Innovative Technologies for Energy Conservation in Food Processing

In order to decrease the energy costs, improvement in energy efficiency of existing systems is the main concern. For this, novel energy conservation technologies, such as computer control system, heat pump, refrigeration cycles, supercritical fluid processing, partial homogenization, non-thermal sterilization, pasteurization, micro-filtration pulse electrical field, high and low intensity UV, enzyme-based cleaners to improve CIP, heat pumping of waste process heat, electrolyzed oxidized water, have been introduced in food processing systems. Capital investments should also incorporate cutting edge, efficient technologies, and processes as the energy prices continue to increase.

Heat pump

Heat is transferred from a high temperature region to a lower temperature by nature, but through the thermodynamic cycle, the heat pump can transfer heat in the opposite direction, thus, operating like a refrigerator/air conditioner. When working matter changes its phase from liquid to gas by evaporation/boiling, it absorbs heat and releases heat when changes back from gas to liquid by condensation. The heat pump system can save up to 66% of the primary energy as compared to traditional systems. Heat pumps are used to increase the drying efficiency of convectional air dryers and can also be used to extract heat from a low temperature energy source, such as geothermal energy.

Heat pipes

Heat pipe consists of an evacuated metal tube, through which heat passes if there is a small temperature difference between its two ends. A certain amount of fluid is placed in the wick of inside of the tube and its one end serves as the evaporator while the other end is the condenser. Heat pipes can also be used to recover waste heat in various thermal operations.

Food irradiation

Irradiation pasteurizes the foods by exposing them to very high energy electrons, such as X-rays, electron beams, and gamma rays which are similar to light waves, ultraviolet waves, and microwaves but have shorter wavelength. As compared to thermal pasteurization, food irradiation is a more efficient pasteurization method for foods without causing significant effect on its quality attributes.

Pulsed electric fields

External electrical field application to a biological cell induces an electrical potential across the cell membrane and structural changes of cell membranes take place when electrical potential exceeds a critical level. At low temperature, pulsed electric fields treatment has the potential to retain fresh and high nutritional characteristics of foods. The main constraint for accomplishment and application of pulse electric fields is its high production costs to the traditional thermal process.

High-pressure processing

High-pressure processing inactivates the microbes by targeting membranes of the biological cells, and during pressurization, water and acid molecules show increased ionization which causes the major killing effect on living cells. The high pressure processing requires power to increase pressure and part of the power consumed is converted to heat for temperature increase due to pressurization.

Membrane processing

The separation processes in food processing systems play an important role for concentration, by-products recovery from waste water, contaminants removal from liquid foods, and treatment of wastewater. Membrane separation consumes lesser energy than traditional processes with or without involvement of phase changes. The membrane separation process has the potential to save energy up to 50% used by distillation and evaporation.

Supercritical fluid processing

Supercritical fluids such as supercritical carbon dioxide (CO_2) are used in food processing to remove moisture from foods. Supercritical CO_2 has a low critical temperature and pressure (31.1°C and 7.3 MPa), hence drying with supercritical CO_2 can be operated at a much lower temperature as compared to the conventional air drying system.

Microwave and radio frequency heating

Microwave and radio frequency are the widely used heating methods in

the food industry. Microwave energy is an electromagnetic wave with frequencies between 300 MHz and 300 GHz while radio wave is the rate of oscillations in the range of about 3 kHz to 300 GHz. The energy is transferred to the material in conventional heating through convection, conduction, and radiation. Energy saved through microwave and radio frequency heating is delivered directly to the product through molecular interaction with an electromagnetic and electric field.

Ohmic heating

Ohmic heating is a rapid and relatively uniform heating method, used in the food industry, in which electrical energy is converted to thermal energy. During ohmic heating, current is applied across the material and an increase in food temperature is caused by the heat generated inside an electrically conductive food material. It provides a rapid and uniform heating process and minimizes the losses of the structure along with the nutritional and quality characteristics of the food product. The electric energy of ohmic heating can dissipate heat up to an efficiency of 94% and this can be influenced by the conductivity of individual components within food and interaction behaviour.

Infrared radiation heating

Infrared radiation is an electromagnetic wave form of energy with more rapid heat transfer than conduction and convection. The major advantage of infrared over convective heating is its higher heat transfer coefficient and can be used to dry foods and deactivate bacteria on the surface of food products.

Strategies for Energy Conservation

Energy conservation is not just an environmental issue but it also helps to bring down the cost of production, and so, is vital for sustainable development of the food industry. Reduced energy consumption also benefits the society by reducing the use of energy resources and the greenhouse gas emissions. For sustainability, efforts must be devoted to not only discovering alternate energy resources in the form of renewables but also through energy efficient devices, processes, and technologies. Minimizing energy input and maximizing product output is possible by implementation of appropriate energy conservation strategies. The adoption of energy conservation methods and participatory approach are defined below:

Energy audit (EA)

Energy audit (EA) is an assessment, analysis, and survey of energy flows for identifying opportunities in energy conservation of any system to reduce energy input without negatively affecting the output.

Total quality management (TQM)

TQM is a management approach to integrate all organizational functions to focus on meeting customer needs and organizational objectives. It uses strategy, data, and effective communications to integrate the quality discipline into the culture and activities of the organization. The main principles of TQM are:

- Customer focussed integrated system
- Process-centred continual improvement
- Strategic and systematic approach
- Fact-based decision making
- Total employee involvement
- Communications

Automatic energy monitoring system

Automation system is used to automatically control the plant operations often used through networks to interconnect sensors, controllers, operator terminals, actuators, etc., to operate more efficiently and safely. Energy monitoring is a prerequisite for energy savings in the food industry as it involves the systematic and periodic monitoring of energy consumption and its dependent parameters. EF

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IMPACT OF CLOUDS AND ATMOSPHERIC AEROSOLS ON SOLAR ENERGY GENERATION

A COMPARATIVE STUDY OF INDIA AND FINLAND TO UNDERSTAND THE EFFECTS

Although solar panels will also absorb diffused and reflective light, peak energy production from PV systems is on sunny days. And, on days with cloud cover, the electricity produced would be below average. Clouds and clouds seeded with aerosols reflect a part of the Sun's incoming radiation back to space. **Sujit Kumar Tripathy**, **Sarvesh Devraj**, **Siddha Mahajan**, and **Dr Anders Lindfors** talk about a system to understand the impact of these to better forecast availability of incoming solar radiation.

India is a renewable resource-rich country. Over the last few years, with a strong support from the Central Government, the country has witnessed an unprecedented growth in green energy installation. With an ambitious target of 100 GW of solar energy deployment by the year 2022, India is looking forward to a future, when the contribution of power production from solar photovoltaic (PV) will be significant to the country's electricity supply. This necessitates development of robust forecasting methodologies for predicting solar resource availability considering the impacts of clouds and aerosols, which strongly influences Indian weather and climatic conditions. Accurate solar resource and hence, solar generation forecasting can lead to efficient scheduling, better load management, etc., hence, ensuring safety and stability of the Indian grid.

Unlike India, in Finland—a Nordic country with a yearly solar resource potential of around 900 kWh/m^2—the influence of aerosols on solar radiation is comparatively less due to cleaner sky conditions. Although the installed PV capacity in Finland is currently low, being around 10 MW,[1] a rapid increase is expected over the coming years. In Finnish conditions, short-term solar variability is mainly driven by varying cloud conditions. Hence, solar forecasts should focus on the correct prediction of clouds.

In India, wide spatial, temporal variation in different types and sizes of aerosols is observed, which influence the shape of solar spectrum reaching the ground. Aerosols usually attenuate radiation of short wavelengths more strongly than that of longer wavelengths. This affects energy generation, which further influences the performance of solar PV systems. The impact of aerosols on solar electricity generation is usually not accounted for while performing energy calculations. There is also a lack of studies that evaluate the impact of aerosols on spectral-level solar radiation and, hence, on solar generation.

'Influence of Clouds and atmospheric Aerosols on Solar energy in India and Finland (ICASIF)', a project funded by the Department of Science and Technology (DST), Government of India, and the Academy of Finland, and being implemented by The Energy and Resources Institute and the Finnish Meteorological Institute, investigates further into the relevant focus areas discussed before with an overall aim of providing improved information on the impact of clouds and aerosols on solar radiation and how the radiation transforms to electricity productions. This research study will be phased over a period of three years and will be carried out through six work packages (WPs).

In-situ Measurement and Analysis of Incoming Solar Radiation and Aerosols

This WP includes on-site measurement of aerosols and solar spectrum at different sites in India and Finland, covering locations with varying aerosol loading. The aim behind these measurements is to collect high-quality solar spectrum and aerosol datasets which along with radiative transfer models can be used to understand the role of aerosols in the variation of spectral irradiance. In India, three locations have been selected for measurement activities, namely Mukteshwar (a location with low aerosol loading), Gwal Pahari (a location with high aerosol loading), and Jodhpur (a location with moderate aerosol loading), while the measurements sites in Finland are Helsinki in the south and Pallas-Sodankylä Global Atmospheric Watch station in the north (Figure 1).

Currently, measurement activities at Mukteshwar and Gwal Pahari in India and Helsinki and Pallas in Finland are under way. Instruments such as Ocean Optics solar spectrometer, CAPS PMex Monitor, Optical Particle Sizer (OPS), Aethalometer, Differential Mobility Particle Sizer (DMPS) along with Condensation Particle Counter, Cimel Sun Photometer, Ceilometer, etc., have been deployed to measure solar spectrum; aerosol parameters, such as spectral distribution, aerosol optical thickness, aerosol/particle diameter, etc. (Table 1 and Figures 2 and 3).

Figure 1 Measurement sites in India and Finland

1 Karoliina A, et al. 2016. FinSolar: Aurinkoenergian markinat kasvuun Suomesa, Available from <https://aaltodoc.aalto.fi/handle/123456789/20264>.

Table 1 Instruments deployed under ICASIF project

Instrumentation	Manufacturers	Operation
Flame Spectrometer	Ocean Optics	Measurement of solar spectrum, 350–1000 nm range
CAPS PMex Monitor	Aerodyne research	Measures the optical extinction of solar radiation due to aerosols
CL-51 Ceilometer	Vaisala	Measurement of aerosols in atmosphere and cloud base height
Sun-Photometer	Cimel	Measures the aerosol optical thickness at selected wavelengths
DMPS	TSI	Measurement of particle concentration and particle size distribution present in the atmosphere
Aethalometer	Magee Scientific	Measurement of mass concentration of carbon black in air
OPS 3300	TSI	Measures particle size distribution in atmosphere.

