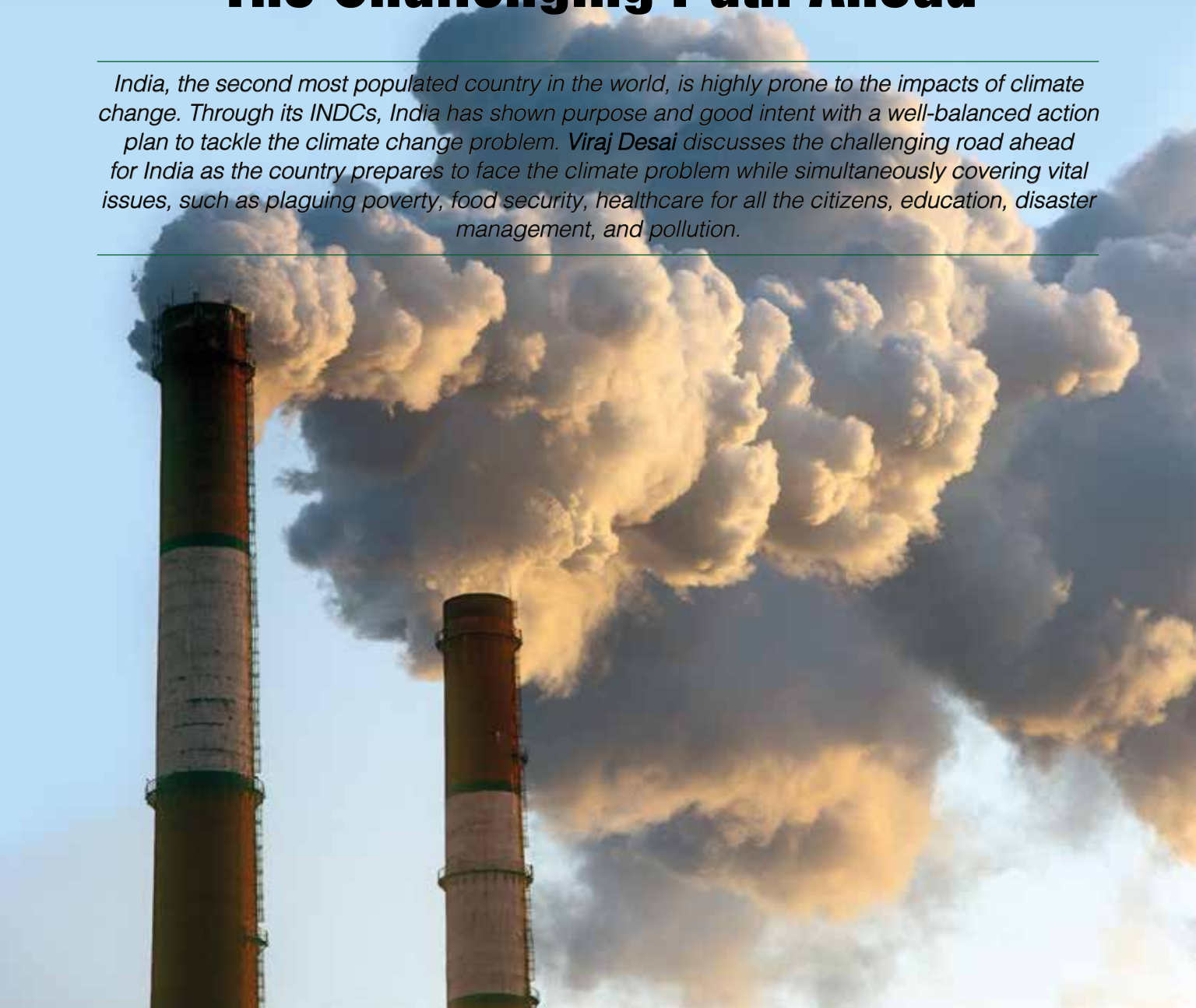
India's Preparations to Tackle Climate Change

The Challenging Path Ahead

India, the second most populated country in the world, is highly prone to the impacts of climate change. Through its INDCs, India has shown purpose and good intent with a well-balanced action plan to tackle the climate change problem. ***Viraj Desai*** *discusses the challenging road ahead for India as the country prepares to face the climate problem while simultaneously covering vital issues, such as plaguing poverty, food security, healthcare for all the citizens, education, disaster management, and pollution.*



The twenty-first session of the Conference of the Parties (COP21) that took place in Paris in November–December 2015 was one of the most significant events that the world had been anticipating with bated breath. While 'climate change' is a challenge that countries worldwide are witnessing, the COP21 was expected to be an inflection point when many of the countries were expected to announce measures that would positively impact environment and reduce their carbon footprint.

Various countries submitted their Intended Nationally Determined Contributions (INDCs) to the United Nations Framework Convention on Climate Change (UNFCCC), an international environment treaty negotiated at the Earth Summit, Rio de Janeiro, in 1992, the first of its meets of heads of over 100 countries to discuss issues pertaining to greenhouse gas (GHG) emissions. INDCs are the means for governments to communicate internationally what steps would be taken for addressing climate change in their own nations. Good INDCs would demonstrate ambitions for reducing emissions, how they would be adapting to climate change impacts and what kind of support would they be needing or provide for adopting low-carbon pathways.

INDIA'S INDCs AND THE CHALLENGES AHEAD

India, one of the fastest growing economies, submitted its INDCs to the UNFCCC on October 2, 2015. The INDCs have demonstrated that the country will act responsibly towards environment but will also continue to grow at the similar rate in order to provide its citizens good standard of living. For a country that faces multiple challenges of climate change along with 25 per cent of its population reeling below the poverty line, the submission to the United Nations signifies that it hopes to set an example for other developing countries to emulate.

The per capita emission of India is just 1.56 metric tonnes, far lesser than most of the developed countries having emissions between 7 and 15. Even though the country has less than 3 per cent of the world's surface area, it has to support over 17 per cent of the world's population. In the document submitted to the convention, India has clearly stated that its aim is to set up an equitable architecture based on principles of 'common but differentiated responsibilities'. Nevertheless, it is a gargantuan task ahead for India as 363 million Indians live under poverty and 300 million citizens lack access to electricity. Figure 1 shows the socioeconomic problems that India is currently facing, all these factors will have to be kept in mind while analysing India's stance at the world forum.

In 2011, the energy consumption per capita globally was 1.88 tonnes of oil equivalent (toe), Indians merely had 0.6 toe. Even the per capita electricity consumption of just a little over 1,000 kWh is barely one-third of the world's average consumption. Of course, the scenario is expected to get better with India focussed on providing 'Power for All' by 2019. However, with a Human Development Index (HDI) of 0.586 and a ranking of 135, India still has a long way to go to meet the aspirations of its population. It is also estimated that over 48 per cent of households in rural areas lack basic socioeconomic services and the challenges also encompass to the livestock population of the country, 300 million in number, facing issues, such as diseases, inadequate supply of fodder due to climate change. Fewer countries face the kind of challenge that climate change brings to a country like ours. Not only is the agrarian economy susceptible to the vagaries of nature, it also has to deal with various natural calamities which it is prone to. With the urban population set to jump to over 600 million and per capita set to triple from the current level, there will be increased demands for housing, energy, transport, and water disposal that would need to be addressed by the government.

What is worth noting is that despite India growing at a fast pace, the emission intensity of its gross domestic product (GDP) in purchasing power parity (PPP) terms at the moment vis-à-vis the countries at a similar level of development, are far lesser. The positive part is that the government has already started taking proactive measures like

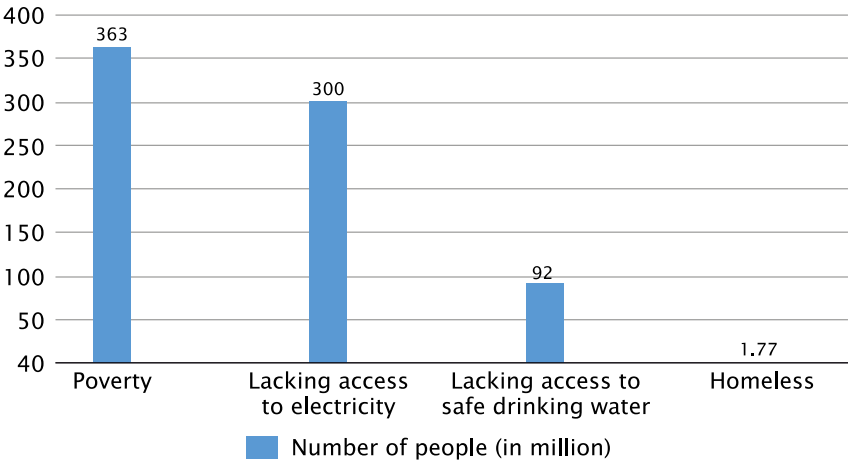


Figure 1: Socioeconomic problems currently faced by India
Source: www.world-nuclear.org/info

increasing focus on tapping various renewable energy sources adopting energy efficiency techniques and also stressing corporates to follow similar renewable energy utilization practices.

