them can have negative impacts on the environment,if poorly planned.

Technological risk

- Facilitate technological development
- Obliged minimum quality standards
- Training and qualification measures

Market risk

- Policy measures and instruments (FiT)
- Investors' specific risk strategies (hedging)
- Facilitate strategy development
- Round tables and workshops with banks, investors, developers, and policy-makers
- Knowledge exchange, trainings, and accompanying/complementary research (scientific/academic)

Risk mitigation: measures II

Risk management measures may be identified through industrial orsectoralbestpractices,andinternational or other widely used/accepted standards. When the mitigation measures have been determined, the next step is to estimate the cost of the risks and their management. This includes both the real cost of the mitigation measure itself, as well as the potential costs associated with non-compliance (increased charges, fines and other penalties, the closure of an operation by environmental authorities, project delays due to permitting requirements, and so on). Estimating such costs is important even if the financial institution or investor may not be directly responsible for them. First,anyunforeseeninstitution could be held liable under certain liability regimes.

Political risk

Political factors will continue to be important, however, we should also remember that predictability generates trust and reduces risk perception.

- Essential:binding,long-term political commitments
- Proven willingness to share risks (by facilitating priority dispatching and guaranteed connection to the grid)
- Transparency and rationality in policy- and decision-making processes:
- Policy design
- Implementation / administration
- Monitoring / adjustment
- Investors / developers: coordinated formation of common opinions / positions regarding

Conclusions and recommendations

A wide range of parameters are involved in arriving at the techno-economic viability, or otherwise, of any renewable energy project. Policy-cum-regulatory framework is quite essential to push forth such projects, which do entail some risk perception as well. A case in point is that of biomass gasifier projects at selected locations in the southern regions, whose feedstock availability prices appreciated heavily following the plant installation. Solar projects do not depend on the fuel price in any way, but bank upon a slew of financial and fiscal incentives from the designated government agencies. The risk sharing and risk mitigation strategies are quite vital along the following few considerations. No less important is putting in place a crystal clear and user-friendly regulatory structure.

Essential risk sharing and risk mitigation strategies.

- Guaranteed market access
- Minimization of political risk by long-term binding governmental commitments
- Ensuring long-term adequacy of policy measures by regular monitoring adjustment

Transparent and simple regulation

- Reduced administrative burden; lower transaction cost
- Less failed planning efforts and targeted actions due to predictable and transparent procedures
- Lower risk perception and transaction cost leading to reduction in needed revenues and increase in efficiency and effectiveness of policy.

SOLAR THERMAL INDUSTRY IN INDIA

OPPORTUNITIES AND CHALLENGES

Anil Kumar Lakhina has 34 years of leadership experience in various departments of the Government of India and multilateral organizations (G-15), in the field of infrastructure, power, renewable energy, finance, pharmaceuticals, rural development, urban development, economic policy, and public administration.

From August 2005–February 2008, Lakhina was the Chairman and Managing Director of Rural Electrification Corporation (REC). Before this, Lakhina was the Vice-Chairman and Managing Director of the Maharashtra State Road Development Corporation (MSRDC).

Lakhina is also the recipient of the Padmashri, one of the highest civilian honours given by the Government of India. At present, Lakhina mentors a global FMCG company and represents a world class solar power development company funded by the Boston-based General Catalysts Clean Energy Fund, and also a large joint sector power generation company. Besides, he has floated a not-for-profit organization called the Forum for the Advancement of Solar Thermal (FAST) for the promotion of grid-connected solar thermal power generation. In an interview with Arani Sinha, **Anil Kumar Lakhina** discusses the present and the future scenario of the solar thermal industry, in particular, and solar energy, in general in India.

Q. In the backdrop of recently initiated Jawaharlal Nehru National Solar Mission (JNNSM), could you please tell us the prime objectives of, the 'Forum for Advancement of Solar Thermal'.

The Forum for Advancement of Solar Thermal (FAST) is a 'not-for-profit' company. It has been floated under Section 25 of the Indian Company Law. Its main objective is to promote the solar industry, in general, and the solar thermal industry ,in particular. FAST is a stakeholder led institution and is slowly evolving itself into a national think tank to address policy,commercial,technological, and operational challenges in promoting the use of solar power in India. FAST will strengthen research and development, remove market barriers, promote business opportunities across the entire value chain, and improve education, and outreach of solar thermal technologies in the country.

FAST has been a proactive player in policy formulation and promotion of

The objectives of FAST are completely aligned with the JNNSM in so far as the usage, growth, and development of component industry, target realization, cost reduction, and capacity-building are concerned. However, its present priority is to represent the nascent players in the corridors of power to meet the basic needs of land, water, evacuation, funds, established technology, and guaranteed off-take of the produced power at remunerative prices.

solar thermal power. FAST has influenced and interacted with the National Solar Mission in the Prime Minister's Office (PMO), Economic Advisory Council, Ministry for New and Renewable Energy (MNRE), Planning Commission, National Manufacturing Competitiveness Council (NMCC), Central Electricity Regulatory Commission (CERC), and other important public and private institutions. FAST is consistently interacting with various state governments and state regulatory authorities to propagate and popularize the deployment of solar thermal technologies.

FAST also advices new players on project implementation. FAST will involve itself in matchmaking of Indian solar thermal players with their counterparts abroad, by spreading awareness of the Indian story in the global markets.

FAST is the only voice on the solar thermal industry and is duly recognized by the MNRE and assisted by various multilateral international bodies.

Q. What is the major role envisaged by your association vis-à-vis the solar mission, in general, and solar thermal programme development, in particular?

FAST has been involved in the deliberations that led up to the National Solar Mission and was heard many times by Shyam Saran, Prime Minister's Special Envoy. Likewise, it assisted the CERC, on behalf of the solar thermal industry, in fixing the tariff for solar thermal generation. It played a vital role in removing the bias against solar thermal industry and contributed in formulating technology agnostic policies. FAST is committed and consistent with the objectives of the JNNSM and sees its role in mentoring the solar thermal industry to emerge from ground zero to enviable heights in a short period of time. It will assist, develop, and zealously clear all the impediments in the accelerated growth of solar thermal industry. It shares the belief of the JNNSM, that solar thermal power tariff must come down dramatically in the next 5–6 years and achieve coal-based power parity by 2032. The objectives of FAST are completely aligned with the JNNSM in so far as the usage, growth, development of component industry, target realization, cost reduction, and capacity building are concerned. However, its present priority is to represent the nascent players in the corridors of power to meet the basic needs of land, water, evacuation, funds, established technology, and guaranteed off-take of the produced power at remunerative prices. It is engaged in laying a strong foundation for the industry to develop and look up. On the other hand, it passionately impresses upon both the industry and the government agencies that excessive competition expected from new companies will be bad for their knees and will not help the nation to stand tall on solar thermal power. The major role of FAST is to build a fair and all weather bridge between the industry and the agencies of the government, so that the policy formulation leads to grand results.

Q. Despite being expensive in comparison to solar thermal power, solar PV (photovoltaic) grid power generation has rolled affront in terms of a few megawatt capacity installations? What in your opinion are the reasons for the absence of any large-scale solar thermal power plants in the country? Are there any weak links in the commercial promotion of the solar thermal power generation programme in the country?

In India, the five year plans define our priorities. Solar power is much more expensive than conventional power. Generation of grid-connected solar power is impossible without the financial support of the government. It is not surprising that the total grid-connected solar power is about 10.28 MW in the country. It is nearly impossible to sell solar power, five times more expensive in comparison to conventional power. Consequently, we could not develop solar power generation plants in our country. The policy-makers were aware of the potential but were reluctant to spend on research or its usage.

International awareness on environmental degradation, increasing costs of fossil fuels, and an outcry against carbon emissions worldwide are some of the factors that persuaded Indian planners to look towards encouraging and harnessing renewable sources of energy and find innovative methods of continuous research, generation, and subsidization.

Emphasis on grid-level solar power generation is new for us. We have only 550 MW of grid-level solar thermal power generation in the entire world. The generation of power from solar PV and thermal technologies did not happen in India because of policy apathy. We are fortunate that the solar PV component industry has grown impressively to meet the needs of countries that have provided subsidies for solar power. The likes of Moser Baer and Tata BP Solar developed capacities over a short period of time. They are in a position to absorb the fruits

Trough, tower, fresnal, and dish technologies in the field of solar thermal power generation are well known and have received a lot of attention from the investors. According to one study, out of about 8000 MW of solar thermal power plants under development, trough technology accounts for 4538 MW, tower technology for 2530 MW, and the balance for other dish-based activities.

of emerging research and reduction in the cost of PV cells. They have a head start over the solar thermal industry undoubtedly. This industry is capital intensive and other countries like China, Taiwan, Japan, and so on, have taken an enormous lead in the development of scale and capacities. Importing such cells is also exporting jobs. On the other hand, solar thermal industry potential to improve its capacity utilization through recycling heat, creating storage, fuel hybridization, and other measures, in the solar field and power blocks is immense. Above all, solar thermal technologies can be enormously and substantially indigenized at a low cost and with limited effort.

Commercial production of grid-connected solar thermal power is dependent on two major risks—technology risks and execution risks. It is imperative that we carefully mitigate these risks. Our developers must import technologies from proven and experienced sources for the first phase of 500 MW installation by 2013. Procurement of any faulty technology will be suicidal and must be nipped at the bud by the policy instruments. It is better to wait than have cheap or faulty designs. The second risk is in execution. We must engage the best EPC contractors to execute the well-sourced designs and avoid cheating on procurement costs in the first phase.

Q. There is a wide range of solar thermal power technologies available in the global marketplace especially in countries such as the US and Spain. To what extent would you support the full reliance on such imported technologies, if, we have to make any real headway in this field?

Trough, tower, fresnal, and dish technologies in the field of solar thermal power generation are well known and have received a lot of attention from the investors. Out of these, trough and tower technologies have larger appeal and acceptance. Trough technology is older and more established. It is, therefore, more popular with the developers. According to one study, out of about 8000 MW of solar thermal power plants under development, trough technology accounts for 4538 MW, tower technology for 2530 MW, and the balance for other dish-based activities. We must rely on the plants under successful operation than plants under development. As discussed before, we must choose proven and successful technologies over the experimental ones in the first phase of our development. FAST supports all measures that mitigate technology and execution risks. In the absence or lack of knowledge and experience in the solar thermal industry, it is better to import designs or technology of making solar fields, arranging troughs, or mirrors on automated tracking devices, fixing seamless tubes on the exact focal lengths, and carrying proven molten fluids with low boiling points that cause superheated steam to drive turbines. By the time the second phase begins, we will have sufficient experience and emerging industry to propel a rapid scale up with reduced reliance on imported technologies. We have done such experiments in the automobile, television, and telecom sectors with aplomb and should follow such tried and tested methods.

Q. What are your views regarding the legislative and regulatory framework present in India for the deployment of solar thermal technologies. What further measures are necessary in this regard?

JNNSM has accepted the legislative framework provided by the National Electricity Act, 2003, National Energy Policy, National Tariff Policy, and the Integrated Energy Policy. The regulatory framework led by the CERC has been quite proactive in fixing the guidelines on the determination of tariff, for both solar PV and solar thermal technologies. JNNSM has been finalized by the Parliament of India. Its innovative approach on the Renewable Energy Certificates (REC) and increasing obligations on buying RECs equal to a predetermined proportion of the energy consumed, will be a potent legislative instrument for the development of solar power generation. JNNSM has also outlined a series of measures like creation of solar parks, setting up of very small and very large demonstration plants, encouraging manufacturing of the solar component industry through special incentive packages, creating conditions for R & D, constructing solar grid through RPOs, and so on, to spur demand.

