mechanical relay opened or closed the circuit. This meant stopping or starting the flow of power going to the batteries. However, that is no longer the case as the present day charge controllers use the Pulse Width Modulation (PWM) technique. The clear objective is to gradually reduce the amount of power supplied to the batteries, as they get closer to a fully charged state.

Such an advanced version allows the battery to be charged with less stress

Solar MPPT controller

supplying power to a DC load, which may be connected directly to a battery. MPPT is most effective and efficient under the following conditions.

- *Cold weather, cloudy or hazy days*: normally solar modules perform better at cold temperatures and MPPT is used to derive the maximum power available from them.
- *When the battery is deep discharged:* MPPT can extract more current and charge the battery if, it has a low state of charge.

on it. The resultant outcome is a definite increase in the life of a battery. It offers one more advantage that it cannot keep the batteries in a fully charged state known as 'Float' indefinitely. It is important to mention here that the PWM feature, despite being more complex, does not have any mechanical connections to break. A still improved version of the charge controller is known as the maximum power point tracking or MPPT controller. It is capable of converting the excess voltage into amperage. Thus, by changing the excess voltage into amps, the charge voltage is kept at an optimal level, while the time needed to fully charge the batteries is reduced. This enables the solar power system to operate optimally at all times.

Simple working of a MPPT controller

The key function of MPPT is to extract the maximum available power from a PV module by making it operate at the most efficient voltage—the maximum power point. Simply put, it checks the output of a module, compares it to the battery voltage, and then fixes the best power that PV module can produce to charge the battery. Following this, it converts it into the best possible voltage so as to obtain the maximum possible current into the battery. It is also capable of

The voltage change

Wires join a solar panel to a charge controller. Lower voltage in the wires running between these two units will result in higher energy loss in the wires than higher voltage itself. Consider the use of a PWM charge controller with a 12 V battery, the voltage from the solar panel to the charge controller typically has to be 18 V. Using a MPPT controller allows much higher voltages in the wires, from the panels to the solar charge controller. The MPPT controller then converts the excess voltage into additional amps. This brings up a clear advantage of having much lower power loss in the wires.

Reversing the flow

There is an additional advantage too, in terms of preventing reverse-current flow. As is very clear, solar panels do not produce electricity at night. In that case, electricity can flow backwards from the batteries through the solar panels. This can have a negative effect of draining the battery thus, leading to power wastage as well. The charge controller detects as and when no energy is coming from the solar module. Following this, it opens the circuit, which effectively means disconnecting the solar panels from the batteries. It is known as, 'stopping the reverse current flow'. Now you may like to know if MPPT controllers come with a higher price tag. Yes, these types of controllers cost slightly more than the PWM range of charge controllers, but repay the clearly held advantages as well.

Broad technical specifications of MPPT controllers

Staging the charge controllers

The charge controller is usually installed between the solar array and the batteries, where it automatically maintains the charge on the batteries using a 3-stage charge cycle as described below.

a) Bulk stage

During the bulk phase of the charge cycle, the voltage slowly rises to the bulk level. It is usually between 14.4 V–14.6 V, while the batteries draw maximum current. The attainment of bulk voltage makes way for the absorption stage.

b) Absorption stage

During this phase, the voltage is maintained at bulk voltage level for a specified time. It normally lasts for an hour. The current slowly tapers off as the batteries charge up.

c) Float stage

After the absorption time passes, the voltage is lowered to float level. This is normally between 13.4–13.7 V. The batteries draw a small maintenance current until the next cycle.

Case specific example

It is believed that majority of the charge controllers being used now are of the PWM type. The new generation MPPT controller is even better. These match the output of solar modules to the battery voltage so as to ensure maximum charge (amperes). Like for instance, your module may be rated at 75 W, but you

will not be able to get full 75 W, unless the battery is at an optimum voltage. Remember power/watts is always equal to volts time amperes. Suppose one is working with a regular charge controller, where the batteries are low at say, 12.4 V, a 100 W module rated at 6 amps at 16.5 V (6 × 16.5= 100 W) will only charge at 6 amps times 12.4 V, which means just 75 W. Simply put, about 25% of the battery capacity is lost for nothing. To change this situation for better, use a MPPT controller. It simply compensates for the lower battery voltage by delivering close to 8 amps into a 12.4 V (12.4 × 8~100 W) battery thus, maintaining the full power of a 100 W module.

Summing up the key features

The solar charge controllers are quite a vital piece of equipment in a solar PV system. Thus, it is important to track the following features at the time of system purchase/deployment.

Low-voltage load disconnect (LVD): reduces damage to batteries by preventing deep discharging.

Reverse current leakage protection: disconnects the array to prevent feedback into the solar modules at night.

System monitoring: analogue or digital display meters, indicator lights and/or warning alarms.