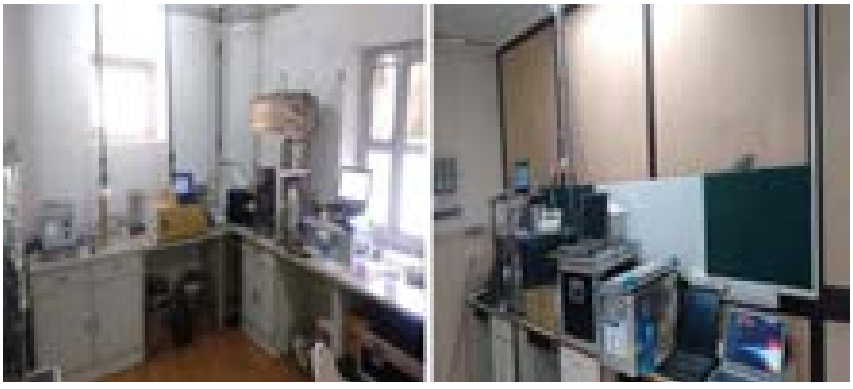

Figure 2 ICASIF measurement stations at Mukteshwar (Left) and Gwal Pahari (Right)

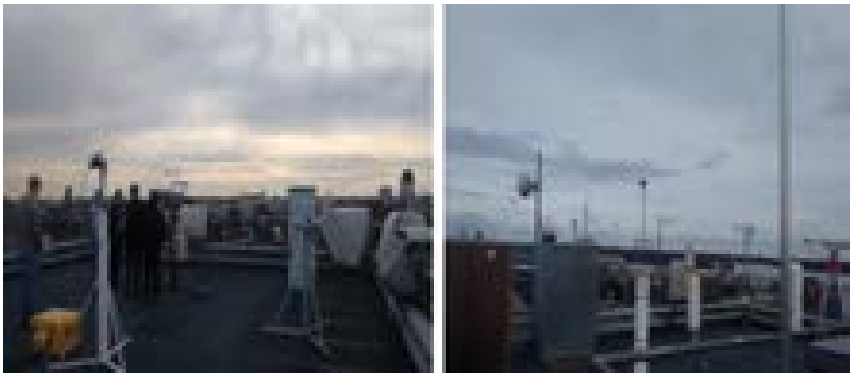

Figure 3 ICASIF measurement stations at Helsinki, Finland

The measurement activities at all these locations will be carried out for a minimum duration of six months, which will lead to a continuous, valuable solar spectrum, aerosol data base will be used for further work.

Improved Satellite Estimates of Solar Radiation over India

This WP aims to validate satellite-based shortwave radiation datasets over India against ground measured radiation data obtained from the meteorological measurement networks of Indian Meteorological Department. The satellite dataset to be validated is Surface Solar Radiation Data Set—Heliosat (SARAH) by Meteosat of EUMETSAT.[2] The focus is to perform statistical error analysis to determine satellite dataset quality over India. Also, the project intends to improve the satellite estimates over India by using radiative transfer modelling to better understand the effect of aerosols on solar radiation. Here, the aerosol information comes from the previous WP.

Forecast of Solar Radiation Based on Satellite-Observed Clouds

A method will be developed for forecasting solar radiation conditions a few hours ahead (typically one to two hours ahead forecast) using satellite-observed cloud information as input. First, it is intended to develop an algorithm for forecasting the cloud mask using high-resolution wind and cloud mask products by now-casting SAF (NWC-SAF) of EUMETSAT. Later, it will be combined with clear sky surface radiation values to obtain a surface solar radiation forecast. The method will be developed and tested for Finnish conditions, where clouds are the most important factor influencing short-term variability of solar radiation. The methodology will be later customized for Indian conditions.

Forecast of Solar Radiation with the use of Forecasted Aerosol Information

The idea is to use forecasted aerosol information of European Center for

2 Müller R, et al. 2015. Surface Solar Radiation Data Set - Heliosat (SARAH). Satellite Application Facility on Climate Monitoring. DOI:10.5676/EUM_SAF_CM/SARAH/V001. Available from <http://dx.doi.org/10.5676/EUM_SAF_CM/SARAH/V001>.

Medium Range Weather Forecast (ECMWF) along with radiative transfer models for predicting the spectral clear sky global horizontal irradiance (GHI) available for solar energy production at Earth's surface 1–2 days in advance. This work will be done for Indian conditions, where aerosol variations are strong and have an important impact on the availability of solar radiation. The forecasted GHI information will be validated against measured GHI values, and the forecasted aerosol fields of the ECMWF model will be compared to the measured aerosol properties.

Understanding the Influence of Variations in the Solar Spectrum on Solar PV Energy Output

The main purpose of this WP is to evaluate the impact of aerosols on solar spectrum and hence on solar PV generation. Installation of an experimental grid-connected PV system with Maximum Power Point Tracking at Gwal Pahari, Gurugram, is under progress. Generation values from this PV system will be logged and compared with the theoretical generation values, calculated using PV module characteristics (e.g., module efficiency, spectral response, etc.), radiative transfer model, and in-situ measured GHI values. Readings from devices, such as DMPS, OPS, Sun Photometer, etc., will be used to draw conclusion regarding impact of aerosols on solar spectrum and hence solar PV generation.

Future Availability of Solar Radiation

Considering the change in climate as well as atmospheric composition, this research study also intends to assess how solar radiation conditions are expected to change in accord with the climate change for various emission scenarios of the future. Future aerosol properties for 2020 and 2030, and the corresponding state of solar radiation reaching earth's surface, will be predicted using the ECHAM5-HAM climate model.[3] Outcomes from this WP may give us insight into aerosol emission from different activity sectors (household, industrial, and transportation), and how it can affect future climate and solar radiation. EF

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3 Stier P, et al. 2005. The aerosol-climate model ECHAM5-HAM, *Atmospheric Chemistry and Physics* 5: 1125–56. DOI:10.5194/acp-5-1125-2005, 2005.

NATURAL GAS
IS IT THE ALTERNATE FUEL?

Natural gas mainly consists of methane and is the cleanest option among fossil fuels. While it is not at par with renewable sources of energy, such as solar or wind, yet it is more readily available resource. Also to be fair, the renewable resources are still lagging behind in terms of installed base to completely replace fossil fuels. Energy resources, such as wind and solar, are also laced with challenges, such as intensive real estate requirements, government subsidies, etc. In this article, **Monika Paliwal** talks about the role natural gas can play in providing energy security while addressing climate change.

In our contemporary economies, energy sector is deriving its functional power from fossil fuels. According to the US Energy Information Administration's estimates even in the present scenario, fossil fuel supplies are contributing to approximately 86% of the world's energy. The major fossil fuels that contribute in the energy sector are coal, oil (petroleum), and natural gas. As study conducted by ExxonMobil (NYSE:XOM), one of the world's largest oil and gas firm, stated that it is only a matter of time until natural gas replaces coal as the main global energy source.

Reviewing Renewable Energy

Over the past few decades, heavy dependence on the fossil fuels has triggered a remarkable rise in our global temperature. This is one of the major reasons why we are looking for alternative energy sources, that is, the renewable sector. However, environmental pollution due to use of fossil fuels could be addressed by technocratic advancements in energy generation from fossil fuel as well.

Tremendous advancements have been made in the field of renewable energy sector and case studies have shown that cities can operate only on renewable energy. It is commonly observed that a few cities have set themselves as examples by positively demonstrating high dependency for energy generation on renewable sector, such as Reykjavik in Iceland, Vaxjo in Sweden, Copenhagen in Denmark, and Vancouver in British Columbia, Canada, to name a few. However, it is essential to be cautious before making the assumption that this can be immediately applicable at the global scale and a successful transfer of all our energy needs can be achieved from renewable energy sources only.

Are All Non-Renewable Energy Sources Equally Polluting?

In common parlance, all fossil fuels are inevitably considered as equally polluting. The various pollution generating characteristics of different fossil fuels need to be analysed; most importantly, that not all fossil fuels are equally polluting and there are technocratic advancements in our present fossil fuel driven power generation that have shown remarkable reductions in the pollution levels. All are aware that burning of coal causes smog, soot, acid rain, global warming, and toxic air emissions. However, burning of oil and natural gas is different in regards to their emissions. Natural gas is a fossil fuel, and yet, the greenhouse gas emissions that cause global warming from its combustion are much lower than those from coal or oil. As per data reflected by the National Energy Technology Laboratory in 2010, natural gas emits 50%–60% less carbon dioxide (CO_2) than coal. Comparison between natural gas, oil, and coal have shown that CO_2 emission from natural gas is 117 000 pounds of air emissions produced per billion Btu of energy, which is approximately half of coal carbon emission. Coal emits 208 000 and oil emits 164 000 pounds of air emissions produced per billion Btu of energy, respectively.

Although burning of natural gas at a power plant too produces nitrogen oxides and CO_2, the quantities of these pollutants emitted are lower than those produced by burning coal or oil. Also, emissions of sulphur dioxide and mercury compounds from burning of natural gas are negligible. On the other hand, methane a primary component of natural gas and a greenhouse gas, can also be emitted into the air when natural gas is not burned completely. Similarly, methane can be emitted as the result of leaks and losses during transportation. These leakages can be dealt with better harnessing technology and better extraction and transportation processes. Along with this, incomplete combustion of natural gas should be addressed.

Current State of the Energy Sector

There is a history of using fossil fuel in the energy sector, and a sudden change in the raw material of generating energy might not be a globally feasible solution. Developing countries, especially, shall require more time to make a complete shift, and then too, it may hamper its production market and perhaps cause

disturbances in their energy production, which will be reflected in its GDP. As pointed out in the Trader News Source article (November 15, 2016), 'the shift towards renewable energy and the diversification of supplies will create opportunities and threats for the global energy industry'. Trader News Source has also reported, 'renewable energy sources provide benefits such as the diversification of energy mix, but this brings a fresh challenge that shall require amendments in business models and regulatory policies'. Thus, the changes in energy sector are expected to take place; however, it shall be a multi-sectorial effort that will require time and technological upgradation. In this scenario, natural gas could act as a 'bridge' fuel between the fossil fuels and renewable energy sector.

In the present conditions, in order to reduce carbon emissions that are a key component in causing global warming, there is a need to look at alternatives available within fossil fuels, such as oil and natural gas. This shift is not going to adversely affect the market economies. On a technological level, it is an acceptable change and pollution emissions of natural gas are remarkably low. According to a statement by the Deputy Head of the International Energy Agency, the current wave of natural gas availability shall be harnessed and used by industries all over the world. This reflects that a shift from coal to natural gas will be a swift and acceptable move at the global scale.

Natural Gas

Natural gas is receiving its much deserved place in the energy sector because it can be transferred from the natural gas wells to markets via pipelines, reducing the transportation cost tremendously and also supplying a reliable and continuous flow in the energy supply. Over 95% of natural gas used in the United States moves from the well to market via pipeline. Natural gas pipeline networks include three distinct systems comprising a gathering system that carries natural gas from individual wells for bulk processing at a treatment facility. Second, a transmission system that carries the processed natural gas over long distances, at times even around a country. And last, a local distribution system that delivers natural gas into homes, businesses, and power plants to name a few. Natural gas pipelines are generally smaller in diameter than petroleum pipelines.

Natural gas usage in energy generation is the need of the hour as it addresses various issues related to reduction in pollution and causing less carbon emissions, a source of energy production wherein transportation cost is really negligible, alongside it requires less changes in the energy generation process. One of the prime problems associated with natural gas is the issue of leakage, and if leakages are successfully reduced, natural gas will be the least polluting fossil fuel. According to the Climate and Clean Air Coalition estimate, over 8% of the total worldwide natural gas production is lost annually due to venting, leakage, and flaring.

Harnessing Natural Gas

Here, it is important to discuss the commonly known nuances related to natural gas extraction. Usually natural gas is produced as a by-product of

oil extraction. However, when oil and natural gas extraction presents a safety issue, one has to follow either venting or flaring of the natural gas in order to avoid any accident. These are wasteful practices that lead to pollution and unambiguously contributes to climate change as well as causes losses in revenue and waste of the recovered resource. Flaring is the practice of burning gas that is considered uneconomical to collect and sell. This is because of either its quality is not of an optimum level that would get buyers or its quantity is not feasible to extract and at times a combination of both factors. Flaring is practiced by burning gases as a precautionary measure to avoid any further damage. There are evidences that show flaring is better in comparison to the emissions of VOCs (volatile organic compounds) and HAPs (hazardous air pollutants) as they are reduced to 29 tonnes and 1 tonne, respectively. On the other hand, flaring natural gases result in the release of more than a tonne of nitrogen oxides, and almost half a tonne of carbon monoxide per well. According to United Nations Environment Programme, 'Working to Reduce Methane and Black Carbon' these activities collectively result in nearly 2 Gt of CO_2 equivalent of greenhouse gas emissions per year.