In fact, the broad policy framework was laid down by the National Environmental Policy 2006, which stated that sustainable development along with respect for ecological constrains are imperatives of social justice. In a way, the National Action Plan on Climate Change (NAPCC), implemented through eight missions, which clearly show the priorities for mitigation and adaptation to combat climate change. Some of them include:

- *Energy Conservation Act*: Encourage efficient use of energy and its conservation
- *National Policy for Farmers*: Sustainable development for agriculture
- *National Electricity Policy*: Access to electricity and promotion of renewable energy

Besides this, innovative measures, such as cess on coal, increase in taxes on petrol and diesel and instruments, such as Renewable Energy Certificates (RECs) and Renewable Purchase Obligations (RPOs) are steps that have shown some results in moving towards more energy efficient use. In fact, India was one of the first countries to voluntarily announce reduction of emissions intensity of its GDP by 20–25 per cent from 2005 level by 2020, despite no binding obligations. Thanks to the slew of measures taken, the country has been able to reduce emission intensity by 12 per cent between 2005 and 2010, a remarkable feat for a country growing at a fast pace.

Clean and efficient energy system

The government is promoting greater use of renewable energy and a shift to the supercritical technology for its coal-based power plants.

Renewable energy capacity growth

There is a significant spike expected in the addition of renewable energy capacity in the country (Figures 2 and 3). India has set an ambitious target for installation of 175 GW renewable power by 2022.

As is evident, India will be witnessing a spike in renewable energy capacity addition over the coming years. This is being done with the twin objective of reducing India's burden of oil imports and also providing sustainable energy for millions across the country. Schemes, such as 25 Solar Parks, Ultra Mega Solar Power Projects, canal top solar projects, and one hundred thousand solar pumps for farmers are already under implementation. Besides this, solarization of over 55,000 petrol pumps across the country is truly an innovative way in order to utilize the country that receives abundant sunshine. India's installed hydropower capacity is 46.1 GW of which 4.1 GW is small hydro.

The country's major chunk of the population is dependent on biomass energy but it is inefficient and, hence, the government has initiated measures for promoting cleaner and efficient energy use. The installed capacity of biomass is targeted at 10 GW by 2022 from the current level of 4.4 GW, which would help the rural population tremendously. However, since India is primarily dependent on coal for its electricity needs and would continue to do so in the near future, it has taken a number of

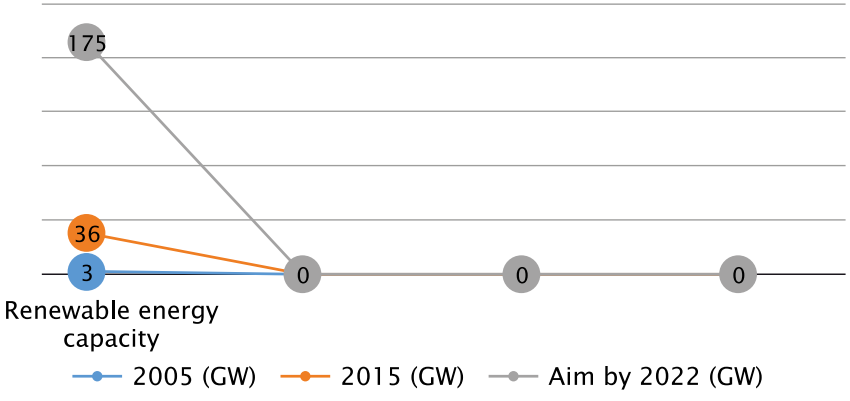


Figure 2: Renewable energy capacity growth and target set for 2022 by India
Source: www.world-nuclear.org/info

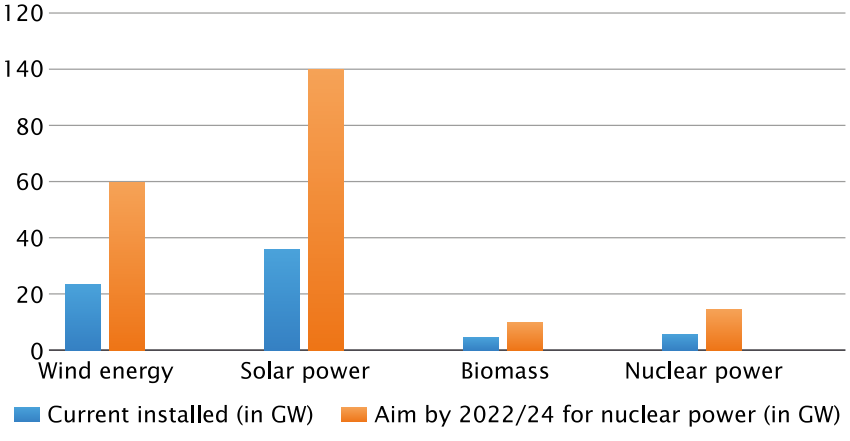


Figure 3: Renewable energy capacity growth target set by the Government of India to be achieved by 2022
Source: www.world-nuclear.org/info

steps to reduce the carbon footprint generated by coal plants. Through Clean Coal policies such as mandating 144 old thermal stations to improve energy efficiency, introduction of ultra-supercritical technology being explored and stringent check on emissions by thermal plants, it is expected that the country would reap benefits in the coming time. Other than this, the launch of the National Smart Grid Mission to strengthen power supply network and plug-in-leakages will provide a huge boost to the electricity scenario in the country.

ENERGY EFFICIENCY IS SAVING ENERGY

If augmenting capacity is the government's big step, conserving energy through energy efficiency is an important plank for India to save millions of precious units. For this, the National Mission for Enhanced Energy Efficiency, which aims to avoid about 20 GW of electricity consumption and savings of 23 million tonnes per year at full implementation stage, is an ambitious target. But, India has shown to the world that development is possible and so is environmental conservation. Between 2005 and 2012, the government managed to avoid 20 GW of energy consumption. Measures, such as introduction of efficient lighting by using compact fluorescent lamps (CFLs) and light emitting diode (LED) bulbs are expected to save billions of units annually. Additionally, the Bureau of Energy Efficiency, a one-of-its-kind body, that was formed to provide labelling standards to appliances have managed to add 21 devices to the list. With the government promoting awareness amongst consumers, it has resulted in many consumers getting conscious of purchasing energy efficient devices whereas even companies realizing the changing mindsets have started producing more of energy efficiency devices. Even lending agencies that are providing funds for energy efficiency projects are supported by the government through the Partial Risk Guarantee Fund for Energy Efficiency.

The Energy Conservation Building Code will be setting out minimum energy standards for commercial buildings. This is a vital step as it is anticipated that over half the buildings are yet to come up in the country. Innovative measures, such as energy rating system, efficient utilization of resources are already resulting in saving precious power. The government's mission to develop 100 smart cities and also sprucing up 500 cities under the Atal Mission for Rejuvenation and Urban Transformation (AMRUT) highlight the seriousness to address the rapid urbanization that is taking place and providing its citizens an opportunity to be a part of sustainable cities. Additionally, waste to energy projects, investment in solid waste management projects over the years, reuse and recycle of water, and the launch of 'Swachh Bharat' Mission are some of the unique initiatives which are expected to bring about a transformation.

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SMART TRANSPORTATION

India is also pushing forward for low carbon infrastructure and public transport systems like 'dedicated freight corridors' that would not only ease the freight movement but also bring down the fuel consumption of locomotives. Additionally, the Indian Railways will be using solar power on its land and rooftops of coaches. The Delhi Metro Rail Corporation (DMRC) has already earned carbon credits as it has the potential to reduce 0.57 million tonnes of CO_2 annually. Development of waterways and inland transportation is being given a priority as it is not only the cheapest mode of transport but is also considered extremely fuel-efficient. Since the country's road sector is the fastest developing, India has also initiated Green Highways Policy that would ensure that trees are planted on both sides of the 140,000 km of highways that would come up under this. Additionally, solar-powered toll plazas have been made mandatory across the country. Since the country is also touted as the fastest growing car market, the National Electric Mobility Mission Plan aims to promote adoption of hybrid and electric vehicles in the country by doling out incentives. The Kochi International Airport in Kerala has set a wonderful example for others to follow by being the first airport in the world to rely solely on solar power.

AFFORESTATION AND REDUCING POLLUTION

The government's eventual plan to have 33 per cent of the geographical area under forest cover is on track as the country was able to increase tree cover from 23.4 per cent in 2005 to 24 per cent in 2013. Technological adoption is taking place rapidly in the country. The Continuous Emission Monitoring System that mandates polluting industries to do real time monitoring of emission as well as Common Effluent Treatment Plants to treat effluents are just few of the measures to ensure that India's industries also take some steps to reduce pollution. The National Air Quality Index launched in 2014 for Indian cities shows information on air quality.

AGRICULTURE AND WATER

With nearly 60 per cent of the country's net sown area dependent on rainfall, the vagaries of climate has a direct impact on food security and food supplies. This is why the launch of National Food Security Mission, Mission for Integrated Development of Horticulture, National Mission for Sustainable Agriculture, and Pradhan Mantri Krishi Sinchayee Yojana are important schemes that have been launched for enhancing food security in the wake of various threats facing agriculture. Additionally, soil testing laboratories have been set up across the country and methods are being looked at for better weather forecasting for early warning signs. The government's aim to enhance water use efficiency by 20 per cent will be vital considering that water scarcity is already prevalent in many parts of the country. Along with this, rainwater harvesting is being taken up by various state governments very seriously. The setting up of National River Conservation Directorate for conserving various water bodies will play an essential role in the future considering that many rivers are important sources of water for the citizens.