Over current protection: achieved with fuses and/or circuit breakers.

Mounting options: flush mounted, wall mounted, indoor or outdoor enclosures for all weathers.

Temperature compensation: utilized whenever batteries are placed in a non-climate controlled space. The charging voltage is adjusted to the corresponding temperature.

PWM: an efficient charging method that maintains a battery at its maximum state of charge and minimizes build-up of sulphur by pulsing the battery voltage at a high frequency.

MPPT : a new charging method designed to extract the maximum power possible out of a solar module by altering its operating voltage to maximize the power output.

Do these come cheap?

As is now quite clear, a solar charge controller is a vital link in a PV system. However, it does not incur a huge cost. In a typical off-grid solar PV system, for example, a home lighting system, about 50% of the cost contribution comes from the modules. Battery cost is slightly lower at about 30%, while the charge controller typically represents just about 10% of the total installed cost of an off-grid system. Charge controller prices tend to move considerably less than the prices of solar modules. Solar Buzz, which is a prominent PV market consulting company, highlights the movements of charge controller prices on the Internet over a period of the last two years. According to this report, the US Index again remained unchanged at $ 5.87 per ampere.

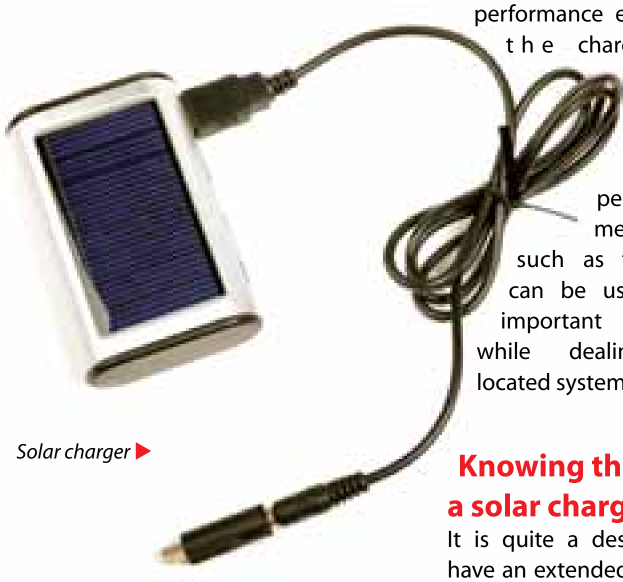
In the procedure generally used for the purpose, the price index (PI) methodology involves summing up of the prices of all charge controllers on the survey. Then, it is to be divided by the cumulative amps output of the same products. Thus, we can obtain a price per amps as indicated in Table 1. It is to be remembered here that there are several other factors besides the amperage, which are related to the performance as well as the technical capabilities of the individual charge controller models. There is also a distinctive comparison, when it comes to comparing charge controllers vis-à-vis the solar modules and inverters. Worldwide, a large number of companies produce these charge controller units as against a limited number of those engaged in the production of modules or inverters.

Most recent developments

Solar charge controllers have lately been equipped with the world's latest technology better known as the Digital Signal Processing (DSP). The world

Price per amphere rating of solar charge controller

S.No.	Period covered	US $/Amp	Euro/Amp	Remarks
1.	June 2008	5.84	3.74	The dollar price has remained more or less constant as against clear variations in the Euro price per amp. Nearly 133 models of charge controllers available in the market were dealt with in this survey. Accordingly, the number of companies which participated in this survey ranged between 25–35.
2.	December 2008	5.87	4.58	
3.	June 2009	5.88	4.23	
4.	December 2009	5.87	3.87	
5.	May 2010	5.87	4.40	



Solar charger ▶

of science and engineering is full of signals, and digital signal processing is the science of using computers to understand these types of data. Selected companies are now offering DSP-based solar charge controllers, such as Su-Kam. It has recently developed a unique, real time monitoring software for charge controllers. Various features displayed in this manner are the following.

- Solar module voltage
- Battery voltage
- Charging current
- Ah input into the battery (as a function of time)
- Battery status
- Charger efficiency
- Charging mode
- System temperature

Customer friendly advantages

It is quite possible to preset various parameters like battery voltage, boost voltage, and float voltage, in addition to turning on/off the unit through this interactive software. Customers can very well adjust the battery parameters as per their requirements without even touching the internal circuit. The entire charging profile can be represented in a graphical form, which is automatically stored. Stored data can then be used for a meaningful analysis and performance evaluation. It also logs the charger parameters at an interval, defined by the user for analysis, besides keeping a record of its performance. Modern means of communication, such as the e-mail and SMS, can be used to forward some important parameters especially while dealing with remotely located systems.