However, there are technocratic solutions to this issue in the form of flare-less or 'green completions', which is a practice to reduce the pollution related to harnessing natural gas. In this process, fluids and solids are separated with the help of heavy-duty separators, also known as 'flow-back units'. Through this process, flaring and venting can be avoided while increasing revenue and reducing loss of a resource because the gas is either cycled back through the well bore or sent directly for consumption with the help of pipelines.

Moving towards CNG Usage

Natural gas in the form of compressed natural gas (CNG) is considered as a preferable fuel alternative to petrol and diesel. In contemporary times in India, CNG is seen as an effective measure to curb rising air pollution. The National Green Tribunal has been established for effective and expeditious disposal of cases relating to environment. In September 2016, a bench headed by NGT Chairperson Justice Swatanter Kumar had asked Uttar Pradesh and Haryana governments to contemplate the possibility of installing CNG stations in the National Capital Region (NCR). This step was taken towards improving air quality in Delhi-NCR. The National Green Tribunal has further added weight to it by warning to halt state transport of northern states that surround the capital if they did not introduce CNG, stating that most particulate matters in the air inhaled by Delhi residents are originating from outside Delhi.

State governments have also moved towards CNG application in vehicles to improve air quality. The Delhi Government in June 2016, as it explored options to curb pollution, launched a programme to run two wheelers on CNG. This programme is being implemented by Indraprastha Gas Limited (IGL) and one of its parent companies, GAIL (India) Limited. Under this programme, these two wheelers are expected to be 40% more economical than the petrol ones. The performance

of 50 CNG retrofitted two wheelers would be monitored during the pilot phase and the learnings from the project would be used to develop the roadmap for introduction of CNG in two wheeler segment across the nation. As per the idle emission test, hydrocarbon emission from CNG-retrofitted two wheelers are 75% lesser and CO emissions are 20% lesser than petrol-driven models. Such endeavours are steps moving in the direction for cleaner fuel such as natural gas. Perhaps natural gas is emerging as the most preferred alternative.

At present, CNG Retail Outlets of GAIL and its joint ventures are available in the states of Delhi, Maharashtra, Uttar Pradesh, Gujarat, Andhra Pradesh, Tripura, and Madhya Pradesh in India. They are a total of 386 CNG Retail outlets. These are successfully catering to more than six lakhs vehicles. GAIL (India) Limited has currently 16 CNG outlets at Dewas, Sonepat, Kota, Meerut, Vijaipur, Dibiyapur, Firozabad, and Panvel. It will be commissioning other outlets very soon. A joint venture of GAIL Gas and Vadodara Mahanagar Sewa Sadan has nine CNG outlets in Vadodara. These figures are representing the transfer of fuel sources from diesel and petrol towards a cleaner fuel that is CNG.

Daily Uses of Natural Gas

There are many successful implementations of natural gas in our day to day life. One household example is that of PNG (piped natural gas) in Delhi-NCR. Also known as 'positively natural gas', it has gained a tremendously popular place in every household since its inception in 1998. According to IGL (Indraprastha Gas Limited) Annual Report, in the year 2015/16 average sale per day of PNG is 4.00 mmscmd (million standard cubic metres). As it is an alternative to cylinder supply of LPG (liquefied petroleum gas), which had various issues related to safety and security along with accessibility because it was difficult to carry heavy cylinders for day-to-day utilization. Thereby, availability of PNG has provided an immediate solution to these problems, and it is well reflected by the data on number of new connections every year. During the year 2015/16, there were 46 229 PNG connections in Delhi and 29 337 PNG connections in the NCR, and the total number of connections went up from 560 752 in March 2015 to 636 318 in March 2016. This is accompanied by some tremendous efforts to avert any accidents due to leakage by providing an immediate customer support, whenever needed. Significantly, PNG supply in Delhi has crossed 87 million man hours accident free till March 31, 2016. Thereby on a household level in Delhi NCR, natural gas is now widely accessible and has till now low cases of accidents related to leakages.

Natural gas has revamped electricity production wherein coal-based power plants are now shifting to power plants run on natural gas. Pragati Power Station in New Delhi is 330 MW combined-cycle gas turbine power project. Emission of oxides of nitrogen (NO_x) has been limited to 35 ppm, which are operating at a scale that is considered as one of the lowest in the country, for which special technology is used by installing dry low NO_x combustors. It is a functional example where adaptation of technocratic amendments is showing positive results in reducing polluting emissions within an accepted time scale.

According to studies conducted by the Intergovernmental Panel on Climate Change in 2014, natural gas has lower particulate matters emissions. This is important for cities such as Delhi where $PM_{2.5}$ and PM_{10} has recently in October–November 2016 caused various problems related to health and visibility. Natural gas has much lower CO_2 emissions, which is considered responsible for global climate change together with other greenhouse gases. Alongside, it has much lower sulphur dioxide (SO_2) emissions, which is a prime causal factor responsible for acid rain. Nitrogen oxides (NO_x) emissions are highly responsible urban smog and emission of these are lower. The low-carbon property of natural gas has a beneficial effect in reducing pollution and offers more energy per unit of CO_2 emitted than coal or oil. Invested with the contemporary advancements in technocratic level, such as combined cycle gas turbines (CCGT) and combined heat and power (CHP), these plants run at higher thermal efficiencies and result in half amount of CO_2 emitted per kWh generated by CCGTs.

Successful combinations of power plants working in collaboration with natural gas and renewable energy systems are both operational along with low environmental costs. These combinations have the potential to deliver integrated solutions for residential and even commercial sector. For the residential market, solar applications are becoming increasingly available and utilized; this can be successfully complimented by natural gas as a companion fuel. On these grounds, natural gas can act as a companion fuel and play a key role in the transition to a low-carbon emission energy provider.

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The SOLAR QUARTERLY

The Sun is Definitely Rising But Will it Shine?

A peek into the challenges facing the solar industry

Solar tariffs in India have continued to fall during the last 2–3 years, almost reaching grid-parity levels. Claims of reaching coal-parity in a not-too-distant future are no longer considered blasphemous. Thus, it seems that the key question is no longer how low the solar tariffs can go but how quickly? Are these falls in tariffs sustainable? Will such low tariffs propel growth? Are lenders financing these projects? What are the risks in the industry? These are some of the key questions in the mind of stakeholders who are either present in the solar industry or evaluating entry into this industry. In this article, **Rahul Gaba** and **Gurpreet Chugh** describe the key drivers of solar tariffs, explore how low the tariffs can go, gauge what risks the industry is facing, and caution on what can de-rail this growth.

The total installed power capacity in India stood at 301 GW in March 2016, of which renewables form 14% and solar forms a mere 2%. India's current per capita consumption of electricity is 900 kWh/annum compared to 2200–3500 in Eastern European countries and 5000–6500 in Western European countries. India is a growing economy and electricity demand is expected to rise significantly over the next two decades as more and more consumers get electricity access and the standard of living improves. While India may still not reach parity with Eastern Europe per-capita consumption by 2030; nonetheless, increasing demand for electricity will require significant new capacity additions and the total installed capacity is expected to reach 467 GW by 2022 and 730 GW by 2030. In order to grow sustainably, the Government of India has embarked on an extremely ambitious, renewables-fuelled growth strategy with a target of achieving 100 GW installed solar capacity by 2022. If India does indeed deliver on these aggressive renewable energy (RE) targets, solar power will comprise 21% of the installed capacity in 2022 compared to only 2% today (Figure 1).

Solar Scale Up in India

Such phenomenal growth aspirations are great news for the Indian and global solar community alike as India will possibly provide the fastest growing market for products and services in the solar Industry. This is one of the biggest reasons why we have seen rapidly falling solar tariffs in India as more and more global and Indian companies have identified this potential and want to get in early. Some international companies have also paid entry premiums and bagged projects at low tariffs to get a foot in the door.

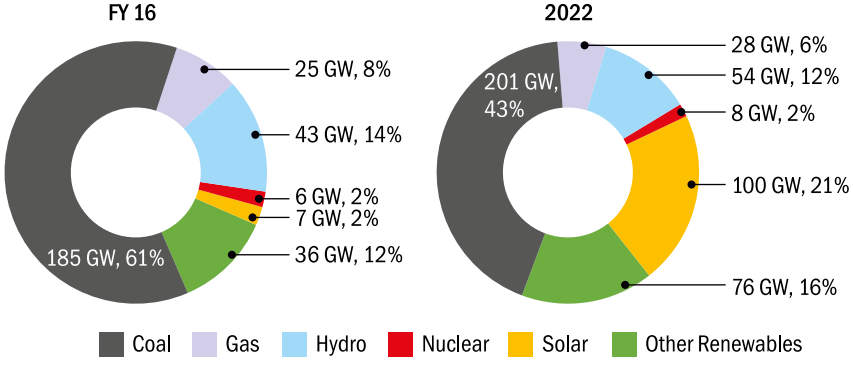

Figure 1 Installed capacity mix in GW(all-India) in FY 2016 and expected in 2022

Since the inception of National Solar Mission in 2010, various policy measures, such as accelerated depreciation, viability gap funding, renewable purchase obligation, etc., have been adopted by the Government of India to support solar sector growth. Such measures along with reverse tariff mechanism for bidding resulted in rapidly falling tariff bids. Overall, as the installed solar capacity grew eight fold during the last five years, it was accompanied by drop of 72% in tariffs (Figure 2).

What this means is that the cost of power from new solar plants in India today is comparable to that from a hydro-power plant and lower than that from a LNG-based power plant (even when LNG prices are at historical lows) (Figure 3).

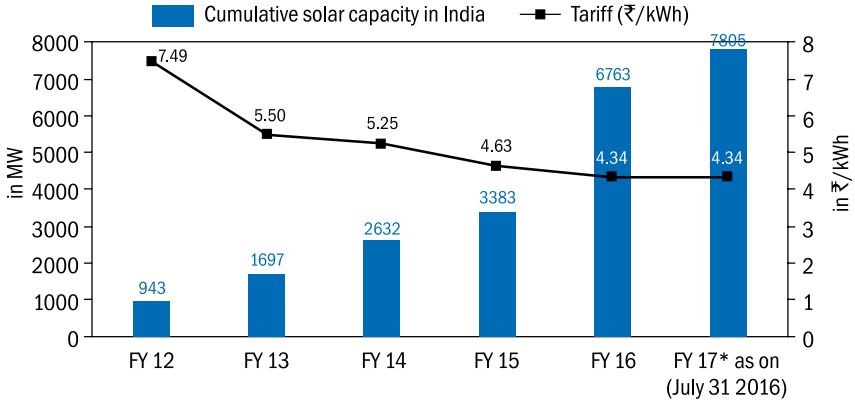

Figure 2 Increasing solar capacity accompanied by reducing tariffs

Source: CEA, MNRE + Business intelligence reports

Global Trends

The trend of falling solar tariffs is not unique to India. Low tariffs in reverse auctions are being witnessed around the world. Tariff benchmarks across North America, Latin America, and Middle East too have witnessed a downward trend, and tariffs fell by more than 50% between the global lowest in 2013 (for a project in New Mexico, USA) and the global lowest in 2016 (for a project in Dubai, UAE). Conspicuously, the lowest solar bid in India is still considerably higher than the global lowest—₹4.34/kWh (Rajasthan 2016) is double of ₹2.01/kWh (Dubai 2016) (Figure 4). These bids cannot and should not be compared simply because the key factors, such as incentives, land costs, currency hedging, cost of capital,

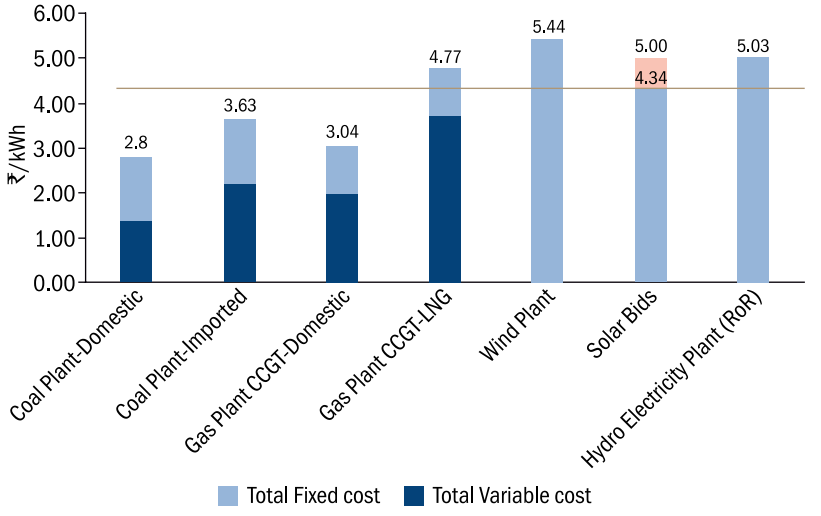

Figure 3 Comparison of cost of power from different sources

Source: ICF analysis

solar radiation is a critical factor as it impacts the project viability and tariffs significantly. A 1% increase in CUF can lead to a reduction of about 0.20–0.25 ₹/kWh in tariff. Consequently, the states with higher irradiation levels, such as Rajasthan, have seen lower bids on average compared to states with lower irradiation levels.