HEALTH

Climate change and its health related impacts are here to stay. This is why the country has stated that the National Health Mission will play a catalytic role in improving the healthcare needs of the country by identifying vulnerable population, building knowledge base and expertise as well as increase awareness and community participation. Programmes such as Integrated Disease Surveillance Programme and National Vector Borne Disease Control programme are expected to mitigate vector-borne diseases, such as malaria and dengue in future.

DISASTER MANAGEMENT AND PROTECTING BIODIVERSITY

Since the country is prone to natural disasters, such as floods, droughts, earthquakes amongst others, India has set up a Disaster Management body that would closely monitor any early signs of cyclones or suggest evacuation and also help State governments bolster disaster risk mitigation capacity. With India being home to one of the largest species of flora and fauna, efforts are being taken to ensure protection of various species. In fact, the protected area network has surged from 427 in 1988 to 690 in 2014. The Himalayan region, a strategic one but prone to global warming, is being studied for addressing issues such as Himalayan glaciers and associated hydrological consequences.

UTILIZATION OF FINANCES

A cess imposed on coal to the tune of ₹50 per tonne has been quadrupled to ₹200 per tonne, which would form the

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corpus of National Clean Environment Fund. This fund will be utilized for financing clean energy, technologies and until 2014, the aggregate amount was $2.7 billion, of which $2.6 billion is being used for 46 projects. The government has also increased taxes on fossil fuels and cut its subsidies on petroleum. These actions mean an implicit carbon tax, $140 for petrol and $64 for diesel, which is far higher than initial tax envisaged of $25–35 per tonne. Various banks have started issuing green bonds, for example, YES BANK Ltd, for raising funds that would fund green projects in the country. There have been good responses for these as well.

BOLD INDCs EVEN WITHOUT BINDING TERMS

In light of the above, India's INDC aims to adopt a climate friendly and cleaner path for economic development and achieve reduction in emissions intensity of its GDP by 33–35 per cent by 2030 from 2005 level. The country's strong push to renewable energy projects will add about 40 per cent of power installed from non-fossil fuel based energy resources by 2030 especially with technology transfer and low-cost international finance. India will be building capacities, would collaborate on research, and would deploy cutting-edge climate technology. India will look to significantly reduce carbon footprint and emissions in the overall scheme of things, rather than any specific department. It is estimated that the country would need $206 billion for implementing the actions in fisheries, agriculture, water and forestry (Figure 4). The NITI Aayog (National Institution for Transforming India) has estimated that low carbon development would entail $834 billion by 2030, a gargantuan amount, which would require cooperation from developed countries.

CONCLUSIONS

Even though the recent decisions do indicate a huge jump in climate change actions by the current Indian government, the intent signifies that India will act responsibly even without necessary coercion of developed countries. The leaders have clearly specified their commitment to combat climate change and cooperate with global efforts. However, India's development is more challenging as it must look at both development agenda but also plan ahead for future pressures that may arise.

Strategies such as increase in renewable energy capacity by five times by 2022, energy conservation of up to 10 per cent of the current energy consumption by 2018–19, etc., are all meant for taking India closer to the global objective of fighting climate change. The aspirations of developing countries to achieve equitable distribution of resources for a large segment of population is a daunting task but India not just demonstrates that it is possible but is also leading the way by moving in the right direction. Whether or not, the country is able to fulfil all of its promised INDCs needs to be seen but what is clear is that India shall not allow developed countries to impose any binding contract in the name of climate change. Prime Minister Modi and other senior leaders have made it amply clear that the country is mature enough to realize the ongoing effects of climate change and is itself a recipient of some of its problems. However, pragmatism prevails and the government has specified its intent rather than toeing the line of any one country. Policy changes, effective implementation mechanisms, close monitoring as well as a stringent timeline to bring about huge milestones in India's economy will all contribute in a positive manner to climate. Despite the country being ranked poorly on the HDI and a number of its cities being criticized for being extremely polluted, it is expected that the developments or projects being executed currently will have a role to play in the times to come. Hence, developed countries should look at moderating the consumption and utilizing their investments for development activities in countries with people living at subsistence level instead of specifically asking developing countries to cut down emissions. EF

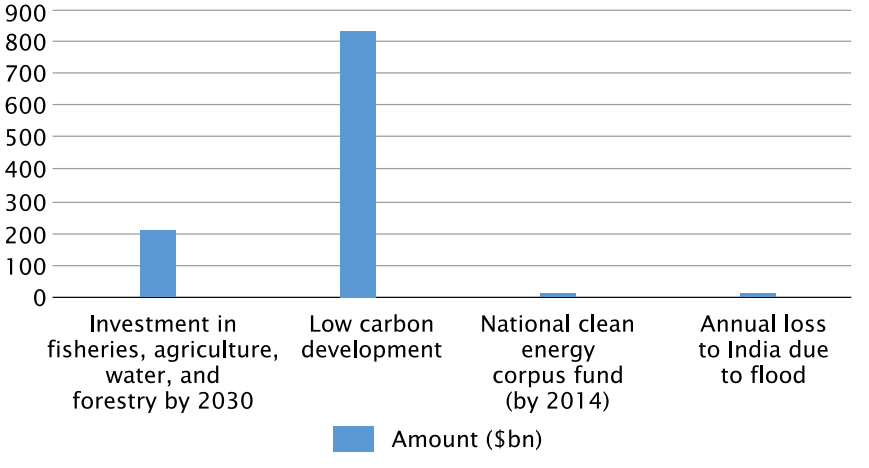

Figure 4: Investments needed to be done by India for reducing emissions
Source: www.world-nuclear.org/info

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The SOLAR QUARTERLY

DSSC
A New Era of Future Solar Cells
A Boon for Solar Energy Technique

*With about 300 clear, sunny days in a year, India is blessed with abundant solar energy. The geography and climate favour India and the country took lead at the international arena with the launch of the International Solar Alliance at the COP21 in Paris, recently. Keeping the enormous potential of solar cell technology in mind, **Dr K R Genwa** and **Chanchal Mahawar** discuss the advancements in solar cell technology with particular reference to dye-sensitized solar cells (DSSCs) that have emerged as attractive and promising solar cells in recent years. They discuss the science and technicalities involved in the preparation, working, detailed structure, and operating principles of DSSCs. Read on to know more…*

Enormous quantity of energy is available via renewable and non-renewable sources; the only difference between them is eternity. Non-renewable sources are finite and if they are continually used, one day they will run out. Energy from non-renewable resources includes fossil fuels, coal, petroleum gas, etc., which causes enormous harm to the earth's environment. Burning fossil fuels produces photochemical pollution from nitrous oxides, and acid rain from sulphur dioxide. Burning fuels also produces greenhouse gases (GHGs), including vast amounts of CO_2, that may be causing the phenomenon of global warming that the planet is currently experiencing.

GEOGRAPHY FAVOURS INDIA'S SOLAR CAPACITY GROWTH

Solar energy can be easily converted and used for electricity generation. It is energy from the sun and without its presence, all life on earth would end. Solar energy has been looked upon as a serious source of energy for many years because of the vast amounts of energy that are made freely available, if harnessed by modern technology. Speaking of India, India lies in northern hemisphere, the line of Tropic of Cancer passes through Madhya Pradesh, the region at which the sun appears directly perpendicular on June 21 in an event that is called Summer Solstice, and lies at 23°26'14.1" north of the Equator. Most regions on the Tropic of Cancer experience two distinct seasons: an extremely hot summer with temperatures often reaching 45°C (113°F) and a warm winter with maximum temperature around 22°C (72°F). Much land on or near the Tropic of Cancer is part of the Sahara Desert, whilst to the east, the climate is torrid monsoonal with a short wet season from June to September and very little rainfall for the rest of the year. Looking upon the temperature range

of both summer and winter, it is an ideal place for the installation of solar power plants.

The 21st session of the Conference of the Parties (COP21) to the UNFCCC was held in Paris in November–December last year. India's Prime Minister Shri Narendra Modi and French President Mr François Hollande launched the International Solar Alliance (ISA) at the COP21 in Paris on November 30, 2015, as a special platform for mutual cooperation among 121 solar resource rich countries lying fully or partially between Tropic of Cancer and Tropic of Capricorn. The alliance includes 121 countries that support the "Declaration on the occasion to launch the international solar alliance of countries dedicated to the promotion of solar energy". The alliance is dedicated to address special energy needs of ISA member countries. The participants are not only from Latin America and Africa but also include the USA, China, and France, who would all work together to increase solar capacity across emerging markets. The ISA is conceived as a coalition of solar resource rich countries to address their special energy needs and will provide a platform to collaborate on addressing the identified gaps through a common, agreed approach. Otherwise also, through the Jawaharlal Nehru National Solar Mission (JNNSM), the Government of India has set the ambitious target for installation of 175 GW renewable power by 2022, which includes 100 GW of grid connected solar power.

ADVANCEMENTS IN SOLAR CELL TECHNOLOGY

In 1839, the photovoltaic effect was discovered by Alexandre-Edmond Becquerel, a French physicist. This was 'the beginning' of the solar cell technology. The era of the solar energy power plants began with the introduction of thin film and crystalline silicon solar cells (photovoltaic cells).

Though conventional photovoltaic devices are promising for the direct conversion of photons into electrons, the prohibitive cost of these cells is uncompetitive with conventional power generating methods. On the contrary, dye-sensitized solar cells (DSSCs) have emerged as attractive and promising solar cells in recent years.