JNNSM has provided the mechanism for bundling solar power with the unallocated power of NTPC. The National Vidyut Vyapar Nigam (NVVN) of NTPC will buy and market the bundled solar power to the states. This overarching role of the Ministry of Power may lead to serious issues in coordination and spontaneous state participation. One can notice how Gujarat has not followed the bundled power route established by the Government of India and decided to buy the power from the developers directly to meet the high cost by loading on the large consumer base instead.

Some measures need immediate

attention. Rajasthan has aggressively allocated land and promised water and evacuation arrangements, and creating a huge mismatch between the aspirations of the solar power producers and the capacity of NVVN to purchase power. Thus, there is an urgent need to review Rajasthan's capacity to provide uninterrupted water to solar thermal plants for a period of 25 years. Liberal allocation of land may be a welcome step for the state but a problem for the selection of the right solar power producers. Enthusiasm of 8000 MW-worth of applicants for a 1000 MW of programme will lead to a bidding process and consequent under-quoting. Winners may succeed in bidding but lose out on building plants.

Financing solar initiatives is another measure that is in need of urgent attention. The solar sector needs massive funding. Success in the funding of conventional power plants has primarily been because of the existence of two giant, specialized public sector lending, non-banking financial companies, namely the Power Finance Corporation and the Rural Electrification Corporation. Solar power has no mother financial institution. Indian Renewable Energy Development Agency (IREDA) is financially weak and needs immediate strengthening of an equity base to drive the development of solar power plants.

There has been a delay in formalizing the National Solar Authority that must look ahead and listen to the new players, understand the technologies, mitigate the risks, and help convert intentions into realities. This institution has been suggested by the JNNSM. Its organization, structure, and methodology of operations need to be debated and finalized.

Q. Given the fact that the solar thermal power generation programme has to go through a learning curve under the actual field operating conditions, how important are the capacity-building initiatives?

Capacity-building initiatives are extremely important. There is an acute shortage of trained personnel to implement the ambitious initiatives. Solar industry is a new entrant in the energy sector in India and indeed in the entire world. The JNNSM talks about training 1000 young scientists and engineers for senior level positions. However, we also need intermediate and plant level functionaries. Training centres must emerge in various states, particularly in Andhra Pradesh, Gujarat, and Rajasthan, close to other the project sites. Local industrial training institutes could be offered incentives and laboratories to bridge the gap.

Q. Would you like to convey any special message to the readers of, *The Solar Quarterly,* **especially those who are willing to tread the solar thermal power pathway for a greener future?**

Solar power is abundant in India and, with a little bit of push, it can make India a global player. The successful start-ups will reap good rewards as they are at the beginning of the curve of a energy revolution in the world. The scale-up is going to be enormous and the improvement in technology dizzy. The valuation of such companies is going to be fun and joy. With every passing year, we will be reminded of the similarities with diminishing cost of computers worldwide and vanishing tariff of mobile phones in India. The world's energy development scenario is not going to be quite as it is today. It is going to be reorganized come what may. Be a part of the change. Thus, the message is, join the radiance and force of the sun and save the planet from carbon emissions and environmental deterioration. Nimble steps have been taken by JNNSM and the vision is sunny. Fortunately, the *Sun God* is brighter on our side, and is the perennial answer to our persistent problems!

The views presented in this interview are strictly those of the person interviewed. TERI may/may not subscribe to the views.

FINANCING RENEWABLE ENERGY IN INDIA

Rajat Misra with more than 15 years of experience in the power sector, started his career with Bharat Heavy Electricals Ltd's (BHEL) research and development division, where he specialized in dynamic analysis of equipment and structures, especially seismic and wind analysis. Presently, he is the head of the power and water sector division of SBI Capitals Market, where he has been involved in many key assumptions such as BID advisory to Tata Power for the 4000 MW Mundra UMPP and advisory to MNE, Government of Oman, for the Sur independent water and power project. He has successfully syndicated for wind SPV in India, India Energy. In an interview with Arani Sinha, **Rajat Misra** talks about the role of finance in the renewable energy sector in India.

Q. A broad range of financial institutions are now investing or lending money to the RE (renewable energy) sector. Could you kindly tell us what structured financing actually means, in terms of its relevance for the RE sector?

Structured finance can be broadly defined as optimizing the cost of borrowing in a manner, which suits the requirements of the borrower and the lender. Usually a mix of financial products such as rupee term loan, external commercial borrowing, bonds, credit guarantees by multi-lateral agencies such as The Asian Development Bank (ADB)/ The Multilateral Investment Guarantee Agency (MIGA), and so on, are employed to bring down the cost of borrowings. The RE sector suffers from variations in energy generation due to the seasonality of the weather patterns. Structuring also takes into account the servicing of debt that is in line with the variations in energy generation. Repayment is also structured in accordance with the prevailing tariff stream in the particular state.

Q. What are your specific views on the Ministry of New and Renewable Energy's (MNRE) generation-based-incentive scheme for solar power projects being implemented through Indian Renewable Energy Development Agency Limited (IREDA)?

The lenders have a positive outlook towards generation-based incentives (GBI), as those promoters that avail

GBI are serious players in the RE sector and are more concerned about the performance of their units. GBI obviously helps to improve revenue and the return on equity (ROE). It is also attracting foreign direct investment (FDI) in the RE sector. Companies such as Acciona and Indian Energy have successfully raised debt through the State Bank of India (SBI) and have commissioned their wind energy projects. It is expected that other such companies from the US and Europe will set up shops in India.

Q. How far do you think that the timely release of financing to the solar energy projects would help to reap the maximum possible dividends?

Without the availability of financing, solar projects, as envisaged in the Jawaharlal Nehru National Solar Mission (JNNSM) may never become a reality as solar power is the costliest power to produce, and without the availability of financing, it is unlikely, that in spite of the government incentives any developer will come forward to set up any solar power plant of significant capacity. SBI has financed the first wind energy project on a non-recourse basis and thus, a model example was set as to how the RE projects in wind could be financed. Once a solar energy project is financed on a non-recourse basis, it will serve as a model for other companies and financial institutions to follow suit.

Q. How can the debt servicing capability and viability of the solar energy projects be improved?

The debt servicing capability may be improved through the provision of termination payments under a concession agreement. This is a kind of a back-ended agreement and is now being used in the road sector. Agencies such as MIGA and/or ADB can also provide a back-ended credit agreement, in case a project is unable to service its debt obligations towards the end of its debt repayment cycle.

Q. The JNNSM has been launched recently. What type of role do you envisage for the SBI in the current scheme of things?

SBI is already having discussions with many developers for financing. Once credit issues related to technology and Power Purchase Agreements (PPA) become clearer, SBI will wholeheartedly support such projects. One must remember that there is very little or no experience as far as financing of solar power projects is concerned. The initial phase in the JNNSM will be a learning curve for all the parties involved in the development of a solar power park of significant capacity.

Q. To what extent do you agree with the policy of according differential treatment to the producers of solar energy projects, for example, to produce energy at higher plant load factor?

Since, the solar energy sector is relatively new, we have not yet come across any example of providing differential treatment to the producers of solar energy.

Q. How much is your risk perception vis-à-vis the financing of large-scale power generation through RE technologies, and in what ways can you obviate them?

Large-scale projects in the RE sector have already become a reality; while the wind energy sector has seen wind farms larger than 200 MW, developers are already exploring the idea to develop 100 MW solar farms. Parallel to this, the state government of Gujarat is putting efforts to set up solar parks up to 3000 MW capacity. Such parks are also being planned in other states such as Tamil Nadu. Technological innovation aimed at achieving a higher plant load factor is perhaps the best way forward to reduce the risk associated with RE projects in the long run. Local manufacturing of solar energy components will also help bring down the cost per MW and achieve better economies of scale.

Q. You have been associated with the RE financing area for a while now. What are the challenges that you had to face in this specific area?

Seasonal variation becomes an issue in the RE area. Small Hydro Projects (SHP) can suffer from lack of monsoon and, of course, variation in the wind velocity and wind density can affect the wind energy sector. Similarly, in the solar energy sector, we will encounter sunny and not-so-sunny days. All these factors have to be taken into account while structuring the financing of a project.

Q. The SBI has always been at the forefront of training human resources at various levels. Have you launched any such programme to make your staff aware about the issues, challenges, and opportunities confronting the Indian RE sector?

The SBI has been at the forefront of the RE sector, it has taken the lead in financing the first non-recourse funding for wind energy, and now is in the process of installing wind farms to offset its own consumption of power. SBI has recently commissioned 15 MW of wind power in Gujarat, Maharashtra, and Tamil Nadu, and it is in the process of installing an additional 20 MW in the state of Gujarat to further offset the consumption of energy across all of its branches in Gujarat. We are confident that this model will be replicated in other states as well. SBI also has a strong RE team that is aware of all the challenges in this sector.

Q. **Would you like to convey any special messages to the readers of *The Solar Quarterly* from the perspective of economic appraisal of solar energy projects in particular?**

I would like to add that as long as developers fulfil the credit worthiness requirement, lenders should not have a problem in lending to RE projects. The solar energy sector certainly holds a lot of promise and it will not be long before India has an established solar energy sector.

The views presented in this interview are strictly those of the person interviewed. TERI may/may not subscribe to the views.

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CURRENT R&D SOLAR

Philipps S P, Peharz G, Hoheisel R, Hornung T, Al-Abbadi N M, Dimroth F, Bett A W. 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

Abstracts

In this paper, 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 is presented. 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 the 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 the Ga0.50In0.50P/Ga0.99In0.01As/Ge shows the highest spectral sensitivity, with up to 10% difference in the yearly energy harvesting.

Keywords: energy harvest, triple junction concentrator, spectral sensitivity

Mawire A, McPherson M, and van den Heetkamp R R J. 2010. **Discharging simulations of a TES (thermal energy storage) system for an indirect solar cooker**. *Solar Energy Materials and Solar Cells* **94**(6): 1100–1106

Abstracts

Models for oil/pebble-bed TES system and the thermal energy utilization (TEU) system of an indirect solar cooker are used to perform discharging simulations. The model is validated with experimental results and reasonable agreement is obtained between simulation and experiment. Deviations between experiment and simulation are accounted by factors such as mixing effects and mass diffusion. Discharging results of the TES system are presented using two different methods. The first method discharges the TES system at a constant flow rate, while the second method varies the flow rate in order to maintain a desired power at a constant load inlet temperature. The results of discharging the TES system at a constant flow rate indicate a higher rate of heat utilization. This is not beneficial to the cooking process, since the maximum cooking temperature is not maintained for the duration of the discharging period. On the other hand, the controlled load power discharging method has a slower initial rate of heat utilization, but the maximum cooking temperature is maintained for most of the discharging process, and is desirable for the cooking process.

Keywords: TES, TEU, solar cooker, discharging process, simulations

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

Abstracts

A comprehensive, two-temperature model is developed to investigate energy storage in a molten-salt thermocline. HITEC, the commercially available molten salt is considered for illustration with quartzite rocks as the filler. 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 the thermocline thermal storage system. Thermal characteristics, including temperature profiles and discharge efficiency, are explored. Guidelines are developed for designing solar thermocline systems. The discharge efficiency is found to have improved at small reynolds numbers and larger tank heights. The filler particle size strongly influences the interstitial heat transfer rate, and thus the discharge efficiency.