The highest cost item in a photovoltaic (PV) solar project is the PV module (>50% of the total Capex). Given the small scale and high cost of solar PV cell and module manufacturing in India, these components have increasingly been sourced from global markets, mainly China and Taiwan. Globally, the module prices have fallen drastically over the last few years primarily due to

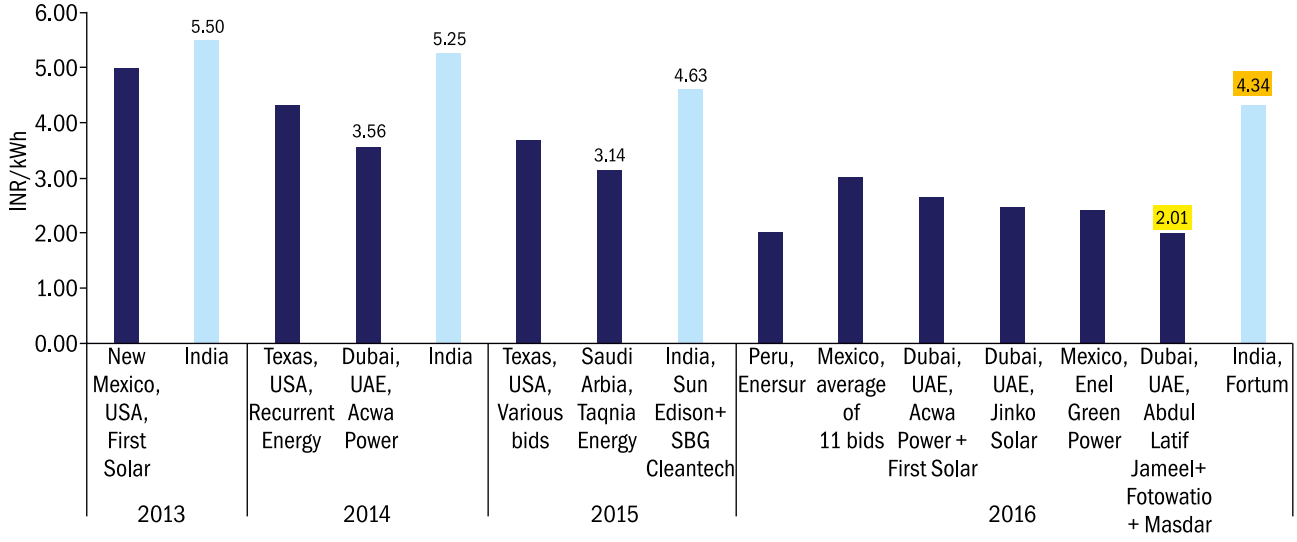

Figure 4 Annual lowest solar bids: Global vs. India

and other project risks vary widely from country to country. However, it is important to understand the global wave that the solar Industry is riding on and assess how this might impact the global risk appetite and also the bidding for projects in India by the same entities that are bidding globally.

Factors Impacting Solar Tariffs

Some of the key factors that impact the solar tariff bids in India include project-related technical aspects, financing aspects, and overall commercial viability of the deal (Figure 5).

While all of these factors (and others) are critical to understand for arriving at the tariff, some of them are more important than the others. For instance, falling poly-silicon prices that fell from $475/kg in 2008 to $17/kg in 2014. This fall in poly-silicon prices coupled with increase in demand for modules and establishment of the global supply chain led to falling module prices. Further,

Project technical aspects	Costs and financing aspects	Overall commercial viability
• Solar irradiation • Whether inside solar park	• Capex and opex • Debt cost • Equity cost and expected IRR	• Buyer credit worthiness • Curtailment risk

Figure 5 Key drivers for solar tariffs in India

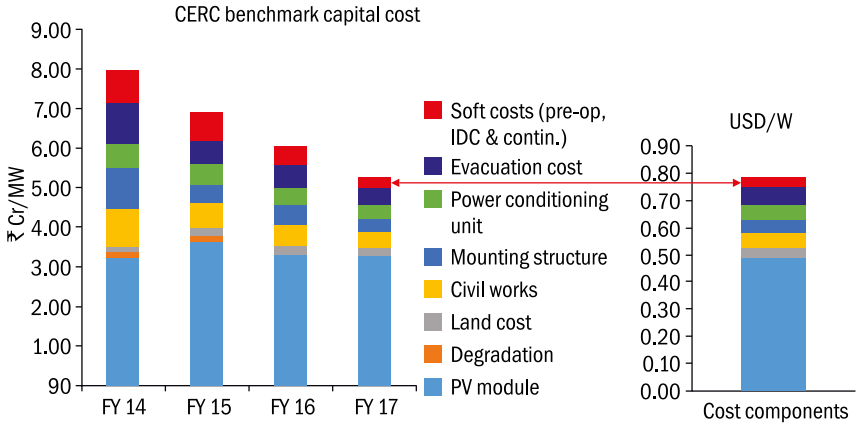

Figure 6 CERC benchmark solar project capital cost FY 17

Tariff optimization while bidding—An illustration

To illustrate how developers look at tariffs while bidding, we will take the CERC capital cost benchmarks and suitable O&M costs for a 100 MW solar project in a state where 19% CUF is possible, say Jharkhand. We assume 70:30 debt:equity financing with debt cost at 11.50% and cost of equity at 15%. With these assumptions, the project can be viable at a tariff of ₹5.25–5.35/kWh over the project life of 25 years. With this base tariff, we further evaluate the impact of optimizing different elements.

The first parameter is the capital cost. While the CERC benchmark cost assumes modules available at $0.50/W, there have been deals where project developers have been able to source Tier 1 modules at lower costs of $0.45/W and even at $0.40/W. A reduction of 10 cents in module prices can lead to a tariff reduction of ₹0.55–0.60/kWh. In case the project is in a state with higher radiation that can lead to 20% CUF (say Telangana or Rajasthan), the tariff can be reduced by ₹0.20–0.25/kWh.

Next, with a strong project promoter balance sheet, the debt may be available at lower rates and 10.5% interest rate is a possibility with refinancing on project completion. This can further lead to a tariff reduction by 0.15–0.20/ kWh. Figure 7 shows some of these optimizations that further impact the base tariff as a cascade of reductions.

In addition, innovative financing structures are being experimented, such as long-term equipment financing, parent company support, solar PV financing, and others. These structures are enabling bidders to further optimize their cash flows by reducing upfront cash outflow thereby increasing return on equity and providing further opportunity to bidders to reduce day 1 tariff bids. Similarly, strategic tie-ups between module suppliers and developers can offer symbiotic relationships to be leveraged.

In addition, alternate tariff models by bid-inviting authorities, such as providing annual escalation, clauses can present additional routes for day 1 tariff reduction.

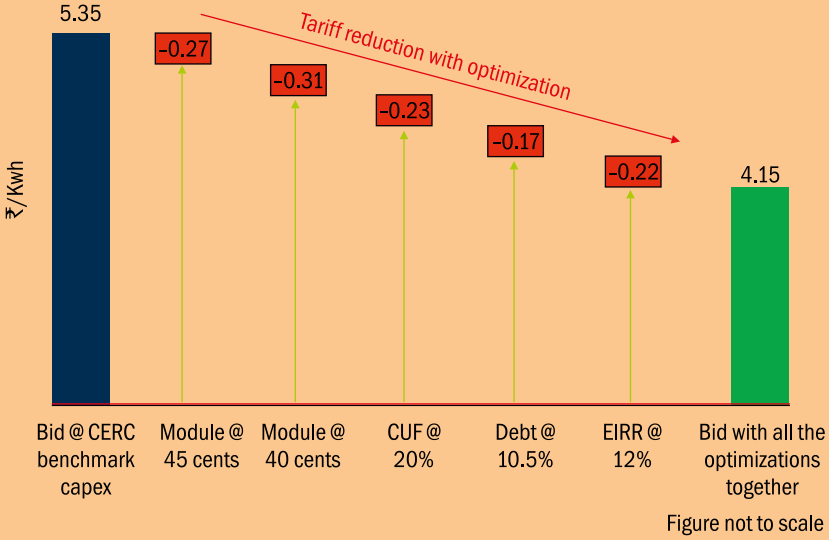

Figure 7 Tariff bid optimization cascade

Source: ICF analysis using ICF-SBM (Solar Bid Model)

in Asian markets, the module prices are significantly lower than in Europe and North America. This is due to the anti-dumping duty on Chinese modules in European Union and North America, which has led to a lot of Chinese modules coming to India at very low prices during the last year. Such low prices for modules had a significant impact on reducing the tariffs being bid for projects.

The next important factor leading to low tariff bids has been the reducing BoS costs in India, which have dropped significantly during the last few years. According to CERC annual estimates contained in the benchmark tariff orders (Figure 6), BoS costs have fallen by 50% during the last four years. Overall, falling Capex has played a significant role in reducing the tariffs being bid for projects during the last few years.

So What Could Eclipse the Solar Growth?

As the solar capacity builds up and more and more projects are developed,

it will result in injection of a significant amount of variable solar power into the grid. In case India is indeed able to install 100 GW of solar by 2022, it will require to ramp up and ramp down requirement of 15–18 GW per hour to balance solar alone. Under such circumstances, it will become critical to ensure that balancing power is made available through variable generation sources, such as pumped hydro, open cycle gas, or other energy storage solutions. There is need for very detailed hourly modelling to understand the requirement of such variable power at state level and undertake advance planning. Such planning would require coordinated response on policy, market, infrastructure, and investments in variable generation assets. The second critical risk will be buyer creditworthiness. Ensuring financeable power purchase agreement terms and enhancing creditworthiness of ailing DISCOMs through innovative payment security mechanisms will be essential to ensure that the RE capacity addition does not falter midway. A strong step has been taken with Ujwal DISCOM Assurance Yojana (UDAY), but it will be equally important to ensure implementation of the measures identified in UDAY especially on loss reduction, energy efficiency, and tariff filing.