Since then, many solar cells were introduced with little advancements, such as cadmium telluride (CdTe), CIDS, amorphous in thin film, and monocrystalline, polycrystalline, buried contact, etc., in silicon solar cell. Later on, multijunction, hybrid, and upconversion solar cells came into action. Amongst these, hybrid solar cells found importance under which many other types were introduced with advancements. Quantum dots, perovskite, solid state, nano-crystalline, dye-sensitized, etc., are the types of solar cells that gave new direction to the development in this sector.

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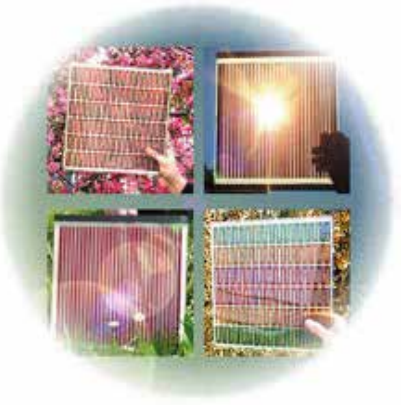
It is a disruptive technology that can be used to produce electricity in a wide range of light conditions, indoors and outdoors, enabling the user to convert both artificial and natural light into energy to power a broad range of electronic devices. The total efficiency of the DSSC depends on the optimization and compatibility constituents; as a conductive mechanical support, a semiconductor film, a sensitizer, an electrolyte and a counter electrode.



Picture 1: Use of DSSCs as attractive window sheets

Picture 2: Use of semitransparent DSSCs for decoration

PREPARATION

It is based upon the principle of photosynthesis—conversion of solar energy into chemical energy and production of glucose. It is in a similar way as the DSSC has tin oxide coated conductive glass as a mechanical support where one of the conductive slides will be covered with semiconductor film of a porous layer of titanium dioxide (TiO_2) nanoparticles (photo anode). The homogenous mixture of TiO_2 is prepared and in particular a chemical solution is prepared for the uniform coating purpose. One of the important factors that affects the cell's efficiency is the thickness of the nano-structured TiO_2 layer which must be less than 20 nm to ensure that the diffusion length of the photoelectrons is greater than that of the nano-crystalline TiO_2 layer. Then the TiO_2 layer is dried and sintered. This slide is coated with molecular dye by soaking it in the dye solution for 30–45 minutes or 24 hours (for result variations). Excess dye is removed by water or other solvents and the slide is dried. Finally, a counter-electrode made up of the conductive glass coated with suitable catalytic material (can be graphite, Pt, Mo, etc.) at the inner surface is covered on the anodic plate for closing the circuit. At last, two–three drops of modified electrolyte solution (for completion of redox reaction; I^-/I^{3-}) is poured between the slides (Figure 1).

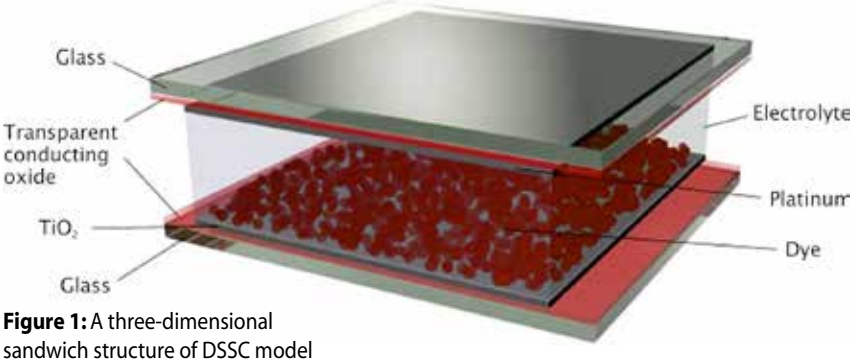


Figure 1: A three-dimensional sandwich structure of DSSC model
Source: http://inhabitat.com/solarprint-develops-ready-to-print-solar-cells

TECHNIQUES EMPLOYED IN PREPARATION OF A DSSC

Titanium dioxide coating

The working electrode was formed from fluorine-doped tin oxide (FTO), resulting in a transparent conductive electrode. The FTO surface is subjected to cleaning, and this can be done by using the following procedure: step-wise ultrasonic treatment in detergent, DI-water, acetone, and 2-propanol for 15 minutes at room temperature. A TiO_2 paste containing 20 nm sized particles (Solaronix, T/SP) was deposited onto the cleaned FTO substrate, via blade coating, to form a transparent, porous titanium oxide film. The doctor-blading process was repeated twice. The blade coated TiO_2 film was sintered in air at 500°C for 60 minutes. Also, to maintain adhesion between the TiO_2 nanoparticles in the porous film, the film can be treated with 40 mM $TiCl_4$ in a dry oven at 70°C for 30 minutes. The samples were then rinsed with DI-water and ethanol, and sintered in air at 500°C for 60 minutes. The edges of the sample were subsequently trimmed.

Adsorption of dye

To form the solar cell device, the TiO_2 film should be first immersed in a particular dye solution, consisting of particular solvent for dissolution (polar or non-polar solvent depending upon dye solubility), at room temperature for 24 hours. The dye-adsorbed TiO_2 film

Figure 2: Dye adsorbed on TiO_2 paste

should be then rinsed with acetonitrile or any other solvent and dried at 70°C for about 10 minutes (Figure 2).

Preparation of counter electrode

Conventional counter electrodes were prepared using a thermal reduction method. An H_2PtCl_6 solution was deposited via spin coating onto cleaned FTO glass and then heated at 450°C for 60 minutes. Other method is the particulate counter method, to form the particulate counter electrode, TiO_2 particle paste (Solaronix, R/SP) was blended with H_2PtCl_6 solution at a ratio of 0.2 ml of H_2PtCl_6 solution per gram of TiO_2 paste. The blended paste was blade coated onto cleaned 0.7 mm holed FTO and then sintered at 450°C for 60 minutes. The same sintering process was used for both the conventional counter electrode and the particulate counter electrode (Figure 3).

Redox electrolyte

Electrolyte containing I^-/I^{3-} redox ions is used in DSSC to regenerate the oxidized dye molecules and hence completing the electric circuit by mediating electrons between the nanostructured electrode and counter electrode. NaI, LiI, and R4NI (tetraalkylammonium iodide) are well-known examples of mixture of iodide usually dissolved in non-protonic solvents, such as acetonitrile, propylene carbonate, and propionitrile to make electrolyte. Cell performance is greatly affected by ion conductivity in the electrolyte, which is directly affected by the viscosity of the solvent.

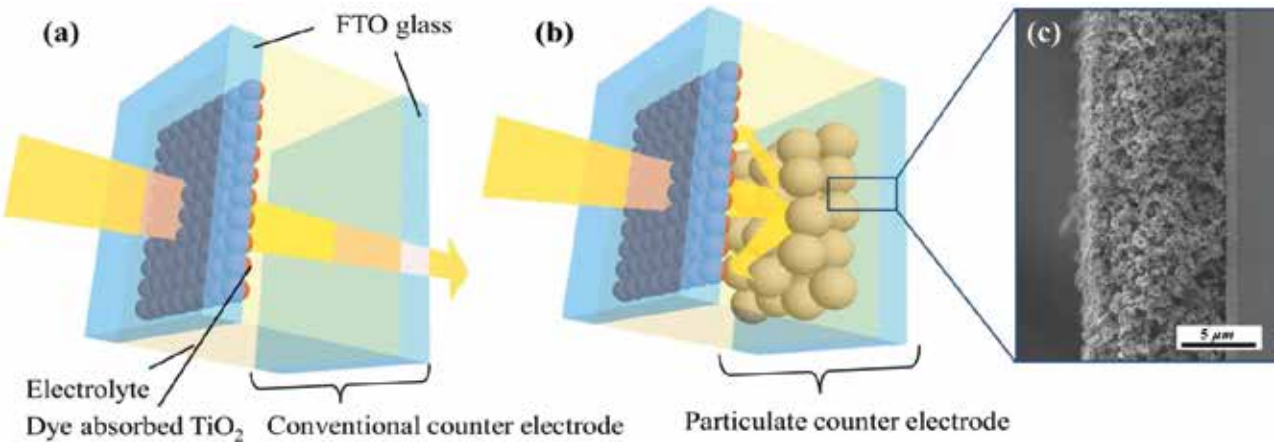


Figure 3: Schematic diagrams of the DSSCs with: (a) Conventional counter electrode; (b) Particulate counter electrode. The path of incident photons is shown by the arrows for each solar cell; and (c) Cross-section SEM image of particulate counter electrode
Source: DOI:10.1364/OME.3.000739

WORKING OF A DSSC

The dye is the photoactive material of DSSC, and can produce electricity once it is sensitized by light, it catches photons of incoming light (sunlight and ambient artificial light) and uses their energy to excite electrons, behaving like chlorophyll in photosynthesis. The dye injects this excited electron into the TiO_2. The electron is conducted away by the nano-crystalline TiO_2. A chemical electrolyte in the cell then closes the circuit so that the electrons are returned back to the dye (Figure 4). It is the movement of these electrons that creates energy, which can be harvested into a rechargeable battery, super-capacitor or another electrical device. In DSSCs, the photosensitizer is one of the most important components influencing solar cell performance, because the choice of sensitizer determines the photoresponse of the DSSC and initiates the primary steps of photon absorption and the subsequent electron transfer process. Performance of the cell can be explored by measuring different photovoltaic parameters, such as power point value, corresponding current (I_{pp}) and potential (V_{pp}), open-circuit potential (V_{oc}), short-circuit current (I_{sc}), and cell efficiency.