Keywords: molten salt thermocline, Darcy law, discharge efficiency, thermal analysis

Margeta J and Glasnovic Z. 2010. **Feasibility of the green energy production by hybrid solar + hydro power system in Europe and similar climate areas**. *Renewable and Sustainable Energy Reviews* **14**(6): 1580–1590

Abstracts

This paper analyses the hybrid solar and hydro system as a unique technological concept of the sustainable energy system

that can provide continuous electric power and energy supply to its consumers and the possibilities of its implementation in Europe and areas with similar climate. The sustainability of such system is based on solar photovoltaic (PV) and hydroelectric (HE) energy as renewable energy sources (RES). For the purpose of connecting all relevant values into one integral SHE system, a mathematical model was developed for selecting the optimal size of the PV power plant as the key element for estimating the technological feasibility of the overall solution. Sensitivity analysis (parameter analysis) was made for the model, where local climate parameters were varied: solar radiation, air temperature, reservoir volume, total head, precipitation, evaporation, and natural water inflow. It has been established that, apart from total head (which is to be expected), solar radiation, hydro accumulation size, and natural water inflow have the biggest effect on the calculated power of the PV power plant. The obtained results clearly show a wide range of implementation of the new energy source (SHE system), that is, from relatively colder zones to those abundant in solar energy, but also with relatively small quantity of water, because it only recirculates within the system. All this suggests the necessity for further development of hybrid systems (RES + HE systems), and to the fact that they could play an important role in achieving climate objectives.

Keywords: SHE system, hybrid system, solar power, hydro power, RES, HE

Al-Salaymeh A, Al-Rawabdeh I, and Emran S. 2010. **Economical investigation of an integrated boiler–solar energy saving system in Jordan**. *Energy Conversion and Management* **51**(8): 1621–1628

Abstracts

Jordan is relatively poor in conventional energy resources and is basically a non-oil producing country. To a very large extent, its energy supply relies on imports. It is, therefore, unlikely that any future energy scenario for Jordan will not include a significant proportion of its energy from renewable sources, such as solar energy. The lack of an integrated energy saving system, which utilizes the solar energy for domestic hot water as well as for building space heating, was the main motivation for the present study. In Jordan, there is no existing system that can provide the integration mechanisms of solar energy and fuel combustion with electrical ones. Also, adding new and related products increase sales of current boiler products and can be offered at competitive prices.

During our investigation, we found that the market demand for boiler–solar integration system, in terms of the system acceptability, system feasibility, and system value is very high, especially after the increase in oil prices during the last three years, 2006–08. The market trend shows that even though solar collector is not attractive as an energy source for domestic hot water, the combined system for space heating and domestic hot water is fully accepted. However, the market demand for such a system is not completely identified yet but the awareness and the discussion of the idea shows a good potential. The economical study about the integration system of boiler and solar energy shows that using solar water heaters to heat space, and for domestic water use is cost-effective. Payback can be as low as three years, and utility bills are much lower than they would be using a conventional heating system. The initial draft and design of a prototype for the boiler–solar–electrical integration system has been carried out.

Keywords: boiler, solar energy system, Jordan, domestic hot water

Shabani B, Andrews J, and Watkins S. 2010. **Energy and cost analysis of a solar-hydrogen combined heat and power system for remote power supply using a computer simulation.** *Solar Energy* **84**(1): 144–155

Abstracts

A simulation programme, based on Visual Pascal, for sizing and techno-economic analysis of the performance of solar-hydrogen combined heat and power systems for remote applications, is described. The accuracy of the submodels is checked by comparing the real performances of the system's components obtained from experimental measurements with model outputs. The use of the heat generated by the Proton Exchange Membrane (PEM) fuel cell, and any unused excess hydrogen, is investigated for hot water production or space heating while the solar-hydrogen system is supplying electricity. A 5 kWh daily demand profile and the solar radiation profile of Melbourne have been used in a case study to investigate the typical techno-economic characteristics of the system to supply a remote household. The simulation shows that by harnessing both thermal load and excess hydrogen, it is possible to increase the average yearly energy efficiency of the fuel cell in the solar-hydrogen system from just below 40% up to about 80%, in both heat and power generation (based on the high heating value of hydrogen). The fuel cell in the system is conventionally sized to meet the peak of the demand profile. However, an economic optimization analysis illustrates that installing a larger fuel cell could lead to upto a 15% reduction in the unit cost of the electricity to an average of just below 90 c/kWh over the assessment period of 30 years. Further, for an economically optimal size of the fuel cell, nearly half of the annual energy demand for hot water of the remote household could be supplied by heat recovery from the fuel cell and utilizing unused hydrogen in the exit stream. Such a system could then complement a conventional solar water heating system by providing the boosting energy (usually in the order of 40% of the total) normally obtained from gas or electricity.

Keywords: simulation model, visual pascal programming, techno-economic analysis, solar radiation profile, Melbourne

Cambronero L E G, Cañadas I, Martínez D, Ruiz-Román J M. 2010. **Foaming of aluminium–silicon alloy using concentrated solar energy**. *Solar Energy* **84**(6): 879–887

Abstracts

Solar energy is used for the work reported here as a non-conventional heating system to produce aluminium foam from Al-Si alloy precursors produced by powder metallurgy. A commercial precursor in cylindrical bars enclosed in a stainless-steel mould was heated under concentrated solar radiation in a solar furnace with varied heating conditions (heating rate, time, and temperature). Concentrated solar energy close to 300 Watt/sq cm on the mould is high enough to achieve complete foaming after heating for only 200 s. Under these conditions, the density and pore distribution in the foam change depending upon the solar heating parameters and mould design.

Keywords: non-conventional heating systems, Al-Si alloy precursor, powder metallurgy

Grena R. 2010. **Energy from solar balloons.** *Solar Energy* **84**(4): 650–665

Abstracts

Solar balloons are hot air balloons in which the air is heated directly by the sun, by means of a black absorber. The lift force of a tethered solar balloon can be used to produce energy by activating a generator during the ascending motion of the balloon. The hot air is then discharged when the balloon reaches a predefined maximum height. A preliminary study is presented, along with efficiency estimation and some considerations on possible realistic configurations.

Keywords: solar balloons, energy efficiency, black absorber

Akbulut A and Durmu A. 2010. **Energy and energy analyses of thin layer drying of mulberry in a forced solar dryer**. *Energy* **35**(4): 1754–1763

Abstracts

This paper is concerned with the energy and exergy analyses of the thin-layer drying process of mulberry via forced solar dryer. Using the first law of thermodynamics, energy analysis was carried out to estimate the ratio of energy utilization and the amount of energy gain from the solar air collector. However, exergy analysis was accomplished to determine exergy losses during the drying process by applying the second law of thermodynamics. The drying experiments were conducted at five different drying mass flow rates varying between 0.014 kg/s and 0.036 kg/s. The effects of inlet air velocity and drying time on both energy and exergy were studied. The main values of energy utilization ratio were found to be 55.2%, 32.19%, 29.2%, 21.5%, and 20.5% for the five different drying mass flow rate ranged between 0.014 kg/s and 0.036 kg/s. The main values of exergy loss were found to be 10.82 W, 6.41 W, 4.92 W, 4.06 W, and 2.65 W with the drying mass flow rate varied between 0.014 kg/s and 0.036 kg/s. It was concluded that both energy utilization ratio and exergy loss decreased with increasing drying mass flow rate while the exergetic efficiency increased.

Keywords: exergy analyses, forced solar dryer, thermodynamics, drying experiments, exergetic efficiency

Luque A and Martí A 2010. **Electron–phonon energy transfer in hot-carrier solar cells**. *Solar Energy Materials and Solar Cells* **94**(2): 287–296

Abstracts

If the heat transfer from electrons to phonons is low enough, hot-carrier solar cells may yield very high efficiency. In this paper, we calculate this heat transfer for the two inelastic mechanisms known to limit the electric conductivity: the multi-valley scattering in non-polar semiconductors and the coupling of electrons to longitudinal optical phonons in polar semiconductors. Heat transfer is ruled by matrix elements deduced from electric conductivity measurements. The cell power extracted from hot-carrier solar cells affected by this mechanism, but otherwise ideal, is deduced. It is found that Si and Ge solar cells, mainly under concentrated sunlight, might lead to better efficiencies than conventional cells.

Keywords: hot-carrier solar cells, longitudinal optical phonons, polar semiconductors, Si and Ge solar cells

Kalidasa Murugavel K, Sivakumar S, Riaz Ahamed J, Chockalingam Kn K S K, Srithar K. 2010. **Single basin double slope solar still with minimum basin depth and energy storing materials**. *Applied Energy* **87**(2): 514–523

Abstracts

Solar still is a simple device, which can convert available waste or brackish water into potable water using solar energy. A single basin double slope solar still with an inner basin size 2.08 m × 0.84 m × 0.075 m and that of the outer basin size 2.3 m × 1 m × 0.25 m has been fabricated with mild steel plate and tested with a layer of water and different sensible heat storage materials, such as quartzite rock, red brick pieces, cement concrete pieces, washed stones, and iron scraps. It is found that, the quartzite rock, of 0.65 inch, is the effective basin material. The still is theoretically modelled. In the previous researcher's work, variation in transmittance is taken as constant. The variations in solar incidence angle and transmittance of the covers are also considered in this work. The theoretical values are compared with actual values. The theoretical water and glass temperatures and the theoretical production rate are having higher deviation with actual. Hence, another thermal model developed for this is applied to validate the results accurately. It is found that, the theoretical production rate using thermal model agrees well with the experiment.

Keywords: solar incidence angle, quartzite rock, thermal model

Compiled by Shantanu Ganguly, Fellow, TERI <shantanu.ganguly@teri.res.in>

SOLAR TECHNOLOGICAL UPDATE

Absorption chiller as thermal compressor A/C: Solar air conditioning

Absorption chillers use heat instead of mechanical energy to provide cooling. A thermal compressor consists of an absorber, a generator, a pump, and a throttling device, and replaces the mechanical vapour compressor, saving energy at multiple sources. Absorption chillers can substantially reduce operating costs because they are powered by low-grade waste heat. Vapour compression chillers, by contrast, must be motor- or engine-driven.

With the Adsorption Chiller S 08 and S 15 (ACS 08, ACS 15), offered by Eco&Eco, it is now possible, for the first time, to generate cold from thermal driving energy, even at a low power range. In places where solar heat is available, the Eco&Eco offered absorption chillers are an alternative that is more environment-friendly and cheaper to operate, than conventional compression chillers. This is a viable option for generating cold from already occurring and insufficiently used heat, while using as little electrical energy as possible. After four years of research and development, Eco&Eco with its German partner, offer a compact and powerful adsorption chiller that comes in two sizes: with a specified cooling power of 7.5 and 15 kW. By simply coupling several ACS units, economically viable systems with a cooling power of upto 60 kW can be created.

http://www.ecoyeco.com/solar-air-conditioning/

Thermal solar tube

With the invention of the solar thermal tube, which is also called the evacuated solar tube solar water heating by using flat-panel solar panels is a thing of the past.

Its components are as follows.