Overall there is a strong potential for growth of solar power in India, and this presents an exciting opportunity to domestic and international investors. Many investors have already entered or are close to entering the solar value chain and have aggressive plans for ramp up. Capital will be available from both domestic and international sources. Likewise, technology and human capital too can be quickly ramped up to support this growth. The only factor determining how much of this promised growth materializes will be the ability and willingness of DISCOMs to buy this clean power and integrate the variable nature of this power into the grid. EF

Mr Rahul Gaba and Mr Gurpreet Chugh, ICF international. Email: Gurpreet.Chugh@icfi.com

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INTERSOLAR INDIA 2016

With events spanning four continents, Intersolar is the world's leading exhibition series for the solar industry and its partners. It unites people and companies from around the world with the aim of increasing the share of solar power in our energy supply. Intersolar India is the country's largest exhibition and conference for the solar industry. The event's exhibition and conference both focus on the areas of photovoltaics, PV production technologies, energy storage systems, and solar thermal technologies. Since being founded, Intersolar has become the most important industry platform for manufacturers, suppliers, distributors, service providers, and partners in the global solar industry.

With 25 years of experience, Intersolar has the unique ability to bring together members of the solar industry from across the world's most influential markets. Intersolar exhibitions and conferences are held in Munich, San Francisco, Mumbai, São Paulo, and, starting in 2016, in Dubai. These events are complemented by the Intersolar Summits, which take place in emerging and growing markets worldwide.

Since Indian Prime Minister Shri Narendra Modi declared energy a top priority, the Indian market has been showing great momentum. By 2022, the country aims to achieve an installed photovoltaic capacity of 100 GW. The country has ambitious goals, and the atmosphere in India is one of radical change. This year Intersolar India gave the industry a significant boost and offered the perfect opportunity to discuss upcoming steps, opportunities, and challenges.

Intersolar India was officially inaugurated by Dr Robert Habeck, Minister of Energy, Agriculture, the Environment and Rural Areas for the German state of Schleswig-Holstein. He praised the development of India's renewable energy industry and emphasized that exhibitions such as Intersolar India help to achieve

Intersolar India—India's largest exhibition and conference for the solar industry—was held at the Bombay Exhibition Centre in Mumbai, October 19–21, 2016. The positive development of the Indian solar market was noticeable at the exhibition. The number of visitors was 10% higher than at the previous year's event, and the number of exhibitors increased by an impressive 20%. Businesses and investors made the most of the opportunity to network, and numerous agreements and collaborations were initiated. The organizers also reported positively on the conference, where around 800 attendees discussed India's solar industry with 122 speakers.





ambitious goals, as they act as an industry platform and bring together all of the key stakeholders.

Smart renewable energy, which refers to the combination of energy generation, storage, grid integration, and energy management, was a very popular topic at the exhibition and sparked animated debate at the exhibition forum in particular. At the session 'Smart Renewable Energy: Microgrids—Serving Unconnected Remote Village Communities to Grid Connected City Consumers', experts shared their experiences of bringing electricity to small villages through microgrids. The latest developments in the industry were presented at the session 'Smart Renewable Energy: Electrical Energy Storage (ees)—What are India's Drivers for ees Solutions?'

Shared Booth HUSUM Wind India

This year also marked a first for Intersolar India: the debut of cooperation with the internationally renowned exhibition HUSUM Wind, which proved to be a great success with the exhibition guests. The shared booth gave visitors the opportunity to learn more about wind energy and its implementation in the Indian market. There was a lot of interest, as numerous Indian firms operate in both the solar and wind power sectors.

Lively Discussions at the Intersolar India Conference

The accompanying conference took place in parallel on October 19 and 20, 2016. A central topic was private and industrial rooftop systems. In the session 'Commercial & Industrial Rooftop Systems—Field Experience in India', Dr Nalin Shinghal, Chairman and Managing Director of Central Electronics Ltd, explained that rooftop systems will achieve grid parity in the near future. This is an important step, since although India plans to install 40 GW of solar capacity on private rooftop systems, its current capacity is just 800 MW. Sukesh Kumar Jain, Power Secretary for the Government of the National Capital Territory of Delhi, told the session titled, 'Residential Rooftop Systems—System Design and Field Experience in India that the city will play a central, pioneering role. By 2020, he said, 1 GW of private rooftop systems should be installed there, with a further GW installed by 2025. There was also discussion around the challenges facing the expansion of private rooftop systems. Arvind Karandikar, Managing Director at Nexus Energytech Pvt Ltd, mentioned that the financing of these systems must be structured more simply and that business models in this area need better support.

ees India

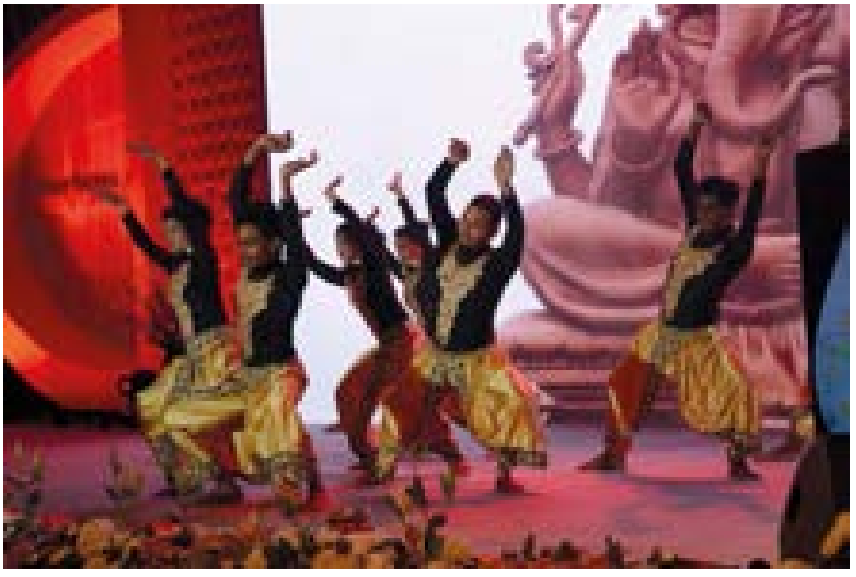
In 2016, ees (electrical energy storage) India again took place in parallel to Intersolar India. At the companies' booths, numerous visitors learned more about the energy storage sector. This event complements the exhibition perfectly because batteries are essential for India's journey to a renewable future. EF

PETROTECH-2016

Petrotech-2016—the 12th International Oil & Gas Conference & Exhibition—was hosted by the Ministry of Petroleum and Natural Gas, Government of India, in New Delhi from December 5–7, 2016. The Petrotech series of international Oil and Gas Conference and Exhibition provides a platform for national and international experts in the oil and gas industry to exchange views and share knowledge, expertise, and experiences. The theme of this year's conference was 'Hydrocarbons to fuel the future—Choices & Challenges'.

The Minister of State (I/C) for Petroleum and Natural Gas, Shri Dharmendra Pradhan inaugurated the Petrotech 2016 Exhibition at Pragati Maidan, New Delhi. The Petrotech-2016 Exhibition witnessed participation of nearly 600 exhibitors from over 50 countries covering 15 000 m^2 of exhibition area. This year's Exhibition is much grander in scale with participation from more overseas companies. The exhibition continued from December 4–7, 2016.

Inaugurating the exhibition, Shri Pradhan said that it provides a convergence point to every element, dimension, product, technology to congregate at one point and there has been enthusiastic response from various stakeholders. It also offers a unique platform to the international companies, service providers, and technology companies to have interface with all India stakeholders at one place. Over the years the oil & gas sector has played its part in making energy affordable and accessible through the length and breadth of the country in driving the Indian economy in terms of generating employment, skill development, bringing in FDI, enhancing trade, and boosting strategic partnerships. He added that discoveries of better technologies are regularly transforming the sector, which offers opportunities for those who are ahead of the curve but



also pose challenges to companies who follow conventional approach to this dynamic subject.

The Petrotech 2016 main Conference was inaugurated by the Honourable Prime Minister of India, Shri Narendra Modi on December 5, 2016. Speaking at the event, PM Modi said "Indian economy is expected to grow five times by 2040" and energy is one of the most important drivers of this growth. "Sustainable, reasonably priced energy is crucial for development," he added.

The Ministerial Session on Day 1 saw participation from Afghanistan, Bangladesh, Bhutan, Brazil, Mauritius, Nigeria, Qatar, Sri Lanka, and Nepal. The delegates shed light on oil and gas energy scenario in their respective countries, favourable policies, etc. Plenary session 'Uncertain Oil Prices' captured the crude oil price debacle in terms of risks, uncertainties, potential opportunities, and damages.

Speaking at the session 'Natural Gas: The Road Towards Cleaner and Prosperous Future', Ms Mary Hemmingsen highlighted the role of Gas in clean energy systems. She spoke about the prospects of gas being the cleaner fuel choice for power, transport, and chemical. This year, the Petrotech broke away from tradition to give due focus to 'Alternative Energy'.

On the last day, 11 MoU were signed, including a consortium agreement between IOCL, BPCL, and HPCL, intending to set up India's biggest oil refinery cum petrochemical complex with a ~60 MMTPA capacity along the western Coast of India in Maharashtra and for setting up five 2G ethanol plants in various parts of the country. Union Ministers Shri Nitin Gadkari, Shri Piyush Goyal, Shri Anil M. Dave, and Shri Dharmendra Pradhan were present during the ceremony. Portals were also launched by ONGC, OIL and IOCL under 'Start-Up India'. The initiative aims at fostering entrepreneurship and promoting innovation by creating an ecosystem that is conducive for growth of start-ups. The last day also witnessed books and knowledge papers being launched.

The Union Finance and Corporate Affairs Minister Shri Arun Jaitley presented the Petrotech-2016 awards on the last day of the conference. The Minister of State (I/C) for Petroleum and Natural Gas Shri Dharmendra Pradhan was also present on the occasion. Speaking at the occasion, Mr Jaitley said that the volatile prices in this sector and its impact of economies is a matter of continuous concern. He further added, "This sector holds a major position in Prime Minister Shri Narendra Modi's vision to provide sustainable, reliable, and reasonably priced energy."

It was also announced that Petrofed and Petrotech Society will be merged and next Petrotech will be organized by the new entity 'Federation of Indian Petroleum Industry'. EF

TAPPING THE SUN TO MEET INDIA'S SOLAR TARGET

India has made a commitment of 100 GW from solar in its INDCs. To meet this target, the solar projects are coming up at a much faster rate than ever before. **Nandit Bindal**, Director, Sun-Tap Solar Projects (P) Ltd, in an email conversation with **Abhas Mukherjee** tells *Energy Future* about being a leading solar project developer and EPC.

We have read that yours is 'India's Largest Solar Ramming Contracting Company'. Please share your thoughts on this.

Yes, we are India's largest solar ramming contracting company; we have catered to more solar ramming contracts in India than all other contractors combined in the year 2014/2015. We are also the largest capacity owners of solar ramming equipment.

SunTap collaborated with Spanish Company, TIF Energy, and came together as Sun Tap TIF Energy. Could you please throw some light on this collaboration, and the various projects that you have successfully completed under this association?

Under the association with TIF, we have completed a good number of large utility scale solar projects. We have catered to more than 500 MW of solar projects in India and are growing at a fast pace.

To name some of our marquee projects, we have rendered our services to 100 MW Acme solar plant in Bap Rajasthan, 100 MW Adani solar plant in Punjab, 5 MW solar plant at T3 Delhi Airport, over 40 MW done for Punjlloyd in Punjab, 24 MW Sunedison in Phalodi, Rajasthan, 25 MW for Ajanta Pharma in Gujarat, and many more.