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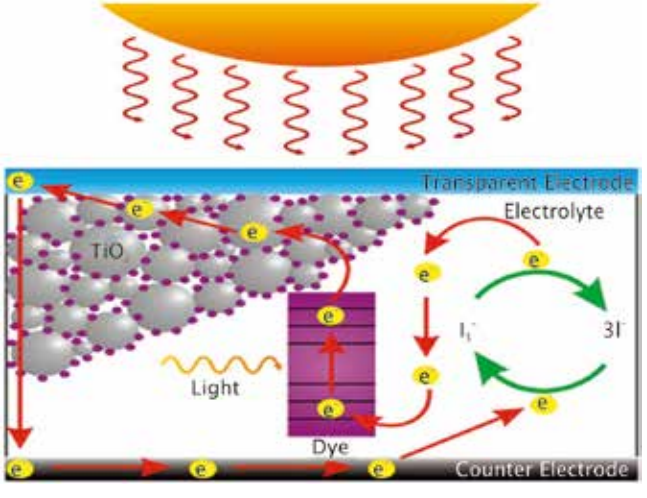

Figure 4: Cyclic process of DSSC

OVERALL REACTION PERFORMED IN A DSSC

$S + photon \longrightarrow S^*$ (a) Excitation process

$S^* + TiO_2 e^-_{(TiO)_2} + \longrightarrow S^+$ (b) Injection process

$e^-_{(TiO)_2} + C.E \longrightarrow TiO_2 + e^-_{(C.E)} +$ electrical energy (c) Energy generation

$S^+ + \frac{3}{2} I^- \longrightarrow S + \frac{1}{2} I_3^-$ (d) Regeneration of dye

$\frac{1}{2} I_3^- + e^-_{(C.E)} \longrightarrow \frac{3}{2} I^- + C.E$ (e) e^- recapture reaction

DETAILED STRUCTURE AND OPERATING PRINCIPLE OF A DSSC

First, a sensitizer molecule, which is adsorbed on the surface of a nanocrystalline TiO_2 electrode, absorbs the incident photon flux and is excited from the ground state (S) to the excited state (S*). One type of photoexcitation causes transfer of an electron from the highest occupied molecular orbital (HOMO) of the sensitizer to its lowest unoccupied molecular orbital (LUMO). Subsequent injection of the excited electron into the conduction band of the TiO_2 electrode results in oxidation of the sensitizer molecule. The injected electron diffuses through the TiO_2 electrode towards the transparent conducting oxide (TCO)-coated electrode and through the external load and wiring, eventually reaches the counter electrode. The oxidized sensitizer is reduced by I^- ions in the electrolyte, regenerating the ground state of the sensitizer, and I^- ions are oxidized to I^{3-} ions. The I^{3-} ions diffuse towards the counter electrode where they are reduced back to I^- ions. Overall, electric power is generated without permanent chemical transformation (Figure 5).

The photocurrent produced in a DSSC is directly influenced by the properties of the sensitizer. For example, the energy gap between the HOMO and LUMO of the sensitizer (which corresponds to the band gap, e.g., for inorganic semiconductor materials) determines the photoresponse range of the DSSC. Absorption over a wide range of wavelengths, extending into the near-IR region due to a small HOMO–LUMO energy gap, is necessary for harvesting a large fraction of the solar spectrum, which in turn produces a large photocurrent and thus results in highly efficient solar cell performance. In addition, the energy levels of the HOMO and LUMO must match the iodine redox potential and the Ecb of the TiO_2 electrode. For electron injection, the LUMO must be sufficiently more negative (higher energy) than the TiO_2 Ecb; the energy gap between the two levels is the driving force for electron injection. The HOMO must be sufficiently more positive (lower energy) than the redox potential of I^-/I^{3-} to accept electrons effectively. Thus, the molecular structure of the sensitizer must be strategically designed so that its properties are optimal for efficient DSSC performance. The authors have fabricated DSSC with the use of some low-cost organic dyes in their laboratory (Figure 6).

CALCULATIONS

Photovoltaic performance: Under full solar spectrum irradiation with photon flux I_o = 100 mW/cm^2 (air mass 1.5), the photon energy to electricity conversion efficiency is defined as (*Source: Gratzel 2003*):

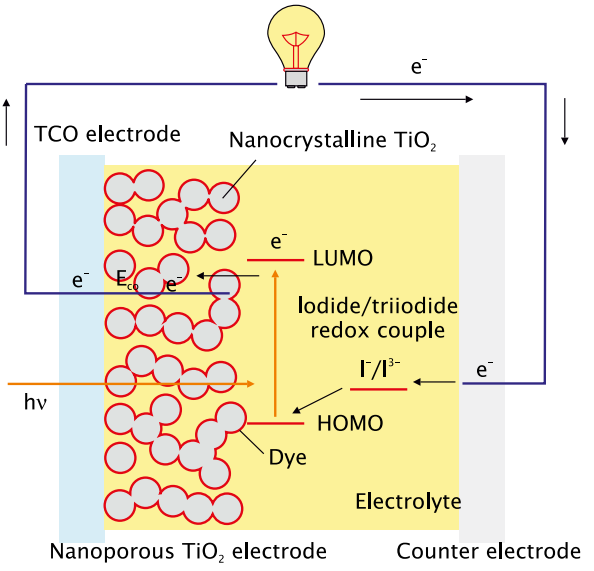

Figure 5: Schematic of a DSSC illustrating the mechanism of electric power generation
Source: Kohjiro Hara, Nagatoshi Koumura, Material Matters 2009, 4.4, 92

Figure 6: Circuit employed in a DSSC

$$\eta = \frac{J_{sc} \times V_{oc} \times FF}{I_o}$$

Where, J_{sc} is the short circuit current, V_{oc} the open circuit voltage, and FF is the fill factor of the solar cell, which is calculated by multiplying both the photocurrent and voltage resulting in maximum electric power delivered by the cell.

Incident photon-to-current conversion efficiency (IPCE):

$$IPCE(\lambda) = \frac{1240(eV\ nm) \times J_{sc}(\mu A/cm^2)}{\lambda\ (nm) \times I\ (\mu W/cm^{-2})}$$

'Dark current' in a DSSC is mainly due to the loss of the injected electron from nanostructured wide bandgap semiconductor (say TiO_2) to I^{3-} (the hole carrier in solution electrolyte).

$$V_{oc} = \frac{K_g T}{\eta} \ln\left(\frac{I_{inj}}{I_{dark}} + 1\right)$$

CONCLUSIONS

Solar photovoltaics power generation has long been seen as a clean energy technology which draws upon the planet's most plentiful and widely distributed renewable energy source—the sun. The solar cell that currently has the largest share in the market is based on crystalline silica, still it is too expensive to be able to compete with conventional sources of energy. The power conversion efficiency of a DSSC is highly reliant on its materials, which puts it at the forefront of research. However, it is not alone in its importance, as other areas are equally crucial in the quest to realize stable, efficient, and low-cost DSSCs. Better performance and high conversion efficiency is impossible without taking into account the importance of the materials in DSSCs, so the focus on the preparation/deposition methods and materials is essential. For this to materialize, many scientists and researchers are looking forward to metallic dyes, as they give far better and long-lasting results. But they are harmful and cause pollution. An alternative for them is now employed in DSSCs by the use of organic and natural dyes. They too are found to give good results and are also cost-effective but are not durable. However, the performance of DSSCs based on organic dyes has not yet exceeded those based on Ru complexes. To achieve higher performances for solar cells based on organic dyes, as compared to that of solar cells based on Ru complexes, sophisticated molecular design of organic dyes is required. Thus, newer type solar cells with improved performance and functionality are continuously being developed. Recent advances have developed DSSCs as a low-cost and efficient alternate to silicon PV cells. Organic dyes have proved to be a viable option for metallic dye-based DSSCs. Realizing the need of the hour, an urge of improvement in solar conversion efficiency is a must. Organic dyes, no doubt gained much attention but still, the durability and efficiency of cells has remained an issue to be resolved, which can be improvised synthetically by means of simple reactions or mixing dyes. Electrolytes used in cells must be chosen in a way that they sustain through the years and can be modified for different purposes. Scientists are still trying for the innovations and the other advancements in present solar cell technologies, so that it can be used as the best alternative for green and clean technology. Hopefully they will succeed in their efforts! EF

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Green ICT Reduces Literacy Barriers in India

A Case Study on I-slates

In 2013, The World Bank and International Energy Agency's (IEA) data noted that in at least 20 countries, half or more public primary schools lacked access to electricity. Together, this number suggests that 90 million primary school students in Sub-Saharan Africa, 94 million students in South Asia, and four million students in Latin America, regularly attend schools without electricity. ***Sharada Balasubramanian*** *points out that there is a ray of hope in the way students in a remote village in Telangana have been provided with electronic solar-powered tablets—I-slates, so that they are not dependent on electricity for their daily learning and education needs. Read on to know more…*

Electricity is very important for expanding literacy in rural areas, as it not just enables introduction of Information and Communication Technologies (ICTs) into the classroom, but is crucial to development in areas where grid power is unavailable. Statistics from the District Information System for Education (DISE) in 2014–15 reveal that only 53.3 per cent of primary and secondary schools in the rural areas of India have electricity connection (Figure 1). About half a million primary schools (each) have less than three teachers. The average per capita income of the families of the students attending these schools is less than $500 per year, making education costlier. In this case, how could they get an educational device or even a textbook?