- Double-layer glass tube that holds a vacuum for very little heat loss
- Acetone gas filled copper heat pipe to transfer heat into the water holding tank

Compared to traditional flat-panel solar water heaters, some of the benefits include good insulation against cold weather with vacuum filled space between the glasses. With this, the outside temperature has no effect on the inside heat and the heat of the water that the thermal tube is heating. In addition, the round shaped, evacuated tube catches the sunlight at a more direct angle any time of the day for maximum 'sun-ray-harvesting'. The sunlight cannot bounce off the flat solar panel glass. Further, the tubes are very strong and can be replaced within minutes.

http://www.ecoyeco.com/thermal-solar-tube/

3M and NREL to develop low-cost thin-film photovoltaic technology

3M, better known as the company behind Post-it, has teamed up with the National Renewable Energy Laboratory (NREL) to develop technology for the creation of low-cost thin-film photovoltaic modules. The $7.33 million partnership will also include biofuel technology development. In addition, to the partnership with NREL, 3M will also contribute its high efficiently ceramic-fibre and aluminium cables for the Desertec Solar Energy Project. The agreements between NREL and 3M establish joint investigations in three key areas of innovation: thin-film photovoltaics, concentrating solar power, and biofuels. 3M and NREL will work to develop and test new moisture barrier films and flexible packaging for thin-film solar cells made of semi conducting layers of copper indium gallium diselenide (CIGS). CIGS cells have achieved a record efficiency of 19.9% at NREL. But, to become commercially successful, manufacturers need to both increase module performance and reduce manufacturing costs.

http://www.ecofriend.org/entry/3m-partners-with-nrel-to-develop-thin-film-solar-energy-technology/

Bacteria may aid solar energy technology

Scientists in the US are studying the light harvesting properties of purple bacteria in the hope of adapting their natural designs in solar technologies. According to scientists at University of Miami, purple bacteria are single-celled microscopic organisms that live in aquatic environments, such as the bottom of lakes and in sea corals. They said the bacteria's natural design seems the best structural solution for harvesting solar energy. Prof. Neil Johnson, a physicist, who is leading the research, says that the bacteria's cellular arrangement could be adapted for use in solar panels and other energy conversion devices to offer a more efficient way to garner energy from the sun. According to

Prof. Johnson, "these bacteria have been around for billions of years, you would think they are really simple organisms and that everything is understood about them, however, purple bacteria were recently found to adopt different cell designs depending on light intensity. The study develops a mathematical model to describe the designs it adopts and why, which could help direct the design of future photoelectric devices."

Johnson and his collaborators from the University of the Andes in Colombia report their findings in the journal, *Physical Review Letters*.

http://www.upi.com/Science_News/2010/05/05/Bacteria-may-aid-solar-energy-technology/UPI-21211273076723/

Not all solar power plants are totally 'green'

Not all solar thermal power plants, touted for their environmental benefits, are pollution-free because they also use other fuels, says US experts. Solar thermal plants are expected to sprout up across the sunny south west part of the US, as the nation looks for the so-called green energy alternatives. But, some of the solar plants are designed to use natural gas or propane boilers to jump-start the units each day, releasing greenhouse gases. While the solar plants would produce only a small fraction of the carbon monoxide, nitrogen oxide, and particulates natural gas-fired power plants produce, the amounts would add up for a region in which no fossil-fuel plants are planned. About 60 solar power projects are on the drawing boards for federal land in southern Nevada, though the US Bureau of Land Management records do not indicate the ones that would be using boilers. About 32 are identified as either solar thermal or concentrating solar power, which includes both solar thermal and advanced solar photovoltaic technologies. The US Environmental Protection Agency says that the impact of a large number of solar thermal power plants on the region cannot be determined since different technologies are used. But some environmental activists are concerned that southern Nevada's air quality could get worse, the *Sun* said.

http://www.upi.com/Science_News/2010/04/26/Not-all-solar-power-plants-totally-green/UPI-15941272309770/

Students preparing for 2011 Solar Decathlon

As part of the government's annual Solar Decathlon event, the next generation of solar energy technology will be on display this fall in Washington DC. In a recent announcement, the Department of Energy (DOE) named 20 collegiate teams that would be participating in the event, which features model homes built by students that are brought for display on the National Mall. Along with the teams from the US, students from other countries will also participate in the event. "These students are tomorrow's leaders in helping develop a clean energy economy. Their innovative projects will help raise public awareness about energy efficiency, help save consumers money, and reduce carbon pollution," said Energy Secretary Steven Chu.

The DOE added that the teams in question will feature technologies suited for a wide range of climates and regions, while also demonstrating how solar energy can be helpful in areas like low-income housing, retirement communities, and other places. Among this year's participants will be Appalachian State University, the University of Massachusetts at Lowell, Tongji University in China, and Ghent University in Belgium.

http://solar.coolerplanet.com/News/19743309-students-preparing-for-2010-solar-decathlon.aspx

SonLight Power, receives renewable energy development award

SonLightPower, Inc. (SLP), a Cincinnati-based international missionary organization, has been recognized by the US Embassy in Honduras for outstanding achievements in renewable energy development and promoting greater education and interest in developing clean, alternative energy in that country. At a ceremony on the 40th anniversary of Earth Day on 22 April 2010, the US Ambassador to Honduras Hugo Llorens presented SLP volunteer Kevin Sasson with the award, which it shares with the Polytechnic University of Engineering (UPI) in Honduras. The partnership between SLP and UPI kicked off last month when engineering students worked with SLP mission teams to successfully install solar energy systems for three elementary schools in the Namasigüe, Choluteca. SLP and UPI were nominated by Ryan Guirlinger, Economic Officer, and Natalie van der Horst, Economic and Commercial Officer, from the US Embassy in Tegucigalpa, who played an important role in expanding SLP's relationships in Honduras. Out of a pool of more than a dozen nominees, five finalists were selected in two categories—private sector and the civil society. SLP and UPI received one of two civil society awards. The US Ambassador, Llorens, made the final selection. An audience of about one hundred leaders from government, private, and non-profit sectors attended the ceremony, which coincided with other Earth Day events sponsored by the US government.

The partnership between SLP and UPI will provide training venues for college engineers, an enriched curriculum, and educational opportunities beyond the classroom. For SLP, training Honduran-based engineers eases the burden of funding trips for the US-based volunteers.

Three years ago, SLP had installed solar energy systems in more than 20 Honduran schools when the Office of the First Lady asked for help for the Honduran Healthy Schools Programme. Still there were about 400 schools without access to grid electricity in remote areas of Honduras. SLP was asked to help. The Honduran leadership has since changed, but in March 2010, Rainey was invited to meet with senior staff in the Office of First Lady Rosa Elena de Lobo to discuss how best to coordinate the completion of this project. SLP makes

a difference by installing solar energy systems that generate sustainable, renewable electrical power for more than 30 years. In most cases, the SLP teams, all volunteers, can install a 300 W solar energy system for a three-classroom school within five hours. The cost of the equipment is approximately $3 500.

Since 2002, SLP and SLP-trained teams have installed solar energy systems in schools, orphanages, and medical clinics in Ecuador, Guatemala, Mexico, Haiti, Ethiopia, Kenya, and Rwanda. In addition, numerous missionaries around the world have purchased equipment from SLP at wholesale prices and/or participated in SLP training.

http://news.yahoo.co\m/s/prweb/prweb3925484

Advance made in thin-film solar cell technology

Researchers have made an important breakthrough in the use of continuous flow micro reactors to produce thin-film absorbers for solar cells—an innovative technology that could significantly reduce the cost of solar energy devices and material waste. This development has been reported in *Current Applied Physics*, a professional journal, by engineers from the Oregon State University (OSU) and the Yeungnam University in Korea. This is one of the first demonstrations that this type of technology, which is safer, faster, and more economical than previous chemical solution approaches, could be used to continuously and rapidly deposit thin-film absorbers for solar cells from such compounds as copper indium diselenide. Earlier the use of this compound depended upon methods such as sputtering, evaporation, and electro-deposition. These processes can be time-consuming, or require expensive vacuum systems or exotic chemicals that raise production costs. Chemical bath deposition is a low-cost deposition technique that was developed more than a century ago. It is normally performed as a batch process, but changes in the growth solution over time make it difficult to control the thickness. The depletion of reactants also limits the achievable thickness.

The technology invented at OSU to deposit 'nanostructure films' on various surfaces in a continuous flow microreactor, however, addresses some of these issues and makes the use of this process more commercially practical. Thin-film solar cells produced by applications such as this could ultimately be used in the creation of solar energy roofing systems. Conceptually, instead of adding solar panels on top of the roof of a residential or industrial building, the solar panel itself would become the roof, eliminating such traditional approaches as plywood and shingles. The research has been supported by the Process and Reaction Engineering Programme of the National Science Foundation. Related technology was also developed recently at OSU using nanostructure films as coatings for eyeglasses, which may cost less and work better than existing approaches. In that case, they would help capture more light, reduce glare, and also reduce exposure to ultraviolet light. Scientists believe applications in cameras and other types of lenses are also possible. More work such as this is expected to emerge from the new Oregon Process Innovation Center for Sustainable Solar Cell Manufacturing, a $2.7 million initiative based at OSU that will include the efforts of about 20 faculties from OSU, the University of Oregon, Portland State University, and the Pacific Northwest National Laboratory.

http://www.sciencedaily.com/releases/2010/04/100420132835.htm

Sunlight with cooling factor

'Refrigerated by sunlight'—we could well see an eco statement like this printed on food packaging in the years ahead. Solar energy is already being used to power air-conditioning systems in buildings, but now researchers also want to refrigerate fruit and other perishable foodstuffs using energy from the sun. Scientists from the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany, are demonstrating that this is feasible in the Mediterranean region using the examples of a winery in Tunisia and a dairy in Morocco. In the MEDISCO project (short for Mediterranean food and agro-industry applications of solar cooling technologies), solar plants for refrigerating milk and wine have been installed in cooperation with universities, energy agencies, and European companies. "Our method is ideal for countries, which have many days of sunshine, and in remote areas where there are no conventional means of refrigeration owing to a lack of water and non-existent or unreliable energy sources. It is environmentally friendly and reduces the use of expensive electricity for conventional refrigerators to a minimum," states Dr Tomas Núñez, scientist at the ISE, listing the advantages of the system. "Refrigeration is always available when the sun shines, which means that it is produced at times when demand is very high."