Also tell us about the work done by your company in the domain of solar rooftops for industries.

We have installed three solar rooftop projects of 100 kW each in Rajasthan, and we are keen on strengthening our presence in rooftop segment.

Rooftop solar systems have a very high return if used as captive plants for industries and commercial institutions. Clubbed with accelerated depreciation and net metering, they are the low-hanging fruits that will enable the adoption of solar power in industries and commercial institutions at a rapid pace.

You specialize in providing foundation solutions, that is, ramming/screwing for solar posts on contract. Kindly elaborate more on this for our readers.

Utility scale solar grid-connected projects are spread over a large land area and need a large number of foundations to be installed in a very short span of time.

For instance, a 100 MW project will need approximately 500 acres of land and over 60 000 foundations to be installed within 3 months. In such cases, traditional concrete piling techniques are very slow, costly, and difficult to manage. Use of concrete and traditional piling is also difficult in remote areas as there is shortage of skilled manpower, and these areas have lot of local issues. Therefore, we offer innovative foundations such as rammed piles and screw piles, which are cost effective, fast, and easy to install. They do not need much manpower and have a machine-based process.

In case of a machine-based process, we do not have any of the aforesaid issues, as only limited manpower is used.

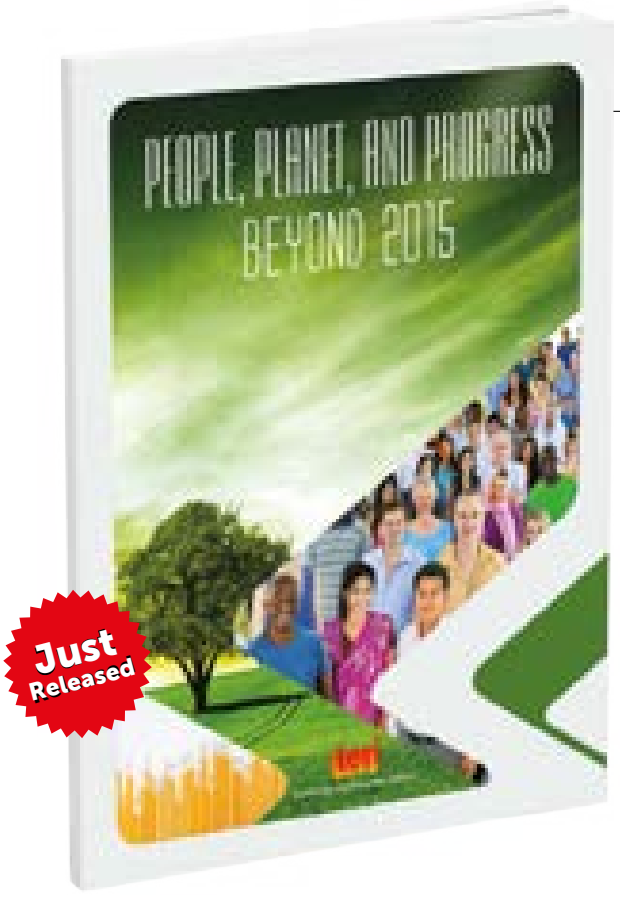
What have been your most successful and satisfying projects so far?

We feel the Delhi airport 5 MW solar plant is the most satisfying project so far owing to its location, which is just adjacent to a runway in Delhi airport.

Finally, would you label yourself an environmentalist?

Anyone who is working in the renewable energy field is enabling renewable energy adoption is helping the world save our environment; therefore, he/she can be called an environmentalist. However there are too many people who are doing greater things to protect the environment and who are really innovating on the technology front to help us preserve it, for instance Elon Musk; so it is better if we label them as environmentalists so that the benchmark is higher. EF

"An analysis of how the progress of people has impacted the planet"



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CURRENT R&D SOLAR

Economic and Environmental Effectiveness of Renewable Energy Policy Instruments: Best Practices from India

Renewable and Sustainable Energy Reviews, Volume 66, December 2016, Pages 487–498

Sapan Thapar, Seema Sharma, Ashu Verma

Renewable Energy (RE) has been identified as a key tool to counter climate change and enhance energy security. Countries across the globe have been promoting this sector by several policy measures. However, limited research has been undertaken on the economic and environmental efficacy of RE policy instruments, especially in context of emerging economies such as India, which have witnessed substantial capacity addition and have set ambitious targets to de-carbonize their economy. This paper identifies 25 innovative practices followed in India that have enabled accelerated RE capacity addition with minimal financial obligations. These include energy entrepreneurship, energy democratization, private sector participation, hedging and apportioning RE procurement, use of auctions with stringent participatory norms, creditworthy counter-party, leverage of risk capital by developmental institutions, regular revision of tariffs, environmental cess on polluting industries, long-term RE purchase trajectory, and incentivizing green power output. Results indicate high financial impact of instruments (support of US$ 3–5/MWh over applicable tariff), which gets neutralized when tax inflow is considered. Lower carbon abatement cost (US$ 3–6/tCO_2eq) depicts high environmental efficacy. The paper shares best practices from India in terms of efficient use of RE policy enablers, which may be contextualized in other emerging economies as per the local requirements.

Financial Attractiveness of Decentralized Renewable Energy Systems—A Case of the Central Himalayan State of Uttarakhand in India

Renewable Energy, Volume 101, February 2017, Pages 973–991

Mohammed Yaqoota, Parag Diwana, Tara C Kandpal

Financial viability is arguably the most important requirement for large-scale dissemination of decentralized renewable energy systems (DRESs). Financial viability of a DRES can vary from region to region as it depends on various geographical and socio-economic factors. With sufficient solar radiation availability throughout the year, abundant forest cover, dependence of majority of population on agriculture, and remote villages facing energy access related challenges, the state of Uttarakhand in India has significant potential for the application of solar- and biomass-based DRESs. Based on the current fuel prices, subsidies, and rebates, this study is an attempt to assess the financial attractiveness of solar- and biomass-based DRESs under various scenarios for their potential users in Uttarakhand.

Improved biomass cookstove, domestic solar water heater, solar lantern, and solar home system are found to be financially viable under almost all scenarios for household applications while dish-type solar cooker, solar PV pump, and solar dryer are not so attractive for household applications. It has also been found that the financial attractiveness of DRESs improve significantly with the removal of subsidy presently being given to fossil fuel-based energy supply options.

Are Shocks to Renewable Energy Consumption Permanent or Transitory? An Empirical Investigation for Brazil, China, and India

Renewable and Sustainable Energy Reviews, Volume 66, December 2016, Pages 913–919
Giray Gozgor

This article investigates whether there is a unit root in renewable energy consumption in three large developing economies: Brazil, China, and India over the period 1971–2014. To do so, it uses four unit root tests assuming one structural break, two structural breaks, and more than two structural breaks. It observes that renewable energy consumption is a unit root process in Brazil, but it is found as stationary in China and India. The article also tackles issues and challenges in the unit root test methodology in energy economics literature and provides implications for renewable energy consumption in three economies.

The Status of Renewable Energy Research on India Solar Energy

Energy Procedia, Volume 95, September 2016, Pages 416–423
Gyanendra Singh Sisodiaa, Pragya Singh

This study presents a status of renewable energy research specific to the Indian context. The Indian academic literature on renewable energy from 1998 to 2014 was reviewed. The major focus was to understand the direction of the energy research (solar) in consumer behaviour context. Therefore, the technological research and patent studies were not taken into account for this study. The papers reviewed represent three broad categories, namely, literature review, empirical studies, and qualitative studies. Through this study, it can be concluded that Indian energy market is not yet well researched academically. A slow growth has been observed since 1998; however, a major shift is observed from 2008 onwards.

CO_2 Emission Reduction Potential Assessment Using Renewable Energy in India

Energy, Volume 97, February 2016, Pages 273–282
Subhash Kumar, Reinhard Madlener

The Indian power sector is experiencing a lot of pressure to supply sustainable electricity at affordable cost due to heavy demand especially in the summer peak season. Most of India's ~~elec~~tricity is produced by fossil fuel-based power plants, which are the source of CO_2 emissions. In this case, renewable energy sources play a vital role in securing sustainable energy without environmental emissions. This article examines the effects of renewable energy use in electricity supply systems and estimates the CO_2 emissions by developing various scenarios under the least cost approach. The LEAP energy model is used to develop these scenarios. The results show that in an ARET (accelerated renewable energy technology) scenario, 23% electricity is generated by renewables only, and 74% CO_2 reduction is possible by 2050. If the maximum energy savings potential is combined with the ARET scenario, the renewables share in electricity supply rises to 36% as compared to the reference scenario, while the CO_2 emission reduction in this case remains at 74%.

Discrete Harmony Search Based Size Optimization of Integrated Renewable Energy System for Remote Rural Areas of Uttarakhand State in India

Renewable Energy, Volume 94, August 2016, Pages 587–604
Anurag Chauhan, R P Saini

In the recent years, decentralized power generation using locally available renewable energy resources has been recognized as a cost-effective alternative of uneconomical grid extension. The present article deals with the size optimization of Integrated Renewable Energy System (IRES) for a cluster of villages of Uttarakhand in India. The proposed IRES consists of locally available renewable energy resources of Micro Hydro Power (MHP), biogas, biomass, wind, and solar energy in order to meet the electrical and cooking demands of the study area. A system operation strategy has been developed in the article for size optimization of IRES. Also, the loss of power supply probability (LPSP) has been used as the reliability criteria in order to ensure the continuous supply of power without any failure problems. Further, in order to utilize renewable energy resources in different contributions, four different resource

scenarios are considered for the study area. Finally, the total net present cost (NPC) of the considered scenarios has been optimized using discrete harmony search (DHS) algorithm. Among different scenarios, MHP–biogas–biomass–wind–solar battery-based IRES offers the lowest net present cost of ₹49.0309 million at the estimated LCOE of ₹5.47/kWh.

Renewable Energy: An Overview on Its Contribution in Current Energy Scenario of India

Renewable and Sustainable Energy Reviews, Volume 60, July 2016, Pages 226–233
Lata Tripathi, A K Mishra, Anil Kumar Dubey, C B Tripathi, Prashant Baredar

Energy is the major source for economic development of any country. In case of developing country, such as India, shortage of electricity works as a barrier for development. In recent years, India's energy consumption has been increasing at a relatively fast rate due to population growth and economic development. Rapid growth of the Indian economy places heavy demand of electric power. Presently, most of the electric demand is fulfilled by coal power plants and creates pressure on fossils fuel. Coal-based power generation is characterized by local and regional environmental degradation as well as greenhouse gas emissions, leading to climate change. Thus, there is need for enhanced energy security along while reducing greenhouse gas emissions. Renewable energy is environmentally friendly source of energy. In present energy scenario, harnessing of renewable potential in effective manner is becoming need of the era, which can provide sustainable power supply as well as mitigate the negative environmental impact due to fossil fuels.

Renewable and Sustainable Energy Reviews Solar Photovoltaic Energy Progress in India: A Review

Renewable and Sustainable Energy Reviews, Volume 59, June 2016, Pages 927–939
Sarat Kumar Sahoo

The mitigation of global energy demands and climate change are the most important factors in the modern days. Development and application of solar energy have been regarded by the Government of India and common people, and they thought that solar photovoltaic energy can provide more energy in future compared to other renewable energies. In the last decade, solar photovoltaic energy research and development has been supported by the central government and state governments. This article discusses the progress of current solar photovoltaic energy in India. It highlights the renewable energy trend in India with major achievements, state-wise analysis of solar parks, and industrial applications. Finally, it discusses the Indian Government's policies and initiatives to promote solar energy in India. This review on solar photovoltaic energy will help decision makers and various stakeholders to understand the current status, barriers, and challenges for better planning and management in this field.