A ray of hope comes from a village in India. At a small government school in Mohamad Husain Palli, a remote village in Mahabub Nagar district in Telangana, students are engrossed working on computers.This school has no electricity, yet, the students can run the computers, thanks to the solar panels installed here. Though ICT initiatives are on the rise in India, it is essential that these technologies are green and sustainable. In 2007, analysis from Gartner showed that ICT is responsible for 2 per cent of global carbon emissions, and is likely to be responsible for 5–8 per cent of the global carbon emissions in future. Hence, making ICT environment-friendly and emission-free is important.

ICT BEYOND GRID: A CASE STUDY ON SOLAR-POWERED I-SLATE

At Mohamad Husain Palli, in 2008, a solar-based ICT intervention brought about transformation, changing the way students looked at education. I-slate, an electronic solar-powered tablet was developed by Dr Krishna Palem, a professor at Rice University, USA, and Nanyang Technological University, Singapore, in association with Villages for Development and Learning Foundation (ViDAL)—an NGO which worked in Mahabub Nagar district; The Institute of Sustainable and Applied Infodynamics (ISAID); and Seso Media Group, USA to cut literacy and power barriers. The device, which just needs 3 W to function, runs on solar power, promotes self-learning, and works well in villages where teachers are less. When the idea was proposed, the district planned to bring in 50,000 I-slates to middle and high school classrooms over a period of three years. Since computers were introduced into the villages much earlier, children were already aware about the basics of information technology.

I-slate went through four rounds of testing, and in every phase, the device was improvised based on the feedback from students. For instance, when the product was introduced, it was bulky, and when this was communicated to the developers, improvisations were made and it was made lighter and easy to use.

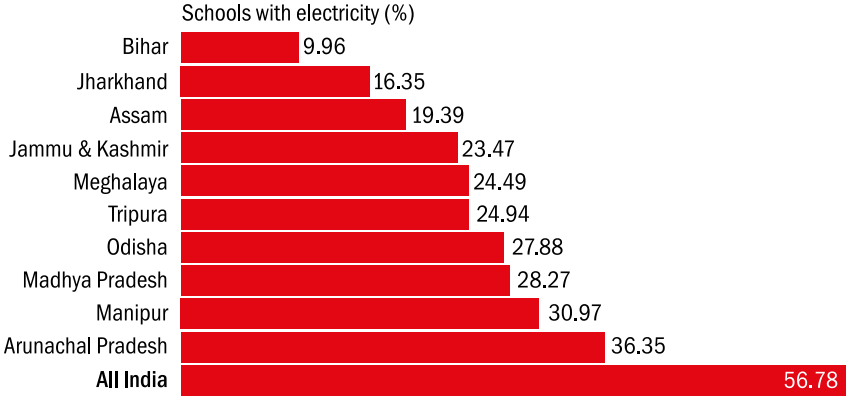

Figure 1 : Percentage of schools per state in India that have access to electricity
Source: DISE

METHOD OF USING I-SLATE

The school books are uploaded into the I-slate in a portable document format (PDF). The book chapters contain a data bank of multiple choice questions (MCQs) with answers, and when a student answers the question, the device will give the answer. Students were trained to use the device, and as time progressed, news and videos were loaded into it for students to know what was happening in the world. Further, students also used the device to take photographs, record videos, listening to audio, other than doing homework (Pictures 1 and 2).

Later, Seso, a designer group collaborated on the I-slate initiative for designing. Then, along with Seso, 826 LA, a not-for-profit organization from Los Angeles chipped in, and a joint effort between Mohamad Husain Palli School and Thomas King Middle School in Los Angeles was initiated. The design team used feedback from children to work on the features. They incorporated elements from video games and social networking to enthuse students. For instance, a colourful cartoon creature in the corner of the I-slate screen changes expression according to the child's actions. The cartoon character shows happiness when the child gets better grades. Computing experts from the USA, Switzerland, and Singapore developed a new technique for doubling the efficiency of computer chips by trimming away the portions that are rarely used. The microchip used in I-slate is just a fraction of the electricity used by computer chips. It is believed that the chips could make it possible for the device to run on

Pictures 1 and 2: Students using the I-slates

solar power in the future, just the way handheld calculators function.

The collaboration for this project was furthered by involvement of social scientists and volunteers from ViDAL, who worked with the research team in refining the hardware and teaching content. The local government welcomed this initiative. Vijaya Kumar, who was the District Education Officer in Mahabub Nagar when I-slate was launched said, "The learning through such technology is a permanent one. The children get spontaneous answers to their questions, which does not happen in regular programmes." The device was chosen by the Institute of Electrical and Electronics Engineers (IEEE) as one of seven technologies that will have world-changing implications on the way humans interact with machines, the world and each other. NTU, one of the collaborators in the project, is focusing on developing green energy projects in line with its sustainability research that consumes less power, and runs on solar. This research will not just promote sustainability, but development of such low-cost technologies will narrow the digital divide among the poorer communities in the world. This has already been witnessed in the case of I-slate.

IMPACT OF THE TECHNOLOGY

Before the introduction of I-slate, students watched television after coming back from school. Today, the scenario is different. A survey was done to understand the use of I-slate beyond school premises. Children spent many hours exploring the device at home and are inclined to learn and do their homework on time. The excitement stems from the fact that children are curious on how technology responds to their touch. It is a relief for teachers as well. Earlier, they waited for a long time, to get books from the government, and that is no longer required now. Students are also freed from the burden of carrying heavy books to school every day. P Niranjana, Assistant Professor, Tata Institute of Social Science (TISS) and an ICT researcher who worked on this product said, "The focus of the project was on how the community could benefit from the technology, rather than introducing a new technology and attempting to fit people into that. This works the other way around. We created something keeping the community in mind".

This is an opportunity for the children to interact and communicate. The teachers learned from the students on using this device, and it improved their relation. This is typically how an ICT initiative in a rural system needs to work. ICT can be a successful initiative only when the local community is involved in the process. For instance, the elders in the family depend on the children to do maths calculations, like calculating their wages, as most of them are labourers. For people in the village, these are life situations. Under such circumstances, the learning elements are quite strong. Before I-slate was in the testing phase, the developers spoke to elders in the family. It was important to involve the elders in the whole process. Niranjana further said, "It is not true that villagers do not want to send their children to school. They lack the resources to do it. If their

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children get support, they will educate them. The communities are intelligent and if the children use the technology for education, they welcome it". Initially, the price of an I-slate was fixed at $48. The project is still awaiting funds for implementation and research is also going on in parallel. The new I-slates will feature a new sense-optimized user interface designed to improve educational outcomes in rural India.

As electricity plays a crucial role in the development and use of ICTs, and sustainable development is the key in developing countries, it is essential to integrate ICT with green energy. There is enough proof that energy is intrinsically linked to economic, environmental, and social dimensions of sustainable development. India has about 300 sunny days, and solar energy can be easily tapped to increase the literacy rate in India, if we can generate funds to support such projects. Extending solar power into remote areas can assist education in a number of ways. In the villages where darkness sets in early, presence of solar lighting can support students' studies by extending their study hours at night. Solar lanterns and solar lighting systems assist them in studying at home. Studies have indicated that rise in the number of solar lights in the villages has a correlation with students taking an interest in studies on their own. Solar lanterns have health and safety advantages in comparison to kerosene lamps which hamper the health of children in rural areas. Another advantage is that, most of the times, school children in villages have to travel long distances, and with solar lights in their hands, there is less fear among parents to send their children to schools. This automatically increases the number of children who can go to school.

SELCO FOUNDATION'S SUCCESS STORY

With a constant focus on serving the unserved and the underserved, the SELCO Foundation is tied to process learning and continual user feedback, with strong partnerships at each step. Innovations at SELCO Foundation are characterized by appropriate technology, customized financing and dissemination, and measurable impact. SELCO Foundation's digital intervention has enabled rural schools to be grid-independent. The solar-powered computer overcomes the issues of inconsistent grid power. The Foundation also set up energy-efficient solar computer laboratory in schools (Pictures 3 and 4). Such interventions are tuned to schools' needs. For ICT to enter schools, portable solar projector system was introduced to make multimedia education accessible and effective. Since it is portable and energy-efficient, teachers could take it home to safeguard against thefts, a common issue in rural areas. The success of the programme demanded a long-term relationship with community, school administration, teachers and parents, which happened in this case. In addition, there is a need to understand the programme itself and how technology performs. This happened with the Foundation's work in Government Higher Primary Schools in Kolar region, Karnataka, for running the Digital Education programme needs via solar-powered computers.