The scientists have installed concentrating collectors, which direct the sunlight onto an absorber by means of a reflector. This makes it possible to convert the solar radiation into hot water with a temperature of 200 degrees. "This extreme water temperature is necessary in order to drive the absorption refrigeration machine for the high external temperatures that prevail there. We do not use electricity to provide the refrigeration, we use heat. The result is the same in both cases: refrigeration in the form of cold water or, in our case, a water-glycol mixture," explains Núñez. As the absorption refrigeration machine produces temperatures of zero degree, the experts use the mixture to prevent the water from freezing. The water-glycol solution is collected in cold accumulators and then pumped through a heat exchanger, which cools the milk. "We use a slightly different system for wine, with the refrigerant flowing through coiled pipes in the wine tanks," says Núñez.

http://www.sciencedaily.com/releases/2010/05/100503111531.htm

Charging electric car batteries in an environment-friendly way

Germany aims to have one million electric vehicles, powered by energy from renewable sources, on road by 2020. And, within 10 years, the German environment ministry expects 'green electricity' to be the source of 30% of the power consumed. Arithmetically speaking, it would be possible to achieve CO_2-neutral electro mobility. As more and more solar and wind energy is incorporated in the power grid, the proportion of electricity that cannot be controlled by simply pressing a button is increasing. In addition, there is a growing risk that the rising number of electric vehicles will trigger extreme surges in demand during rush hour. "What we need is a smart grid that carries information in addition to power," says Dominik Noeren of the Fraunhofer Institute for Solar Energy Systems (ISE). The structure of the grid has to change from a push system based on energy demand to a pull system based on production output. In Noeren's opinion, "electric cars are best equipped to meet this challenge." Introduced in large numbers, they have the capacity to store a lot of energy. On an average, a car is parked for at least 20 hours out of 24. That is more than enough time to recharge them when the wind picks up or the demand for electricity is low. Developed by Fraunhofer researchers, the 'smart' charging station is a device that enables electric vehicles to recharge when the system load is low and the share of energy from renewable resources is high. In this way, peak loads can be avoided and the contribution of solar and wind power fully exploited. "For us, it is important that the end consumers are completely free to decide when they want to recharge. We do not want them to suffer any disadvantages from the controlled recharging of their vehicles' batteries," Noeren emphasizes. That is why he favours electricity rates that adapt to the prevailing situation in the power grid, ones that are more expensive in periods of peak demand and particularly cheap when there is a surfeit of renewable energy. The person using the 'smart' charging station could then choose between recharging immediately or opt for a cheaper, possibly longer, recharging time. If they go for the second option, all they need to do is enter the time when their vehicle needs to be ready to drive again. The charging station takes care of everything else, calculating the costs and controlling the recharging process. Via the display, the user can track the progress of recharging and also see the costs incurred and the amount of energy used.

http://www.sciencedaily.com/releases/2010/04/100421111353.htm

Mitsubishi Electric raises efficiency of multi-crystalline solar cells

Mitsubishi Electric has achieved a new record photoelectric conversion efficiency rate of 18% for 150 mm sq multi-crystalline silicon solar cells, an improvement of 1.2% over the company's previous level. These results have been confirmed by the National Institute of Advanced Industrial Science and Technology (AIST), a public verification agency. Mitsubishi achieved the 18% efficiency rate by adding a low reflectivity surface texture on the multi-crystalline silicon as well as developing a process to print electrodes on the surface of the silicon (metallization) and reducing shade loss of front grid electrodes. In the same surface area as previous products, Mitsubishi achieved a 7% greater electric output, making it suitable for even smaller installations such as narrow roofs.

The main features of the cell includes, using a nano-sized mask material, the Reactive Ion Etching (RIE) method uses highly reactive ions generated by RF plasma, letting ions precisely etch the target materials. This decreases reflectivity from the texturized surface of the multi-crystalline silicon, increasing the amount of absorbed light. New metal electrode material reduces metallization time by approximately half that of previous models, and sustains electrical performance of crystalline. Using modified screens and front metal electrodes, Mitsubishi reduced shading loss of front-grid electrodes by 40% compared with our conventional cells.

(http://www.solarbuzz.com/news/NewsASPT40.htm

Q-Cells and Singulus Co-operate on solar cell coating technology

Bitterfeld-Wolfen-based, Q-Cells AG and Singulus Technologies AG of Kahl/Main have agreed to jointly develop a novel system for coating of solar cells with anti-reflection structures. The goal of the exclusive cooperation is to use the specific expertise of the world's largest solar cell manufacturer, Q-Cells, and the specialists for coating technology, Singulus, to develop a technology that is superior to the previous systems with respect to coating quality and cost effectiveness. This will be achieved through the use of the well-known vacuum coating process used in the DVD production. The energy output of the finished cells will be increased by means of an especially high coating quality of the anti-reflection coating. From the new development, Q-Cells mainly expects lower processing costs compared to the current state of the technology.

Q-Cells AG will decisively help to shape the design of the system. This assures that the new system will be optimally adapted to the needs of solar cell production and that the goal of cost reduction in the production process will take centre stage in the development. Q-Cells will be the first company to employ the new system as a 'launching customer' in existing and new production lines. This advantage will be used by Q- Cells to develop processes for advancing the technology. In order to come closer to the goals of the PV industry in making solar power competitive, a significant reduction in production costs is indispensable. This will only succeed if solar cell developers, with their process experience, work closely together with equipment manufacturers in order to transfer advanced production processes from research and development to production.

http://www.solarbuzz.com/news/NewsEUTE24.htm

AMITY INSTITUTE OF RENEWABLE AND ALTERNATIVE ENERGY, AMITY UNIVERSITY, NOIDA

Amity, transcending boundaries in research and innovation….

Amity is one of the leading education groups in India with over 80 000 students studying across 1000 acres of hi-tech campus with 2 500 strong faculties, offering at least 240 UGC recognized under graduate and post graduate degrees.

It has • 17000 online journals • 5000 on-campus hostel seats • 75 Mbps broadband on 90 Km of fibre-optics • On-campus innovation incubator for entrepreneurial start-ups • 15 acre sports complex with Olympic size swimming pool • 20-lane shooting range and horse riding academy…

In India, Amity campuses are in the following places.

Noida, National Capita Region; Gurgaon, National Capita Region; Jaipur, Rajasthan; Lucknow, Uttar Pradesh; Ahmedabad, Gujarat; Bangalore, Karnataka; Bhubaneswar, Orissa; Chandigarh, Hyderabad, Andhra Pradesh; Indore, Madhya Pradesh; Kolkata, West Bengal; Mumbai, Maharashtra; Chennai, Tamil Nadu; Kochi, Kerela; Patna, Bihar; and Pune, Maharashtra.

Outside India, Amity campuses are in the following places

London, the United Kingdom; Singapore; San Francisco, the United States of America; New York, the United States of America.

Amity is also the official trainer for 30 000 volunteers and 2000 workforce for the XIX Commonwealth Games 2010, Delhi

Amity University has one of the largest and most proactive team of faculty members, scientists, and researchers who are leading the way in various cutting edge areas of science and technology. National and International Research projects have been funded by the Department of Science and Technology, the Defence Research and Development Organization, Council for Scientific and Industrial Research, Department of Biotechnology in the Ministry of Science and Technology, and many other government agencies. The university has achieved the unique distinction of having filed 135 patents in just over a year in areas spanning nanotechnology, biotechnology, biosensors, forensic science, pharmaceuticals, microbiology, software, it, herbals, photovoltaic, and electronics.

AIRAE's MISSION

- To provide the country with trained scientists and engineers in the field of solar and renewable energy
- Provide the capabilities for research and development in the following areas
  - Photovoltaics
  - Solar thermal
  - Wind energy
  - Bio fuels / Bio batteries
  - Design of energy efficient buildings
  - Energy management
  - Simulation and modelling
  - Integration with grid

"Renewable and Alternative Energy is of immense importance for the development and growth of the Nation, and I am glad that great importance is being given to it from all relevant quarters in the country."

Dr Ashok K Chauhan
President, Amity Institute of Renewable and Alternative Energy (AIRAE)
Founder President, Ritnand Balved Education Foundation
(The Foundation of Amity Institutions and the sponsoring body of Amity Universities)

Research for the benefit of mankind…

The faculty of AIRAE jointly with the Amity Institute of Advance Research and Studies (Materials and Devices) – AIARS(M&D), comprises of leading academicians, senior scientists, and researchers who are credited with

- 14 patents
- More than 250 published papers
- 11 Ongoing research projects funded by various departments of Government of India

Academic activities

The University offers Ph D, M Tech, and B. Tech in the field of solar and alternative energy

With global climate change issues occupying a prominent position in science and technology, industry, and international relations, the role of renewable energy management has come in sharp focus in the recent years. M Tech and B Tech in solar and alternative energy, aims to produce skilled professionals who will harness the potential of renewable energy for a greener world and mark themselves in not only India's but also the World's 2020 Mission.

The curriculum covers the following areas

- Solar cell technology: organic / inorganic 3rd generation solar cells
- Wind energy
- Bio-fuels / Bio-batteries
- Novel materials like nano-materials
- Application of photovoltaic technology
- Design of energy-efficient buildings
- Energy management
- Simulation and modelling
- Integration with grid
- Six month industrial training in India or abroad

Various activities

The University frequently organizes and participates in national/international conferences and workshops. Following are the few seminars and workshops that the university students participated in.

- 'Indo-Australia Solar Energy Workshop', sponsored by Department of Science and Technology at Amity University, 9–10 February 2010,
- 'Fostering Solar Energy Research in India', sponsored by DRDO at Amity University 18 November 2008
- Consultancy
- Industrial Consultancy: Mosebaer and REC for Photovoltaic.
- Industry interaction of students

Laboratories

The university has state-of-the art laboratories.

Institution has world class labs with new-age equipments to give students real life experience and conduct innovative research.

Laboratories

- Electrical characterization lab
- Optics lab
- Thin-film lab
- sensor labs
- Bio-chemistry
- Clean room processing facilities

Equipments

Digital Oscilloscope, Keithely Sourcemeter, Keithely Electrometer, Photometer, AFM, Optical Microscope, FTIR, Spectrophotometer, Spectrum Analyzer and lifetime measurements facility for solar cells, Thermal Deposition Chambers, Spin Coater, micro balance CVD Furnace, Particle Analyzer, Laminar Flow tables, Micro centrifuge, Rotavapour…with clean room facility.

Research Areas at AIRAE and AIARS

- Photovoltaic Devices: Organic and Inorganic
- 3rd Generation Solar Cells based on Nano-materials
- Synthesis of Nano-materials
- Chemical, Gas, and Bio-Sensors based on Nanotechnology
- Organic Light Emitting Diodes

Dr V K Jain
Director, Amity Institute of Renewable and Alternate Energy; Former Director Grade Scientist, SSPL (DRDO)
Emeritus Scientist, NPL (CSIR)
Over 100 papers and
14 Patents

"Renewable energy is destined to become one of the fastest growing sectors of the economy in the coming years, and it is estimated that at least 35 000 new jobs will be created. By 2030, $1 trillion would be invested in this sector.

To meet the need for trained people who shall shape the future of renewable energy, Amity Institute of Renewable and Alternate Energy is offering programmes in solar and renewable energy. While Amity Institute of Advanced Research and Studies is carrying out cutting-edge research in various areas to harness the full potential of natural energy resources."

- Applications of nanotechnology in Microbiology
- Water Purification using Nano-materials
- Bio-Nano Technology

Faculties…

Following is a list of distinguished academicians, scientists, and researchers under the coordination of Dr V K Jain, Director, AIRAE.

- **Dr Vasuda Bhatia**, Assistant Professor
  Qualifications: PhD – Texas A and M, the US.
  Post Doc – SMD, Austin (USA); JNCARS, Bangalore.
  Research Interests: Photovoltaics, Nanomaterials, Nano-Devices, Sensors.
  Patent Filed: Two
  Published more than 10 papers.

- **Dr Kanchan Saxena**, Assistant Professor
  Qualifications: Ph D Delhi University with National Physical Laboratory, Delhi.
  Post Doc – Technische Hochshule, Germany.
  Research Interests: Organic Photovoltaics and Light Emitting Diodes.
  Published more than 40 papers

- **Dr Suman**, Lecturer
  Qualifications: Ph D – MDU Rohtak
  Post Doc – Dublin City University, Europe.
  Research Interests: Biosensors, Bio-nanotechnology, Biomedical diagnosis of diseases, bio-batteries, and water cleaning.
  Patent Filed: Four
  Published more than 25 papers

- **Dr Ruchi Srivastava**, Lecturer
  Qualifications: Ph D – Jawaharlal Nehru University, Delhi.
  Research Interests: Nano-composites, third generation Photovoltaics, Sensors, Two and three terminal devices based on organic molecular semiconductors.
  Published more than five papers

- **Dr Abhishek Verma**, Lecturer
  Qualifications: Ph D – Electronic Science, University of Delhi.
  Post Doc. – National University of Singapore
  Research Interests: Organic and third generation solar cells, Self-cleaning and antireflection solar cell panels, organic white LEDs, II-VI Quantum dots, Colorimetric sensors.
  Published more than 10 papers.