Rural Electrification in India: Galilee Basin Coal versus Decentralized Renewable Energy Microgrids

Renewable Energy, Volume 89, April 2016, Pages 422–436
Lynette Molyneaux, Liam Wagner, John Foster

The state of Bihar in India has approximately 75 million people with no access to electricity. The Government of India has pursued a policy of rural electrification through the provision of centralized coal-fired power, which has been unable to resolve the low levels of electrification. Coal supply woes in India have led Indian companies to pursue new coal mines in Australia's Galilee Basin. The costs of these mining ventures will be high due to the mining infrastructure required and long transport distances to rural India. A high-level analysis of mining, transport, and power station investment to meet rural demand in Bihar shows that the absolute investment requirement using coal, especially coal sourced from Australia, is an expensive option. Pursuing electrification through village level, renewable energy micro-systems provides more flexibility. Pollution costs associated with coal-fired generation, employment benefits associated with many village implementations, and a rural load unsupported by industry load, show a benefit associated with decentralized, renewable energy electrification. EF

CLEAN COOKING WITH GREENWAY STOVES

HEALTHIER AND HAPPIER MEALS ACROSS INDIA

In India, more than 850 million people still use biomass as fuel for cooking. This is basically 70% of our population, which increases to 80% in rural India, cooking on traditional stoves or mud *chulhas*. Exposure to the smoke that comes from these stoves has significant health hazards, especially for women and children. The *chulhas* also release a lot of harmful greenhouse gases into the atmosphere, increasing air pollution, and furthering deforestation. An estimated 875 000 premature deaths occur across India due to the *chulha* smoke exposure.

The Greenway Smart Stove designed by Greenway Grameen Infra is an improved clean cookstove with a patented design. The Smart Stove is a single-burner, high-efficiency cookstove designed for long-term, everyday use. The stove can use wood, cow dung, or any agricultural waste, which is the same fuel that is used in a regular mud stove. This helps the users adapt faster to the stove, as it does not require any lifestyle or behaviour change.

The Smart Stove decreases smoke emissions by up to 70% and fuel consumption by 50%. This is on account of higher efficiency of combustion as compared to a regular mud stove. There exists an innovative air regulation system within the stove, which keeps oxygen circulating, ensuring that the fuel is burnt completely. This leads to cleaner smoke, eliminating most of the harmful smoke and particulate matter. It is made of steel and aluminium, to avoid rust, with Bakelite handles for better insulation. The Smart Stove is

Particulars	Smart Stove	Jumbo Stove	Total	Remarks
Total stoves sold till date	346 080	65 920	412 000	
No. of lives impacted	1 661 184	316 416	1 977 600	Average Indian family size = 4.8 per household*
Carbon emissions mitigated (tonnes/year)	553 728	125 248	678 976	1.6 tonnes per Smart Stove and 1.9 tonnes per Jumbo Stove per year
No. of rural districts covered	~120 districts conservatively			

*Source: Indian Census 2011

portable (weighing only 2.4 kg) and highly durable (Greenway provides a manufacturing warranty for 1 year), thus immediately endearing it to the target customers.

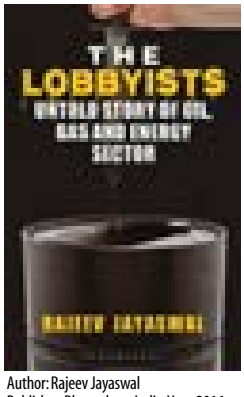
Another model of the stove is the Greenway Jumbo Stove, a size variant, with a loading capacity of 40 kg, as compared to 25 kg for the Smart Stove. This is ideally suited for large families (10–12 members) and small eateries. Both stoves have been certified by the Ministry of New and Renewable Energy (MNRE), Government of India, and the Bureau of Indian Standards (BIS).

By replacing the traditional stoves with the Greenway stoves, as much as two tonnes of CO_2 equivalent emissions is prevented from entering the atmosphere, per stove, every year.

The customers themselves have several interesting reasons for choosing the Greenway stoves, besides the decreased smoke and fuel consumption. Anita, a crèche owner in the Kherwada district of Udaipur, says, "Before using the Greenway Stoves, my daughter-in-law had to sit outside in the porch cooking on the traditional mud stove. She used to feel left out and isolated from other family members, especially when cooking for dinner. But now, she sits inside with us and even watches TV while making rotis. The portability feature of these stoves has increased our bonding." Another customer, Ratnamma from Tumkur in Karnataka says, "It takes half the time now. I can finish cooking for my kids and husband by afternoon, so I have enough time for other activities. My entire kitchen area used to be so dark and smoky, that I didn't want my kids to come near me. But now, my kitchen is clean, and I can monitor their studies, without worrying about their health."

Since the start of the venture, Greenway has sold more than 500 000 stoves across India. The product was designed to provide a sustainable change in clean cooking and thus improve the lives of millions of people, without significantly disrupting their daily lives. EF

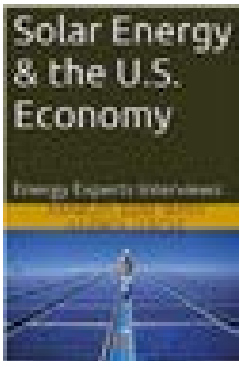
The Lobbyists: Untold Story of Oil Gas and Energy Sector



In early 2000, India caught attention of global petroleum giants after it announced world's biggest gas discovery. In 2004, it announced another world-class oil discovery in Rajasthan. These developments raised India's hope that the world's fourth largest oil importer would be able to significantly reduce over-dependence on the Gulf and other oil-producing countries.
But, subsequent developments belied the hope. Soon India's oil and gas dream turned out to be a nightmare. Controversies gripped domestic oil and gas industry. Greed for gas resulted into a major corporate war. It involved politicians, media, as well as some members of the civic society. The Congress-led Manmohan Singh government was accused of encouraging crony capitalism. Allegations of corruption triggered probes by auditors and investigative agencies. Bureaucrats stopped taking decisions. The government suffered acute policy paralysis. Exploration and production of oil and gas suffered. In less than one decade, India's import dependence jumped. India left Japan behind to become world's third largest oil importer after the United States and China. EF

Author: Rajeev Jayaswal
Publisher: Bloomsbury India; Year: 2016

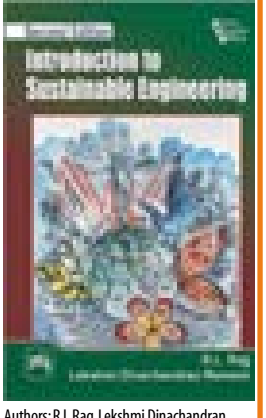
Solar Energy & the US Economy: Energy Experts Interviews - Solar Power



The focus of Volume 2 of *Solar Energy & the US Economy* is on Solar Energy and the Economy. It includes documented contributions of solar to job creation and economic development with projections for the year ahead. The book compares solar industry with other energy industries using specific data for each, which includes other timely information important for states, communities and the nation, and to the well-being of individual consumers.
Part of the Energy Experts Interview Series, national and state experts contribute on key energy topics, such as solar energy, other renewable energy, energy efficiency, alternative transportation fuels, and more. The book addresses energy and job creation, sustainable communities, environmental health, economic development, and much more. The book is presented by the Future is Now Foundation which is a charitable non-profit organization that provides educational programmes on energy and other topics at the state and national levels since 2002. In March 2016, the Foundation sponsored a two-day national Energy Solutions Conference featuring 23 national and state experts. Held via Simulcast, the theme was Renewable Energy & Alternative Fuels. On-demand replays of all presenters, including the interview guest for this book, are available at EnergySolutionsNow.com. The next conference track will be on Energy Efficiency topics. EF

Authors: Marcia Elder, Andrea Luecke
Publisher: Future Is Now Foundation - EnergySolutionsNow.com; Year: 2016

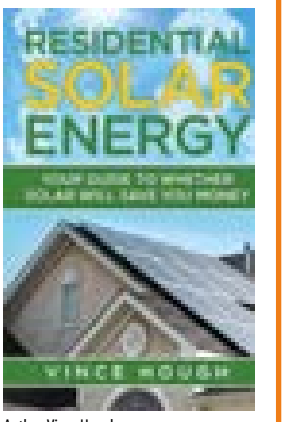
Introduction to Sustainable Engineering



Sustainability has become a *sine qua non* in the study and practice of engineering. This introductory textbook aims to make the concepts of sustainable engineering accessible to the undergraduate students of engineering. This will help them to keep in view the philosophy of sustainability while learning the core subjects of their specializations and will equip them with a set of tools for this purpose. In addition to providing a broad-based introduction to the idea of sustainability and its relevance, the book talks about environment-related legislation, air and water pollution, solid waste management, local and global environmental challenges, climate change, and the steps taken at an international level to manage them. Tools used to ensure sustainability in engineering activities, such as Environmental Management Systems (EMS) and Environmental Impact Assessment (EIA), are mentioned. Green buildings, green computing, green chemistry, sustainable cities, sustainable transportation, sustainable sources of energy, economic and social factors affecting sustainability, including rapid urbanization and poverty, are also covered. A set of questions, some of them quite open-ended, are added at the end of each chapter to help students test their understanding.
The reader is encouraged to use this book as a starting point to explore how the principles of sustainable engineering are relevant to their chosen branch of study and professional practice. EF

Authors: R L Rag, Lekshmi Dinachandran Remesh
Publisher: Prentice-Hall of India Pvt Ltd; 2nd Revised edition; Year: 2016

Residential Solar Energy: Your Guide To Whether Solar Will Save You Money



Author: Vince Hough
Publisher: CreateSpace Independent Publishing Platform; Year 2016

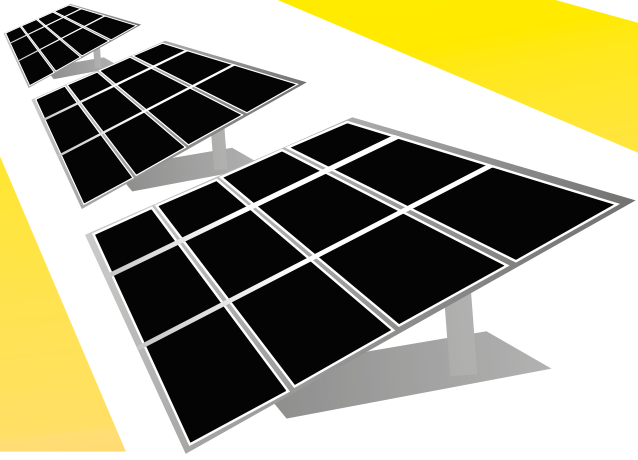
Solar energy is the fastest-growing source of clean energy for the home. Driven by a steady decline in the cost of solar energy over the past 10 years, solar panel sales have skyrocketed in the US. Today, almost 1 000 000 American homeowners reduce their carbon footprint and fight climate change with solar energy. Most of them are rewarded with significant savings on their home energy bills. Does that mean that you will save money by going solar today? The answer is—it depends! The primary determinants of whether you can save money with solar have been your state's solar policy and the solar energy alternative that you pick for your home. Most residential solar sales have taken place in those states that have embraced 'solar friendly' policies. And most solar homeowners have chosen solar systems that they can lease rather than buy, although that may change going forward. Solar energy companies have driven the rapid growth of the residential solar market by installing rooftop solar systems. But since those systems typically generate excess energy during the day (while not producing any energy at night), a means of capturing their excess energy has been needed. Also, battery storage systems are expensive and can eliminate your potential for solar savings.