Knowing the correct size of a solar charge controller

It is quite a desirable requirement to have an extended life span of a solar PV system. A well performing battery also leads to delayed cost of replacement. To make it happen in practice, one needs a properly sized charge controller. The charge controllers are rated and sized by the solar panel array current and system voltage. Amongst the most common voltage configurations are 12 V, 24 V, and 48 V. The amperage ratings normally run from 1–60 amps with a voltage range of 6–60 V. A charge controller monitors the battery's state-of-charge to ensure that when the battery needs charge current it receives it, and also ensures the battery is not over-charged. Following two cases are discussed in brief.

a) Assume that a solar charge controller is rated at 20 amps. It simply means that we can connect up to 20 amperes of solar panel output current to this unit. For instance, a 60 W module has specified values of voltage and current as 17.2 V and 3.5 amps. In case its voltage is brought down to say 14 V, then the amperage increases to 4.28 (14 Vx 4.28 amps=~ 60 W). In other words, it results in 19% enhancement in the charging current for instance. There is a distinct advantage in having a higher voltage solar panel array. Simply put, you can make use of smaller gauge wiring to the charge controller. This may not matter for small distances; however, it can help to keep the wiring cost down for distances of 100 feet between solar panel array and the charge controller. Now, you just think of doubling the voltage from 12 V to 24 V, the current moving through the wire will go down by 50%.

b) Let us assume that we have a 1 kWp solar panel array that runs at 48 V DC and the battery bank is 24 V DC. MPPT controllers are generally rated by the output amperage that they can conveniently handle, and not the input current available from the solar panel array. It is quite easy to know the value of such current carrying capacity by making use of a very simple formula, which is Power= Volt x amps. By substituting the values of power and voltage, we can get the current value of about 41.7 amps. The most common practice is to enhance this value by about 25% so as to account for the special conditions witnessed in the field. This then takes the current value of 41.7 amps to 52.1 amps. The next logical step is to look for a charge controller with that type of current value. It may be the one rated closely at 60 amps of any standard make.

Charging forward

Selected field performance evaluation studies of off-grid PV systems still reveals one problem or the other with the charge controllers in a few cases. The end-users in some cases are also at fault as they try to operate more than the designated loads. An insightful analysis also shows a natural tendency on the part of users to run more load on a few religious-cum-social occasions. A few users seem to bypass the use of charge controller by connecting the load to a battery directly. Barring these small practices, the charge controllers are found to be working in a satisfactory manner. However, this still points towards a vital need of making the users fully aware about the safe practices of using every system component in the best possible way. The rationale lies in charging forward in a smooth and unhindered manner.

The environmental benefits of solar lighting alternatives over kerosene an input–output approach*

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Overview of lighting sources in India

Even today, electric lighting remains a luxury for a sizeable share of households in India. Fifty-five per cent of rural households in India continue to depend on kerosene as the primary source of lighting (NSSO 2007).[1] This high reliance on kerosene for lighting can be attributed to two reasons: one, the fact that electricity is yet to reach 96 023 villages (Ministry of Power 2010) in India, and two, rural areas continue to suffer from frequent blackouts.

Although the Government of India has committed to the electrification of all villages in India by 2012 through the Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), it is unlikely that electricity would be available to all without any shortages within this time-frame (Deshmukh, Gambhir, and Sant 2010). Kerosene lanterns associated with low quality illumination, indoor air pollution, and the ubiquitous issue of misdirected subsidies, are, therefore, expected to remain an important solution to fulfil the lighting needs of many over the next few years. Apart from the air pollution and safety-related aspects of kerosene lanterns, there is concern about the increasing under-recovery on kerosene subsidies, which have increased from Rs 37.51 billion in 2003/04 to Rs 282.25 billion in 2008/09 (Government of India 2010). Moreover, estimates indicate that around 50% of the PDS kerosene does not reach the targeted households (UNDP/ESMAP 2003). From the imports perspective, India currently imports 70% of its crude oil requirements, with estimates suggesting that this figure may reach 85% by 2012 (Financial Express 2007). Therefore, from an energy security perspective, solar lanterns could play an important role, by providing a clean and affordable lighting solution to these rural households.

The manufacture of solar modules is an energy intensive process and it is estimated that the cost of power and fuel for the crystalline silicon value chain itself is above 10% of the cost of the production and manufacture of solar cells and modules (Indian Semiconductor Association 2008). Accordingly, there is a concern whether the solar lantern consumes much more energy and is associated with higher emissions when compared with the kerosene lantern in terms of a life cycle approach to emissions. This paper uses a macro approach to examine whether the solar lantern is, in fact, actually 'cleaner' and 'cheaper' than the kerosene lantern, when compared, in terms of its life cycle costs and emissions.

Methodological approach

This paper uses the Input–Output (IO) approach to determine the carbon emissions associated with the production and use of a solar lantern vis-à-vis a

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[1]2004/05 figures