- **Prashant Shukla**, Research Scientist
  Qualifications: Ph D – Uttar Pradesh Technical University, Lucknow (To be submitted).
  Research Interests: Polymer Nano-composites, Polymeric Electrets, Electro-active Polymers and their transport properties.
  Patent Filed: One
  Published more than 10 papers.

- **Vikesh Gaur**, Lecturer
  Qualifications: ALCCS (M Tech) - IETE (Ongoing).
  Research Interests: CNT based Gas sensing applications. Polymeric Gas sensors.


Clean room facility


FTIR characterization facility


Fabrication of carbon nano cubes


Facility for organic light emitting diode


Optical characterization facility


Preparation of bio-samples in a clean bench

Research fellows

- **Rupesh Basniwal**, M Tech
- **Bhawana**, Research Scholar

DIREC 2010

Delhi International Renewable Energy Conference
Expo Centre - Expo XXI, National Capital Region of Delhi
27-29 October 2010

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www.direc2010.gov.in

EXPERT SPEAK

Answers to questions on solar energy

DR R L SAWHNEY
Professor, TERI University
<rl.sawhney@teriuniversity.ac.in>

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 every one 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. Could you please clarify what is the difference between solar photovoltaic and solar thermal?

Ans: In comparison to all other forms of energy, solar energy has the highest quality (exergy) and hence, has a potential for converting itself to any other lower forms of energy. By using suitable devices, solar energy can be directly converted to electrical form (which is high quality energy) or thermal form (which is low quality energy). The basic unit used for converting solar energy into electricity is a solar cell. The process of conversion of energy of a photon in solar radiation into voltaic (D C electricity) form is known as solar photovoltaic. Solar cell is a semi-conductor device, which is manufactured in a very complex process involving a large number of steps. Moreover, the efficiency of a solar cell is very small, ranging from 5%–19%. This makes the solar photovoltaic systems very expensive.

A black surface converts solar radiation incident on it, directly into thermal energy. Hence, for converting solar energy into thermal energy, only a black coated surface is required, which is simple and less expensive to construct. Once solar energy is converted into thermal energy off the black surface, the black surface starts loosing the converted thermal energy to the surroundings. The rate off loss of thermal energy can be reduced by the appropriate use of glass cover, insulation, and other mechanisms. All solar thermal devices used for heating applications, such as solar cookers, solar

water heating collectors, solar air heaters, solar dryers, solar concentrators for power generation, and so on, contain black surface and glass cover. Compared to solar photovoltaic systems, the efficiency of all the solar thermal systems is quite high, ranging between 40%–60%. As electricity can be used for varied purposes, solar photovoltaic systems have more number of applications compared to solar thermal systems.

Q. Could you please elaborate if there are any advantages of solar thermal water heating systems at a personal level?

Ans: There are many advantages of solar thermal water heating system

1. Benefitting the global climate: The most important advantage of using Solar Water Heating System (SWHS), instead of the normal electrical geyser, will be that we will be helping in reducing global warming, instead of contributing.
2. .Monetary benefits: A 100 litre SWHS will be sufficient for meeting the hot water requirement of an average family of five members. The cost of such a SWHS, including the cost of plumbing, will be about Rs 25 000. The cost of two geysers which the SWHS will be replacing, will be about Rs 10 000–Rs 12 000. So, the additional cost of the SWHS will be about Rs 15 000. Depending upon location in the country and usage of hot water, it may save electrical equivalent of 900–1800 units (kWh) annually. At an electricity cost of Rs 5/kWh, the annual savings may be anywhere between Rs 4500–Rs 9000, giving a pay back period of 20–40 months. After that, for the entire remaining life of 15 years of the SWHS, it will give hot water free, though there some maintenance cost will be inured

   The Central government through various banks provides soft loans at 2% interest rate, for purchase of solar water heating systems. Different states and municipal corporations are providing different financial incentives to the installers of SWHS. The Union Government of Delhi provides a subsidy of Rs 6000 for each domestic system installed. Thus, installation of SWHS financial becomes quite attractive even financially.

3. The other advantage of SWHS is the regular availability of hot water in the morning, when electric supply may be a problem, due to morning peak load during the winter season. It will also indirectly help in reducing transmission and distribution losses of electricity and transportation of coal required for electricity generation.

Q. In India, what is the most significant trends and drivers for the development of the solar energy sector over the coming 10–20 years?

Ans: Of the various renewable technologies in India, solar energy has the largest potential, followed by biomass and then wind energy. But till date, the largest contribution to the grid-connected power generation has come from wind. Till recently, the application of solar energy technology for both electrical applications and thermal applications was not growing at a very significant rate. With increased climate change concerns and consequently launching of the Jawaharlal Nehru National Solar Mission (JNNSM) by the Government of India, now the growth of solar industry is expected to increase at a very fast rate. Under this mission, the government plans to generate 20 000 MW of electrical power (major part of which swill be grid connected) in three phases and install 20 million sq m collector area of SWHS by 2022. If compared to 10.28 MW grid-connected capacity and 3.5 million sq m collector area installed so far, for achieving the targets by 2022, a large number of trained manpower at all levels (scientists, engineers, diploma holders, ITI trained; estimated to be about 1.1 lakh), will be required. For producing this manpower specific courses at post graduate, graduate, diploma, and ITI levels will have to be initiated. We need to increase the existing manufacturing facility of various solar technologies, which already exist in the country. Technologies such as power generation through the solar thermal route will have to be imported. Given that the solar sector will expand, good number of foreign governments and companies are now already signing MoUs with appropriate Indian players.

HOMER

THE OPTIMIZATION MODEL FOR DISTRIBUTION OF POWER

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

Background

Today, renewable energy (RE) projects, which produce power from various naturally occurring resources, such as solar, wind, biomass, and so on, are providing one of the few growth areas for energy developers, investors, and creditors. Simultaneously though, finances related to RE-based projects are facing complexity, whereby the profitability of a RE project is increasingly being related to determining the following.

- Examine the risks connected with the RE projects
- Analyse the impacts of project structure on getting the necessary financing
- Model the trade-offs of pursuing various equity and debt financing strategies

System simulation tools perform the task of providing an insight into these issues from various end-use considerations. HOMER is definitely one such tool, which is widely used for the desired purpose. This article explains the essential aspects of HOMER.

Making a beginning

RE technologies such as solar, wind, biomass, and small hydro power are now gaining worldwide acceptance. Already, a growing number of end-users belonging to the residential, institutional, commercial, and industrial sectors are using such technology-based systems. Here, it is important to mention about the intermittent nature of these sources, from both the qualitative and quantitative considerations. To respond to the RE industry's system analysis and optimization needs, a number of system simulation software's have been developed by selected organizations from time to time. These mainly include TRYNSYS, RET Screen, NSol, PV Watts, PVSyst, and so on. In 1993, the National Renewable Energy Laboratory (NREL), belonging to the US Department of Energy (DOE) began working on HOMER. HOMER originally stand for 'hybrid optimization model for electric renewables'. However, HOMER can model systems that are not hybrid, such as simple photovoltaic (PV) systems or diesel systems. It can also model thermal and hydrogen loads. A large number of individuals, academic and research organizations, government departments, and non-governmental organizations have benefited from the use of this multi- dimensional software.

Basically, HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected PV systems in the following few applications.

- Rural remote uses
- Stand-alone
- Distributed generation

Its optimization and sensitivity analysis algorithms allow a user to evaluate the economic and technical feasibility of a large number of technology options, and thereby to account for uncertainty in technology costs, energy resource availability, and other variables. HOMER models both conventional and RE technologies of the following few types.

- Solar PV
- Wind turbine
- Run-of-river hydro power generator
- Diesel, gasoline, biogas, alternative and custom fuels
- Electric utility grid
- Microturbine
- Fuel cell
- Storage mediums such as batteries, hydrogen, flywheels

Matching the load profiles

For a given area, the load profile will vary considerably depending upon the different consumer categories. The peak electricity demand generally varies from season to season. HOMER is quite capable of meeting the important requirements of the following load types.

- Daily profiles with seasonal variation
- Deferrable (water pumping, refrigeration)
- Thermal (space heating, crop drying)
- Efficiency measures

What HOMER does in practice?

As already mentioned, the micro power optimization model enables you to design both off-grid and grid-connected systems. In fact, you can make use of HOMER to explore and analyse a wide range of system design curiosities, such as the following.

- Which of the technology types are most economical?
- What are the sizes of the components used?
- What is the impact on the project economics, in the event of any variation in, either load profile or the component costing?
- Whether the renewable source (under consideration) is adequate or not?

HOMER performs the following key functions in a user-friendly manner and format.

Least cost combination

It helps to locate the lowest cost combination of components that meet the electrical and thermal loads. In this process, it simulates quite a large number of system configurations, optimizes for the life-cycle costs, and produces the outcome of sensitivity analysis on most inputs.

Hourly calculations

By framing energy balance calculations for each of the 8760 (24 hours × 365 days) on an annual basis, it simulates the operation of a system. For each hour, HOMER compares the electric and thermal load in the hour, to the energy that the system can supply in that hour. Moreover, for such systems, which include batteries or fuel, this innovative software acts as a decisive tool for each hour to know the following.

- How to operate the generators?
- Whether to charge or discharge the batteries?

Assuming that the system takes care of the full load for a complete year, HOMER assesses the following few elements.

- Life cycle cost of the system
  - Capital cost
  - Replacement cost
  - Operation and maintenance cost
  - Fuel cost
  - Interest cost
- View hourly energy inflows for each component (including annual cost and performance summaries)

System optimization

A whole range of possible system design configurations are enabled. In fact, a complete list of feasible systems in relation to their life cycle cost appears.

Sensitivity analysis

Sometimes you may find it useful to see how the results vary with change in inputs, either because they are uncertain, or because they represent a range of applications. You can perform a sensitivity analysis on almost any input.

Few easy steps to use HOMER

A HOMER file has all the information about the technology options, component costs, and resource availability needed to analyse the power system designs. It also contains the results of any calculations that HOMER does. Thus, it is possible to arrive at appropriate, estimated techno-economic details of a solar system under our active consideration. Following few steps are normally involved in this simulation exercise.

- Set up a new HOMER file (HOMER file names end with .hmr for example: PV VsDiesel.hmr).
- Build the schematic details (compares multiple technology options that you want HOMER to consider. Every system design must include either a primary load (that is description of electric demand, deferrable load) or be connected to the grid.
- Enter load details (load details are inputs to the HOMER simulations; the load inputs describe the electric demand that the system must serve). It displays the daily load profile in the table and graph for format.
- Enter component details (component inputs describe technology options, component costs, size, and number of each component that HOMER will use for simulations).
- Enter the resource details (the resource inputs describe the availability of solar radiation, wind, hydro, and fuel for each hour of the year).
- Check inputs and correct errors (checks many of the values that you enter in the input windows for technical correctness).
- Examine optimization results (simulates system configurations with all the combination of components that you specified in the component inputs).
- Refine the system design (mentions how to use the optimization results to improve the system design).
- Add the sensitivity variables (mentions the procedure to enter the sensitivity values).
- Examine the sensitivity analysis results (mentions how to view and enter the sensitivity results to determine, for instance, under what conditions a PV/diesel system is more cost-effective than a diesel system) are as follows.