Schools which had 65–265 students in the age group of 12 to 16 years from lower income backgrounds, coming from interior India, with unreliable grid were selected for the project. These schools faced at least three hours of power cut during the school day. SELCO Foundation reached the rural schools directly to support them with multimedia. The solar-based technology is used for powering portable DVDs, computers, and portable projectors. The projector has an in-built software, which can

Pictures 3 and 4: Computer classes taking place at the energy-efficient solar computer laboratory in schools
Source: www.selcofoundation.org

To understand the national capacity to support ICT integration into education, it is essential for policymakers to know educational institutions which have basic electricity facilities, and identify gaps in infrastructure. This will help them take decisions on ICT tools that are needed. When schools are electrified, it has been correlated with other developments, such as better teachers and improvements in test scores.

recognize standard audio, video, and text files. It can be connected to laptop, android PCs, and USB memory sticks, and can run continuously for about four hours if the battery is fully charged, making it a great solution for rural schools where there are power cuts for 3–4 hours during school day. The solar-powered light-emitting diode (LED) projectors are lightweight and hence, easy to carry from one location to the other. Though computer was owned by some schools or donated by NGOs, the solar power projects were tailored according to the needs of the schools.

Usually, beneficiary schools are asked to contribute half the cost, and the rest is funded by SELCO Foundation's donors. The Foundation contributes in designing, structuring, and financing the programme. The families could pay a small monthly fee for classes if an external faculty is involved. Digital Education focuses on making technology accessible and functional for educational purposes. There are approximately 50–180 school students who benefit in each school through the implementation of this programme. Often, the common problem faced in rural areas with respect to education is lack of technology, power cuts, and theft. To address all these issues, SELCO Foundation's portable solar projector system was introduced. The system has a central charging station, where the teachers can charge the battery, and then carry it along with the projector to classes. This costs between ₹52,000–₹60,000 (inclusive of projector, panel, batteries, charge controller, and warranties). The Foundation works with the institution on financing with available resources. The project has been able to offer better education resources and infrastructure, and reach a wider number of students.

CUTTING ACROSS BARRIERS: A BROADER PERSPECTIVE ON THE USE OF ICTs IN SCHOOLS

A variety of ICT approaches are needed to support teaching and improving overall education management. Where battery-operated ICTs are coming up, majority of ICTs, such as television, computers, and the Internet continue to require a more stable energy source, and for that to happen, ICT has to be integrated to energy that is regularly and readily available. Location is a hurdle in developing nations, as power is not available in these areas and may hinder ICT from entering into these villages. Even if schools have electric connection, constant outages in the grid power impede the use of ICT on a continuous basis.

To understand the national capacity to support ICT integration into education, it is essential for policymakers to know educational institutions which have basic electricity facilities, and identify gaps in infrastructure. This will help them take decisions on ICT tools that are needed. When schools are electrified, it is correlated with other developments, such as better teachers and improvements in test scores. A study states that electricity "allows the access of lower-income people to lighting, communication, and a variety of educational delivery opportunities. One of the major impacts that electrification has created is reducing illiteracy and improving the quality of education". The inverse is also true—schools without electricity tend to perform more poorly than their electrified counterparts. According to data from 45 developing countries, youth literacy rates tend to be lower in countries with electrification rates below 80 per cent.

As per the latest census in India, 72.2 per cent of the population lives in rural areas. It is a well-known fact that potential for solar energy is huge in ICT. The demand for electricity is going to rise with the increasing population, and developing countries such as India, which need to push education into rural areas, and also give them basic electricity, can use solar energy to their advantage. Alternative energy, such as solar and wind power can enable wider inclusion of students in ICT education and significantly reduce the rural urban power divide. Whereas government policies need to focus on generating energy from sustainable sources, ICT designers need to focus on devising technologies that do not need direct grid power, and consume less power. Green ICT initiatives such as I-slate in rural India are scalable not just here, but globally. However, the practical problem still remains financing such technologies that can transform literacy. The World Bank has noted that India's regulatory framework "fails to adequately address utilities' long-term financial concerns". Project developers consequently report difficulty finding credit and financing for renewable energy projects. As a report puts it, "the non-availability of sufficient credit facilities and the difficulties in obtaining required finances for energy saving projects are strong deterrents

to investments in energy efficiency in India.

During the project testing at Mohamad Husain Palli in Mahabub Nagar district in Telangana, the students were allowed to take the I-slates back home. That made a difference, as children could continue their studies and finish their homework in their house. Back in school, teachers could monitor the time spent by students on I-slate, so that they are aware of its usage at home. Rajeswari says, "We thought we could get the government to be excited, however, there are issues. They want the equipment, but they do not want the children to take it home. The district administration has very little discretion and funding, and Central government could have other priorities. Hence, we are looking for private investments to implement this project." According to Pingali, initially the school, teachers, and the regional education officer were supportive, but the administration had its own limitations. They received no other support.

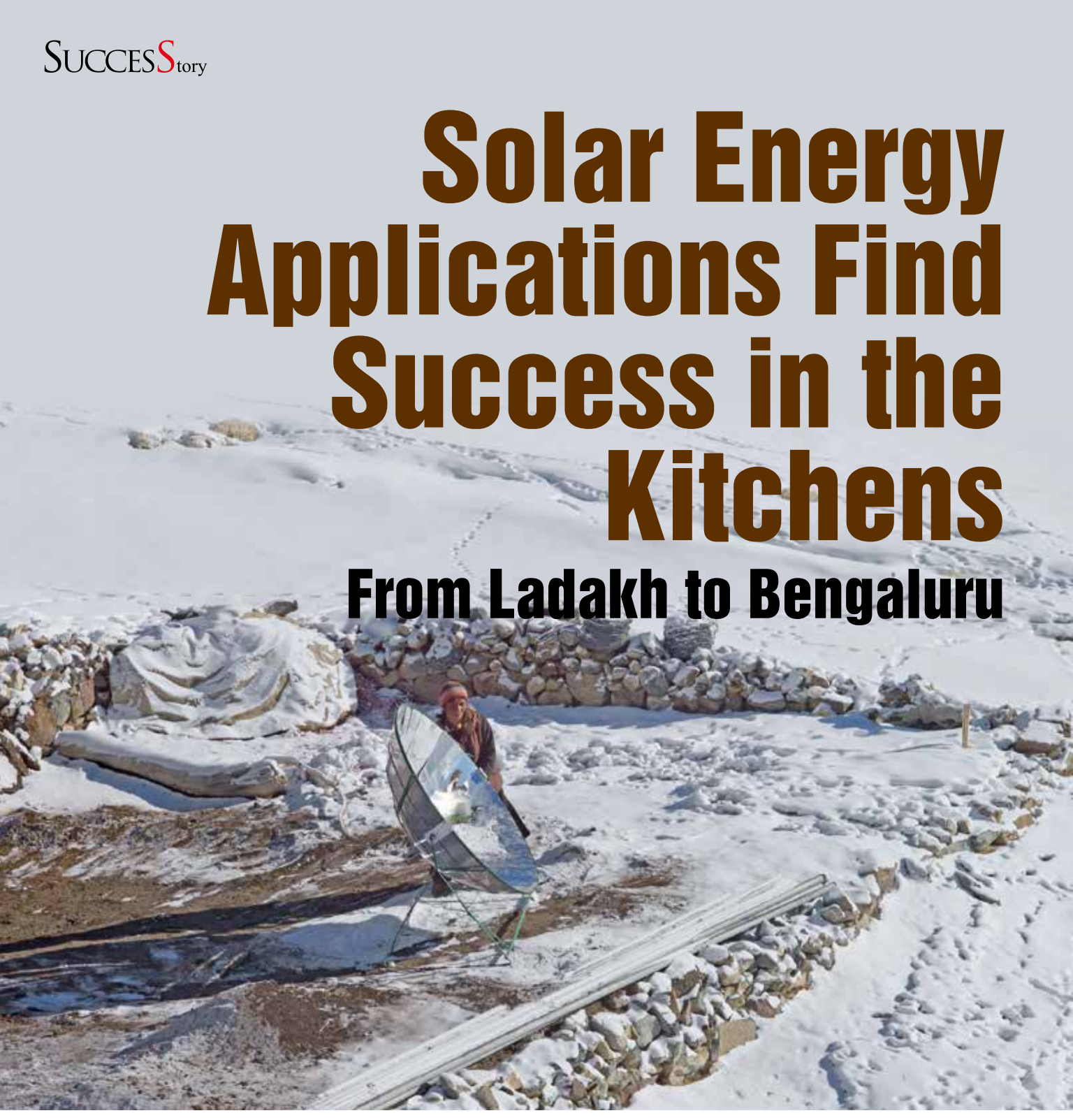
Rajeswari further says, "Government support will definitely help in bearing the Internet cost for example, so that teachers can download information to load onto the device. They can beat part of the cost of the slates, so that we can get funding from external investors." But none of these things have happened so far. After the product underwent four rounds of testing, I-slate is now in the lab where it was invented, as researchers and developers are now strongly looking at private investment to implement this project. Sustainable and low-cost energy saving technologies like this are crucial for development in India and other developing nations where literacy issues are high, and lack of power is a constraint. However, for innovations to be implemented, coordinated efforts among NGOs, technology experts, and the government is essential. On the future of I-slate, Rajeswari says, "There will be variations in the product for various segments of people. However, there will absolutely be no compromise on the quality despite a low-cost initiative. I-slate is a model that can be replicated across the country. If I-slate works in an extremely remote village like Mohamad Husain Palli, why will it not work anywhere else?" She has a valid question! EF

Ms Sharada Balasubramanian is an environmental journalist who has been keenly writing on water, conservation, energy, and rural development for the last several years. Her stories and articles are linked to understanding the linkages of these issues to people, development, and economics. Email: sharadawrites@gmail.com

Note: The author acknowledges the following sources: http://www.dise.in/Downloads/Publications/Documents/Rural_2014-15.pdf; and http://www.selcofoundation.org/project/digital-education/

Solar Energy Applications Find Success in the Kitchens

From Ladakh to Bengaluru



*In this report, **Parul Goswami** highlights the innovative application of the solar energy technologies for cooking purposes in the respective kitchens of an educational institution in Ladakh and a religious organization in Bengaluru. She points out that the increasing costs of fossil fuels and dwindling reserves coupled with adverse impact on the overall environment due to burning of fossil fuels make a strong case for installation of solar steam cooking systems at other organizations and institutions throughout the country.*

India's Prime Minister, Shri Narendra Modi launched the International Solar Alliance (ISA) of 121 countries with the French President, Mr François Hollande, at the Paris COP21 climate summit as a special platform for mutual cooperation among 121 solar resource rich countries lying fully or partially between Tropic of Cancer and Tropic of Capricorn. The alliance includes 121 countries that support the "Declaration on the occasion to launch the international solar alliance of countries dedicated to the promotion of solar energy".