The solution to this storage problem is to let your power company use your excess solar energy to supply power to its other customers. In return, it provides you with energy credits, which you can draw on when the sun is not shining. In some states, however, how much you are credited for your solar energy has become a contentious issue. While many people think of those rooftop solar systems as the way to go solar, new solar models have emerged. One model, for example, installs solar panels for you at a site remote from your home and credits you for their energy production (known as community or shared solar). Power companies are also experimenting with some other solar models that can generate solar energy for you. As a result, the decision to go solar has become more complex today. In this book, the author shares a range of insights that guide you through the residential solar market. You will learn about the intricacies of solar proposals and the various options that are available to go solar. This guide also provides you with a framework to evaluate those options, so you can see which will save you the most money. This guide's essential information will give you the confidence to make the most informed decision about when to go solar with your home. You'll find that this book is your definitive guide on how and when you should go solar. EF

Handbook on Concentrator Photovoltaic Technology

Authors: Carlos Algora, Ignacio Rey-Stolle
Publisher: Wiley-Blackwell; Year: 2016

Concentrator Photovoltaics (CPV) is one of the most promising technologies to produce solar electricity at competitive prices. High-performing CPV systems with efficiencies well over 30% and multi-megawatt CPV plants are now a reality. As a result of these achievements, the global CPV market is expected to grow dramatically over the next few years reaching cumulative installed capacity of 12.5 GW by 2020. In this context, both new and consolidated players are moving fast to gain a strategic advantage in this emerging market. Written with clear, brief, and self-contained technical explanations, *Handbook of Concentrator Photovoltaic Technology* provides a complete overview of CPV covering the fundamentals of solar radiation, solar cells, concentrator optics, modules and trackers; all aspects of characterization and reliability; case studies based on the description of actual systems and plants in the field; environmental impact, market potential, and cost analysis. CPV technology is at a key point of expansion. This timely handbook aims to provide a comprehensive assessment of all CPV scientific, technological, and engineering background with a view to equipping engineers and industry professionals with all vital information they need to help them sustain the impetus of this encouraging technology. EF



RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Simple processing technique could cut cost of organic PV and wearable electronics

A simple solution-based electrical doping technique could help reduce the cost of polymer solar cells and organic electronic devices, potentially expanding the applications for these technologies. By enabling production of efficient single-layer solar cells, the new process could help move organic photovoltaics into a new generation of wearable devices and enable small-scale distributed power generation.

Developed by researchers at the Georgia Institute of Technology and colleagues from three other institutions, the technique provides a new way of inducing *p*-type electrical doping in organic semiconductor films. The process involves briefly immersing the films in a solution at room temperature and this would replace a more complex technique that requires vacuum processing.

- The technique consists of immersing thin films of organic semiconductors and their blends in polyoxometalate (PMA and PTA) solutions in nitromethane for a brief time—on the order of minutes.
- The diffusion of the dopant molecules into the films during immersion leads to efficient *p*-type electrical doping over a limited depth of 10–20 nanometers from the surface of the film.
- The *p*-doped regions show increased electrical conductivity and high work function, reduced solubility in the processing solvent, and improved photo-oxidation stability in air.

This new method provides a simpler alternative to air-sensitive molybdenum oxide layers used in the most efficient polymer solar cells that are generally processed using expensive vacuum equipment. When applied to polymer solar cells, the new doping method provided efficient whole collection. For the first time, single-layer polymer solar cells were demonstrated by combining this new method with spontaneous vertical phase separation of amine-containing polymers that leads to efficient electron collection at the opposing electrode. The geometry of these new devices is unique as the functions of hole and electron collection are built into the light-absorbing active layer, resulting in the simplest single-layer geometry with few interfaces.

https://www.sciencedaily.com/releases/2016/12/161206111449.htm

Throwing new light on printed organic solar cells

Researchers at the University of Surrey have achieved record power conversion efficiencies for large area organic solar cells. In recent years, scientists have been attempting to increase the efficiency of these cells to allow commercial

applications, such as integration into a building's glass façade, generating electricity to power the building. The research was led by the University of Surrey's Advanced Technology Institute (ATI) in collaboration with Oxford University, Aristotle University of Thessaloniki (Greece), and University of Stuttgart (Germany). The project is part of SMARTONICS, a four-year European Commission FP7 programme aimed at developing large-scale pilot lines for the fabrication and printing of organic polymer solar cells.

The results, published in *Advanced Electronic Materials*, demonstrate that dependencies between the chemical and physical properties of the photoactive layer's building blocks within organic solar cells determine the efficiency of these solar cells.

- By using a well-known and low-cost electron donating material (P3HT) in combination with an electron accepting material (ICBA) for the photosensitive layer of the organic solar cells, the research team discovered that different ICBA samples consist of dissimilar isomeric mixtures (isomers are molecules with the same number of atoms of each element, but with the atoms differently arranged).
- These characteristics are critical for the formation kinetics and spatial arrangement of P3HT and ICBA in their photosensitive blend and lead to varying power conversion efficiencies.

Tailoring the fabrication process based on these findings, the research team were able to improve the efficiency of their solar cells from 2.2% up to 6.7%. This is one of the highest efficiencies to have been reported for P3HT blends on a large-area device.

https://www.sciencedaily.com/releases/2016/11/161130083020.htm

Solar power could become cheaper, more widespread

A breakthrough in solar power could make it cheaper and more commercially viable, thanks to research at the University of Warwick. In a paper published in *Nature Energy*, Dr Ross Hatton, Professor Richard Walton, and colleagues, explain how solar cells could be produced with tin, making them more adaptable and simpler to produce than their current counterparts.

Solar cells based on a class of semiconductors known as lead perovskites are rapidly emerging as an efficient way to convert sunlight directly into electricity. However, the reliance on lead is a serious barrier to commercialization due to the well-known toxicity of lead. Dr Ross Hatton and colleagues show that perovskites using tin in place of lead are much more stable than previously thought and so could prove to be a viable alternative to lead perovskites for solar cells.

Lead-free cells could render solar power cheaper, safer, and more commercially attractive leading to it becoming a more prevalent source of energy in everyday life. This could lead to a more widespread use of solar power, with potential uses in products, such as laptop computers, mobile phones, and cars. The team have also shown how the device structure can be greatly simplified without compromising performance, which offers the important advantage of reduced fabrication cost.

Perovskite solar cells are lightweight and compatible with flexible substrates, so could be applied more widely than the rigid flat plate silicon solar cells that currently dominate the photovoltaics market, particularly in consumer electronics and transportation applications.

https://www.sciencedaily.com/releases/2016/11/161122111834.htm

New technology aims to make photovoltaic cells 70% more efficient

Researchers at the Technion-Israel Institute of Technology have developed a technology that could improve the efficiency of photovoltaic cells by nearly 70%. The breakthrough could be a key for overcoming current technological limitations to harnessing solar power to meet the world's energy consumption demands. The study was conducted at the Excitonics Lab, headed by Professor Carmel Rotschild, in the Technion Faculty of Mechanical Engineering, with assistance from the Grand Technion Energy Program and the Russell Berrie Nanotechnology Institute at the Technion, and as part of the lab's European Research Council (ERC) RC project on new thermodynamic tools for solar cells.

- Photovoltaic cells optimally utilize a very narrow range of the solar spectrum—the broad light supplied by the sun. Radiation not within this narrow range merely warms these cells and is not utilized. This energy loss limits the maximum efficiency of current solar cells to around 30%.

In a paper recently published in *Nature Communications*, the Technion researchers describe how their technology is based on an intermediate process that occurs between sunlight and the photovoltaic cell. The photoluminescence material they created absorbs the radiation from the sun and converts the heat and light from the sun into an 'ideal' radiation, which illuminates the photovoltaic cell and enables higher conversion efficiency. As a result, the device's efficiency is increased from 30% to 50%. The inspiration for the technology comes from optical refrigeration, where the absorbed light is re-emitted at higher energy, thereby cooling the emitter. The Technion technology works similarly but with sunlight.

https://www.sciencedaily.com/releases/2016/11/161115132554.htm

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Fax: 5596201
Email: info@bigsolar.gr
Website: www.bigsolar.gr

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Fax: +886-03-599-8449
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Website: www.riteksolar.com

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Tel: +41/32/391-1600
Email: Info@pasan.ch
Website: www.pasan.ch

PI Berlin AG
PV module consulting, testing, research IEC 61215, 61646 & 61730 and UL 1703 ISO 17025, CBTL in IECEE CB scheme. Joint ventures with PICON (thin film) and PI Systems (systems engineering).
Wrangelstrásse 100
D-10997 Berlin, Germany
Tel: +49/30/8145264-0
Email: info@pi-berlin.com
Website: www.pi-berlin.com

NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

International Battery and Alternate Energy Exhibition and Conference

January 6–8, 2017

New Delhi
Website: http://www.batteryfair.co.in/

Windergy India 2017

January 10–12, 2017

New Delhi
Website: http://windergy.in

International Conference and Exhibition on Energy Storage and Microgrids in India

January 12–13, 2017

Mumbai, India
Website: http://www.esiexpo.in

India Rooftop Solar Congress

January 17–18, 2017

New Delhi
Website: http://www.solarquarter.com/indiarooftopsolarcongress

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Exhibition and Conference for the Solar Energy & LED Industry

January 23–24, 2017

Hyderabad, Telangana
Website: http://www.eai.in

Pro SOLAR Conference 2016

January 23–24, 2017

Hyderabad, Telangana
Website: http://www.eai.in

RE Assets India

February 2–3, 2017

New Delhi
Website: http://firstviewgroup.com/reassetsindia/

INTERNATIONAL

ICRET 2017

January 22–24, 2017

Pathum Thani, Thailand

ICEES 2017

January 22–24, 2017

Pathum Thani, Thailand

AEE Solar Dealer Conference

January 25–27, 2017

San Diego, USA
Website: http://10times.com/aee-solar-dealer-conference

Energy, Utility & Environment Conference

February 8–10, 2017

San Diego, USA
Website: http://www.euec.com/

International Conference on Clean and Green Energy

February 8-10, 2017

Frankfurt, Germany
Website: http://www.iccge.org/

Mexico Wind Power 2017

March 1–2, 2017

Mexico City, Mexico
Website: http://www.mexicowindpower.com.mx/2017/en/home/

6th Annual International Conference on Sustainable Energy and Environmental Sciences (SEES 2017)

March 6–7, 2017

Singapore
Website: http://www.env-energy.org/

CEEC Clean Energy Expo

March 29–31, 2017

Beijing, China
Website: http://www.tradefairdates.com/CEEC-Clean-Energy-Expo-China-M675/Beijing.html

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/ Scheme wise Physical Progress in 2016-17 (& during the month of November, 2016)			
Sector	FY- 2016-17		Cumulative Achievements
	Target	Achievement (April - November, 2016)	(as on 30.11.2016)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	4000.00	1641.95	28419.40
Solar Power	12000.00	2112.02	8874.87
Small Hydro Power	250.00	50.92	4324.85
BioPower (Biomass & Gasification and Bagasse Cogeneration)	400.00	101.00	4932.33
Waste to Power	10.00	7.50	114.08
Total	**16660.00**	**3913.39**	**46665.53**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWEQ)			
Waste to Energy	15.00	2.24	161.12
Biomass(non-bagasse) Cogeneration	60.00	0.00	651.91
Biomass Gasifiers	2.00	0.00	18.34
-Rural -Industrial	8.00	4.30	168.54
Aero-Generators/Hybrid systems	1.00	0.38	2.97
SPV Systems	100.00	74.97	382.01
Water mills/micro hydel	1 MW + 500 Water Mills	0.10 MW + 100 Water Mills	18.81
Total	**187.00**	**81.99**	**1403.70**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (in Lakhs)	1.00	0.286	49.384

Source: www.mnre.gov.in

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