Initial cost	$4500
Electricity cost	$1.332 kWh

Quite clearly, HOMER justifies the use of a PV system on technical, economic, and humanitarian grounds.

Since its release in 1993, HOMER has passed through several revisions. Currently, version 2.67 beta of HOMER is available. This version enhanced its capability to model upto 10 generators. It also enables HOMER to have upto 10 battery types compete against each other. HOMER is available free of cost on the HOMER website—www.nrel.gov/homer. Any interested user can easily download the instructions for the software as well as the latest information on the model, sample files, and resource data.

ARUNDHATI: THE NEW GENERATION LI-ION BATTERY POWERED SOLAR LANTERN

Technology should be the driving force in shaping products and services in the 21st century, especially in the area of renewable energy products. The gluttonous consumption of the previous millennium has made the world a polluted, energy-deficient planet.

In the absence of reliable grid electricity, households across the developing world depend on kerosene, candles, and other non-electric sources for their lighting needs. However, these sources are fast depleting. We need reliable, affordable lighting options for developing nations as it extends working hours, and increases employment and income-generating prospects. Light also gives considerable social benefits by reducing injuries from accidents and enhancing the quality of life, especially for those who spend lot of time inside the house.

Harvesting the sun's power to generate electricity and light provides an alternative to smoky fuels and inefficient lighting. Today, a wide variety of solar powered lights are being used to light up the energy-starved communities.

Most recent solutions have revolved around solar photovoltaic panels, lead-acid batteries, and compact fluorescent lamps (CFLs). However, the lead and other harmful materials in the battery packs and the mercury in CFLs poison the environment when they are discarded. The inefficiency of these products intensifies the climate change problem.

To address this issue, Global Telelinks, Hyderabad, has pioneered the use of cutting-edge Lithium-ion (Li-ion) battery technology in solar chargeable lamps. The Arundhati Solar Lantern combines these batteries with extremely low-power consuming, high luminescence, white light emitting diodes (WLEDs) to deliver a product whose charge-versus-discharge ratio is more than double that most of the solar lanterns available in the market today. This makes the lamps last longer per battery recharge than others.

Li-ion batteries can handle hundreds of charge/discharge cycles, and they are lighter than other rechargeable batteries of the same size. Lithium is a highly reactive element, meaning that a lot of energy can be stored in its atomic bonds, which translates into very high energy density for Li-ion batteries. A typical Li-ion battery is six times more effective than a LEAD acid battery, thus saving resources and polluting less.

This makes an enormous difference. Another advantage is that Li-ion batteries offer twice the run-time and a considerably lower total cost of ownership than lead-acid ones. They also hold their charge well because the depth of discharge is much higher leading to longer durations of lighting for every charge cycle.

The WLEDs in Arundhati Lanterns are shatter-proof and last for more than 35 000 hours. Combined with PCB control boards, 'under-charge' 'over-charge' protection, and ABS plastic bodies make the home lantern weather-proof and virtually indestructible.

The lamps have variable switch settings that allow them to give continuous illumination from 8–40 hours per charge. They are flat and extremely light-weight (271 grams), and can be hung flat against walls and ceilings much like the lighting fixtures in homes and offices. This eliminates the large cones of darkness that form over and below conventional lamps.

Another big advantage is that all parts are connected by only three pairs of plug-and-socket joints. This not only avoids complicated soldering but also allows quick repair and maintenance.

All items of the Arundhati range of products (study lights, multi-purpose head lamps) can be charged from multiple sources such as mobile charges, solar panels and community charging, which empowers the local entrepreneur to adopt the pay-per-charge model.

For more details contact:

GLOBAL TELELINKS
www.prakruthpower.com
Hyderabad, Andhra Pradesh,
India
prakruthipower@gmail.com
K/A C V Rao/919949011955

The SOLAR QUARTERLY

FEEDBACK FORM

Your views about *The Solar Quarterly* are invaluable to us. Kindly take some time off to complete this feedback form and send it to the Editorial Team, *The Solar Quarterly*, TERI (The Energy and Resources Institute), Library Block, India Habitat Centre Complex, Lodhi Road, New Delhi—110003 or fax it to (011) 2468 2144/45 or e-mail it to arani.sinha@teri.res.in.

1. Why do you read *The Solar Quarterly*?

☐ To know more about solar energy related issues
☐ Acquire knowledge about issues in general
☐ Like to read the views of people working in this field
☐ The contents are exceptional
☐ Others (please specify)

2. How do you go about reading the magazine?

☐ Read all sections thoroughly
☐ Read certain sections
☐ Read only the main articles
☐ Glance at it generally
☐ Share with family, friends, and colleagues

3. Which section do you find the most interesting?

☐ Features
☐ Interviews
☐ From the archives
☐ Technical corner
☐ Current research and development
☐ University focus
☐ Expert Speak
☐ Learning Package
☐ Others (please specify)

teri
The Energy and Resources Institute

4. Which new section do you feel is the most informative?

☐ From the archives
☐ Technical corner
☐ Current research and development
☐ Web updates

5. What do you think about the new look and feel of *The Solar Quarterly*?

☐ Brilliant
☐ The previous look was better
☐ Needs more work
☐ Design is not a priority, content is
☐ Others (please specify)

6. How do you rate the magazine overall?

☐ Best in the business
☐ Informative and interesting
☐ Marginally useful
☐ Not useful at all
☐ Others (please specify)

7. Which other solar based/renewable energy based magazine do you read?

☐ _____
☐ _____
☐ _____
☐ None

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

☐ _____
☐ _____
☐ _____
☐ _____
☐ _____
☐ _____

10. Any other suggestion?

_____
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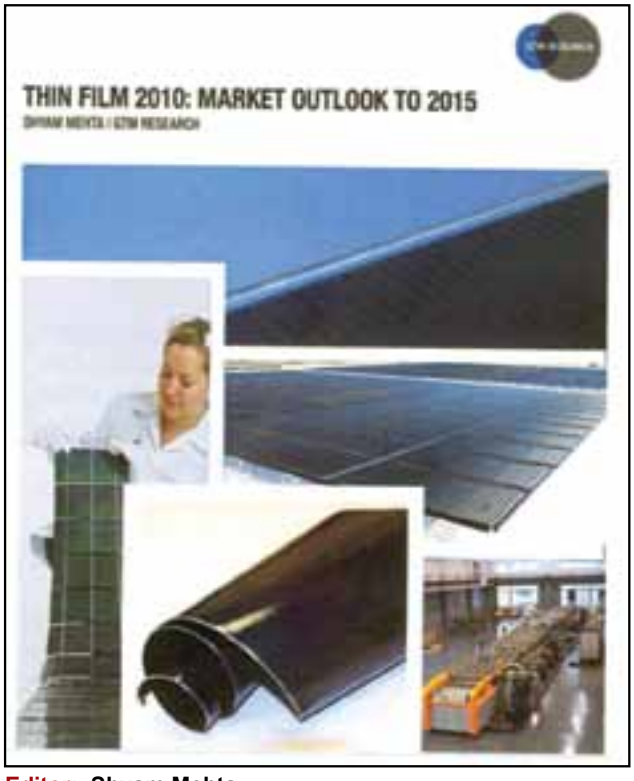
The Energy and Resources Institute

Thin film 2010: market outlook to 2015



Editor: Shyam Mehta

Year: 2010

Price: $2495

Publisher: GTM Research Group

From only 17 megawatts (MW) in 2002 to nearly 1 gigawatt (GW) in 2008 (a compounded annualized growth rate of 96%), thin film's rise over the last decade has been remarkable. The search for alternative technologies to traditional crystalline silicon PV has led to a tidal wave of investment and entrepreneurial activity in thin film, with 170 active companies and over $2 billion in venture capital investment in the space. However, as of 2010, only two thin-film companies have produced in excess of 100 MW annually. The cost structure of most amorphous silicon, considering its low efficiency, is barely competitive with crystalline silicon, and CIGS producers have encountered technical issues in manufacturing that have forced most of them to delay commercial production, a situation which has persisted since 2007. To make matters more difficult, capital constraints led banks and developers to shy away from thin film in favour of more mature and abundant crystalline silicon modules for projects in 2009. First Solar aside, one would have to admit that the results in the thin-film space have yet to live up to the talk. As Asian crystalline silicon, PV producers continue to ramp down costs and increase capacity beyond the gigawatt level, one should ask—will results ever meet expectations, and if so, when? In other words, will thin film fulfil its potential and make meaningful inroads into the solar energy landscape, creating new markets in the process? Or will it be relegated to a bit-player role in the growth of the global PV market?

This 200-page report peels away the layers of hype and speculation that have traditionally shrouded thin-film PV to provide the most comprehensive, granular, and objective assessment of the space available to date. Packed with data points, colour, and analysis, Thin Film 2010 assesses thin film's impact on the global PV market by analyzing all relevant factors that influence demand for thin film, and how these factors interact when determining technology selection in PV markets.

Major findings of the report

1. Thin-film capacity will stand in excess of 10 GW of thin film capacity by the end of 2012
2. Amorphous silicon and turnkey CIGS production will dominate Asian production
3. Best practice producers across all technologies will achieve costs of 80 cents per watt by the beginning of 2012, but there will be significant variation across producers.
4. First solar will continue its dominance, remaining the largest thin manufacturer in the world over the next three years.
5. CIGS and amorphous silicon (particularly turnkey line production) will likely not see meaningful market share until 2012, when cost reductions and efficiency improvements will finally start to drive a competitive product offering at an adequate margin.
6. High margin thin film production will be a game played by the select few.
7. Amorphous silicon will have disproportionably higher market share in non-European, non-feed-in-tariff markets.
8. As efficiencies improve beyond the 12% level, thin film modules will enjoy increasing share in the residential market.
9. All signs point to one of the venture-backed CIGS companies (Solyndra, Nanosolar, Miasole) emerging as successful representatives of this technology.
10. Past 2013, low cost CIGS systems will rapidly begin stealing share from crystalline silicon (and perhaps CdTe) in IPP-governed US, utility scale markets.
11. The coming years should see a great deal more consolidation than has been witnessed so far in the thin film industry.

http://www.gtmresearch.com/report/thin-film-2010-market-outlook-to-2015

Alternative Energy Systems

The official website of the Alternative Energy Systems provides comprehensive information on various products in the alternative energy sector. It has details about various products, from solar pipes to solar cells. It also provides news on various products that are being launched every day in the field of alternative energy. The website also contains list of useful web links, financing and incentive links, and press releases.

http://www.alternativeenergysystems.net/

China Solar Energy

China Solar Energy Holdings Ltd. (China Solar), a company listed on the Hong Kong Stock Exchange (stock code 0155 HK), acquired a controlling interest in a private US-based solar photovoltaic (PV) company, Terra Solar Global Inc (Terra Solar) in January 2006. China Solar is a total solution provider of thin-film production equipment and a leading supplier of Vetrogrid® for BIPV systems. The website contains details about the company, along with business model, equipment and technology, list of Vetrogrid® distributors, financial statements, notices, corporate governance measures, and so on. The equipment technology section specifically talks about thin-film PV technology, Vetrogrid® overview, equipment and technology overview, proprietory S_nO_2 production equipment.

http://www.chinasolar-energy.com/

The Solar Energy Materials Research Group

The Solar Energy Materials Research Group is led by Senior Scientist Wladek Walukiewicz (PI) with Staff Scientists Joel Ager (co-PI) and Kin Man Yu (co-PI). Senior Staff Scientist Zuzanna Liliental-Weber is also associated with the programme. The group is developing novel materials that address the immediate need for sustainable, clean energy sources. The official website contains details of these developments and more. The website has a section, which provides details of what new the group is doing in the form of news items. The website has a section titled 'research'. This section provides details about the research undertaken by the group. The website also provides detail of various key and principle investigators who are involved with this group. Along with updates on group meetings and announcements, this website also provides publication details. The website contains collaborators, scientific organizations, and research tools.

http://emat-solar.lbl.gov/

Texas Solar Energy Society

Texas Solar Energy Society is a not-for-profit organization with a long history of solar and renewable energy outreach and education. Founded in 1976, they have been serving Texas for more than 30 years. The official website of the Texas Solar Energy Society, interestingly, has a section titled 'school', which says that one need not go to a school to learn the basics of a solar power system. Thus, everything about a solar power system is provided in this section. The website has a calendar, which lists all the upcoming events, programmes, seminars, and so on. It has a section, 'renewable energy roundup', which lists speakers, schedules, exhibitors, advertisements, volunteers, sponsors, travels, and lodging.

http://www.txses.org/solar/

NEW BOOK INFORMATION

Solar energy: problems, solutions and experiments

This book deals with the problems, solutions, and experiments in various fields of solar energy and its applications, such as flat plate collectors, evacuated solar collectors, solar water and air heaters, solar dryers, solar concentrators, solar distillation systems, solar house, greenhouse economics, and so on. The book contains a large number of solved examples and solutions to problems. This book will help the readers to enhance their understanding of the subject easily and clearly. A large number of objective questions at the end of each chapter are an attractive feature of the book. This book would be of great interest to students, teachers, researchers, scientists, engineers, and designers engaged in the various field of solar energy and its applications.

G N Tiwari, P Barnwal, S C Solanki, M K Gaur
Anamaya Publishers, New Delhi, 430 pp.
Year : 2010

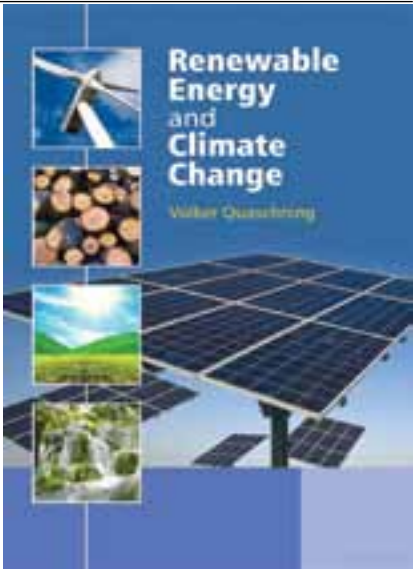
Renewable energy and climate change

This dazzling introductory textbook encompasses the full range of today's important renewable energy technologies. Solar thermal, photovoltaic, wind, hydro, biomass, and geothermal energy receive balanced treatment with one exciting and informative chapter devoted to each. It also has a complete overview of state-of-the-art technologies. Following are the chapters

- a clear analysis on their development potentials
- an evaluation of the economic aspects involved
- concrete guidance for practical implementation
- advice on how to reduce your own energy wastage

If we do not act now to stop climate change, the consequences will be catastrophic. This situation is demonstrated here with the aid of full-colour figures and photographs, data diagrams, simple calculations, and results. A multiplicity of impressive examples from countries across the globe show international 'alternative' energy in action.

With its easy-to-read approach, this is an essential textbook for students on renewable energy courses as well as environment and sustainability courses. Planners, operators, financers, and consultants will find this an excellent manual for planning and realizing climate protection. Furthermore, this book makes great background reading for energy workers, designers, politicians, journalists, and anyone who is interested in the issue of climate change.



Volker Quaschning
Translator: Hedy Jourdan
IEEE Press and Wiley, UK. 308 pp.
Year: 2010

NATIONAL AND INTERNATIONAL EVENTS

National

Green Energy World Expo 2010
14–16 October 2010
Chennai, India
E mail: daisy@gsnaworldwide.com
URL: www.gsnaworldwide.com

Delhi International Renewable Energy Conference
27–29 October 2010
Expo Centre – Expo XXI
National Capital Region of Delhi, India
URL: www.direc2010.gov.in

Intersolar India
14–16 December 2010
Mumbai, India
Tel: 49 7231 58598-0
Fax: 49 7231 58598-28
E Mail: info@intersolar.in
URL: www.intersolar.in

International

Intersolar North America
13–15 July 2010
San Francisco, California, US
Tel: 49 7231 585982-2
Fax: 49 7231 585982-8
E Mail: doeppe@intersolar.us
URL: www.intersolar.us

Exhibition: Indo Renergy 2010
28–30 July 2010
Jakarta, Indonesia
Tel: 62 21 865096-2
Fax: 62 21 865096-3
E Mail: info@indorenergy.com
URL: www.indorenergy.com

Soltec
2–5 September 2010
Hameln, Germany
Tel: 49 571 2 9150
Fax: 49 571 2 0270
E Mail: kontakt@rainer-timpe.de
URL: www.rainer-timpe.de

25th European Photovoltaic Solar Energy Conference
6–10 September 2010
Valencia, Spain
Tel: 49 89 720 12 735
Fax: 49 89 720 12 791
E Mail: pv.conference@wip-munich.de
URL: www.wip-munich.de

PV Rome Mediterranean
9–11 September 2010
Rome, Italy
Tel: 39 02 6630 6866
Fax: 390 2 6630 5510
E Mail: info@zeroemission.eu
URL: www.zeroemission.eu

4th International Solar Cities Initiative (ISCI) Congress 2010
16–19 September 2010
Dezhou, China
Tel: 86 534 22396-29
Fax: 86 534 22396-17
E Mail: jwsjk@sina.com
URL: www.chinasolarcity.cn

12th Renewable Energy Finance Forum-London
20–21 September 2010
London, United Kingdom
Tel: 44 207 779 8995
Fax: 44 207 779 8946
E Mail: energyevents@euromoneyplc.com
URL: www.euromoneyenergy.com

World Renewable Energy Congress XI and Exhibition
25–30 September 2010
Abu Dhabi, United Arab Emirates
Tel: 44 1273 625643
Fax: 44 1273 625768
E Mail: asayigh@netcomuk.co.uk
URL: www.wrenuk.co.uk/wrecxi.html

2nd International Photovoltaic Solar Energy
27–29 September 2010
Beijing, China
Tel: 86 10 87194-788
Fax: 86 10 87194-417
E Mail: ipvsee@solarpromotion.org
URL: www.ipvsee.com

Conference: 3rd Renewable Energy Finance Forum West
28–29 September 2010
San Francisco, California, US

Tel: 44 207 779 8995
Fax: 44 207 779 8946
E Mail: energyevents@euromoneyplc.com
URL: www.euromoneyenergy.com

Solar Power 2010
12–14 October 2010
Los Angeles, California, US

Tel: 1 202 857 0898
Fax: 1 202 682 0559
E Mail: info@solarelectricpower.org
URL: www.solarelectricpower.org

4th POWER Bangladesh 2010
14–16 October 2010
Dhaka, Bangladesh
Tel: 1 347 543 5543
Fax: 1 347 242 2657
E Mail: cems@cemsonline.com
URL: pv-expo.net

Solar Industry Conference (CIS-ES)
21–22 October 2010
Madrid, Spain
Tel: 49 30 72629630-0
Fax: 49 30 72629630-9
E Mail: info@solarpraxis.de
URL: www.solarpraxis.de

5th International Exhibition Energy-Photovoltaic '10
21–24 October 2010
Athens, Greece
Tel: 30 210 6141164
Fax: 30 210 8024267
E Mail: info@leaderexpo.gr
URL: www.leaderexpo.gr

PV Taiwan 2010
26–28 October 2010
Taipei, Taiwan
Tel: 886 2 2725 5200
Fax: 886 2 2725 7324
E Mail: pv@taitra.org.tw
URL: www.pvtaiwan.com

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Website: www.centrosolar.com

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Wholesaler for solar energy products

Head Office: Zeppelinstr. 10
D-82205 Gilching, Germany
E-mail: inlo@donauer.eu
Website: www.donauer.eu

Office Portugal/Spain: Nucle empresarial, Zona
Sul, Amazem 92, Quinta dos Estrangeiros
P-2665-601 Venda do Pinheiro, Mafra, Portugal
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Fax -2464
Website: www.genyalenergia.com

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Phone +49/8721/7817-0,
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Website: www.HaWi-Energy.com

IBC SOLAR AG

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Website: www.ibc-solar.com

PHOCOS AG

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D-89077 Ulm, Germany
Phone +49/731/9380688-0
Fax-50
E-mail: info@phocos.com
Website: www.phocos.com

SOLAR ENERGY INVEST N.E.S GmbH

Engineering, sales, financing, installation, and services of turn-key PV power plants, sale of components as well as off-grid solutions for every demand.

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Karlsruher Str. 12, 10711 Berlin, Germany
Phone +49-30-8973-1620, fax -1640
E-mail: info@solar-energy-invest.de
Website: www.solar-energy-invest.de

STECA GmbH

2A to 140A charge solar controllers for SHS, telecom, and hybrid systems. They specialize in stand-alone applications for rural electrification and industrial markets. Their product range also includes solar thermal controllers and prepayment systems.

Mammostr. 1, D-87700 Memmingen, Germany
Fax +49/8331/855811
Website: www.stecasolar.com

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Website: www.coveme.com

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Phone: +49-7347-67-201
Fax +49-7347-67-209
E-mail: solar@etimex-solar.com

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RENEWABLE ENERGY AT A GLANCE

S.No.	Source/system	Estimated potential	Achievement as on 31 March 2010
I	**Power from renewables**		
A	**Grid-interactive renewable power**	(MW)	(MW)
1	Wind power	45 195	10807.00
2	Bio power (agro residues and plantations)	16 881	861.00
3	Bagasse cogeneration	5 000	1338.30
4	Small hydro power (up to 25 MW)	15 000	2735.42
5	Energy recovery from waste (MW)	2 700	65.00
6	Solar photovoltaic power	—	10.28
	Sub total (A)	**84 776**	**16817.00**
B	**Captive/combined heat and power/distributed renewable power**		(MW)
7	Biomass/cogeneration (non-bagasse)	—	232.17
8	Biomass gasifier	—	122.14
9	Energy recovery from waste	—	46.72
10	Aero generator/hybrid systems		0.99
	Sub total (B)	**—**	**402.02**
	Total (A+B)	**—**	**17219.02**
II	**Remote village electrification**	—	5554 villages/hamlets
III	**Decentralized energy systems**		
11	Family-type biogas plants	120 lakh	41.85 lakh
12	Solar photovoltaic systems	50 MW/km^2	120 MWp
	i. Solar street lighting system	—	88297 nos
	ii. Home lighting system	—	550743 nos
	iii. Solar lantern	—	792285 nos
	iv. Solar power plants	—	2.39 MW$_p$
	v. Solar photovoltaic pumps		7247 nos
13	Solar thermal systems		
	i. Solar water heating systems	140 million m^2 collector area	3.25 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