Significantly, in Ladakh, in Jammu & Kashmir, solar energy has become a way of life. Ladakh's topography is extremely harsh due to high altitude, low rainfall, and the extreme cold, particularly the long winters make the region isolated. Under such conditions, ensuring a sustainable supply of energy becomes an extremely difficult task. Unfortunately, the cold desert and scarcity of biomass resources in Ladakh had made the energy situation heavily dependent on fossil fuels which has led to a huge burden on the economic life of people and the environment at large. It was in this observation that Ladakh needed a development plan for providing energy access to the remote villages and driving sustainability into development planning.

Appropriately, now the Ladakh Renewable Energy Development Agency's (LREDA) 'Ladakh Vision 2025' sees to the sustainable integrated development of the Ladakh region, micro-level planning was carried out in each village to assist development planning with LREDA coming up with a holistic plan for securing energy needs of the region. Solar energy is fast gaining momentum, as this region enjoys 320 cloud free days in a year with highest global radiation. Ladakh, with huge tracts of barren lands, has huge potential for solar energy which can be used to generate electricity. Realizing the region's potential in the field of solar energy, Prime Minister Modi recently announced ₹80,000 crore package for Jammu & Kashmir. Today, top solar companies are tapping business opportunities in the region while also involving the villagers in all the activities of the project, thus developing a participative approach in rural development.

JAWAHAR NAVODAYA VIDYALAYA'S SUCCESSFUL SOLAR COOKING INITIATIVE IN LADAKH

Embracing cleaner and cheaper energy, Jawahar Navodaya Vidyalaya, a residential school in Leh district in Ladakh has implemented an 80 m^2 capacity Concentrated Solar Project for the purpose of cooking for about 600 students and staff of the establishment. LREDA, in the year 2011, commissioned the system (Five Scheffler dishes with 16 m^2 per dish area) on demonstration basis to cater to the energy demands of cooking at the school (Picture 1). Based on the success of the project, LREDA is now implementing 14 more similar systems in the Leh district-based other schools and establishments. Sharing his experience of cooking using solar energy, Mohamed Mossa, the head cook at the school said, "The work load has declined. We can cook tonnes of rice, pulses, and vegetables in these large cookers simultaneously and it saves a lot of time and the system is very easy to use" (Picture 2).

Prior to the implementation of the Concentrated Solar Thermal (CST) system, the school was using liquefied petroleum gas (LPG) for its cooking purpose. "The operation of the solar steam cooking system in the school has led to a drastic reduction in the use of LPG gas over the years. The system helps the school to make annual reduction of 1,080 LPG cylinders usage, saving approximately 14.04 lakh. The solar cooking system also reduces 19 tonnes CO_2 per annum", said Reuben Gergan, Senior Project Engineer of LREDA. He further added that LREDA is also under the process of implementation of solar lighting solutions (solar power plant and solar street lighting) and solar water heating to meet energy needs of the school. "With such systems installed at schools the students will learn about cooking with solar energy and how to save energy and our environment. It will also create curiosity among students about clean energy and inspire them to later pursue careers in renewable energy", suggested Manoj Kumar, a teacher at Jawahar Navodaya Vidyalaya School, Leh.

OTHER SOLAR COOKING INITIATIVES IN INDIA

The Solar Steam Cooking Systems—an innovative low carbon, all-weather

Picture 1: Scheffler dishes installed at Jawahar Navodaya Vidyalaya, Leh, Ladakh
Source: Ladakh Renewable Energy Development Agency (LREDA)

Picture 2: Steam cookers in use at the school's kitchen in Ladakh
Source: Ladakh Renewable Energy Development Agency (LREDA)

Picture 3: Steam cookers in use at the Sree Siddaganga Mutt

cooking solution are being widely used in India today by the leading institutions and industries. The systems are eco-friendly and help in saving emissions caused by fossil fuel-based systems to a great extent without compromising on quality of the steam required. The solar steam cooking systems can be used to cook food for 500 people and above up to 100,000 plus meals. The leading institutions and industries of our country have already adopted the solar steam cooking for their large cooking needs. Two types of solar steam generating systems; one based on fixed receiver E-W automatically tracked concentrating technology (Scheffler) and the other on fully tracked receiver on dish technology (Arun) are under promotion in the country.

SREE SIDDAGANGA MUTT IN BENGALURU PROMOTING SOLAR COOKING

When the entire city of Bengaluru is looking for new avenues in thriving information technology industry, a religious institution (Mutt), at a mere distance of 63 km from the IT city, is looking for renewable alternatives. Sree Siddaganga Mutt is an ancient ashram (a religious institution); it was established by Sree Gosala Siddeshwara Swamiji in the 15th century CE and is currently headed by Dr Sree Sivakumara Maha Swamigalu. Although it is an ancient ashram and its head, Dr Swamigalu is a centenarian (born April 1, 1907), yet they both have showcased to the world a modern, scientific, and environment-friendly vision. Sree Siddaganga Mutt is known for its social revolution. Years ago, when the weak, the oppressed and the so-called backward people were denied the study of Sanskrit texts, it was Sree Siddaganga Mutt which started providing studies in Sanskrit and the Vedas to one and all. Sree Siddaganga Mutt is famous for its Dasoha tradition. According to this tradition, free food is provided to all. It is a challenging task to feed this large number of students and the pilgrims. Annually, for about a fortnight, around 50,000 people who assemble for the Agriculture and Industrial Exhibition, Car Festival of the Mutt, and the Cattle fair, are also provided free food.

The estimated cost of serving meals to the students, the visitors, and pilgrims per day runs into several hundred thousands of rupees and most of this expenditure is met by the donations in terms of food grains and cash. Sree Siddaganga Mutt has always been in favour of promoting alternative sources of energy to help humanity and the future generations. Shivanand Nashi—the Chief Operating Officer with Unisun Technologies, explains about such alternatives. "In the Mutt, type of fuel used for cooking is wood and around 750,000 kg of wood is used for consumption per annum. The total cost of fuel per annum is around 2,250,000 ($44,117.6). Solar steam cooking system is an efficient and hygienic type of cooking solution for industrial/institutional canteens and religious places. The steam generation by Solar Parabolic Concentrators is a tested and proven technology. Apart from its commercial viability, the system is pollution-free, eco-friendly, noiseless, and provides pure energy for cooking food ." Unisun Technologies is the company that has installed solar steam cooking system at the Sree Siddaganga Mutt (Picture 3). The solar steam cooking system is expected to save around 70 per cent of the current fuel per annum if in operation for 300 days.

CONCLUSION

The installation of Solar Steam Cooking Systems makes environmental as well as economic sense in the long run. The increasing costs of fossil fuels and dwindling reserves coupled with hostile impact on overall environment, due to burning of fossil fuels, make a strong case for installation of solar steam cooking systems. EF

Ms Parul Goswami graduated in Journalism from Jamia Millia Islamia University, New Delhi. She has played tennis at international level and is a Delhi-based journalist who is very passionate about writing on renewable energy initiatives. Email: parulgoswami2002@yahoo.com

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7th Intersolar India 2015

India's Largest Exhibition and Conference for the Solar Industry

The seventh Intersolar India, the largest exhibition and conference for the solar industry in India, took place in Mumbai, Maharashtra, from November 18–20, 2015. The positive atmosphere of the exhibition reflected the strong state of India's solar market. Companies and investors took full advantage of opportunities to exchange ideas and information; numerous contracts were signed and cooperation agreements reached. With 200 exhibitors, the event was completely booked out several weeks before the opening date. Companies from 12 countries presented their products, solutions and services to around 11,000 international visitors—an increase of 20 per cent over the previous year. Around 680 attendees discussed the opportunities and challenges posed by India's solar industry with over 100 speakers. Also, the fourth Intersolar AWARD for Solar Projects in India was presented.

On November 18, 2015, Shri Tarun Kapoor, Joint Secretary, Ministry of New and Renewable Energy (MNRE), Government of India, helped open the exhibition at the Bombay Exhibition Centre with great ceremony. Prof. Dr Eicke R Weber, Director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, served as keynote speaker, discussing—The Role of Solar Energy in our Future, Renewables Based Energy System. Exhibitors and visitors were evidently extremely satisfied with this year's exhibition.

HIGHLIGHTS OF THE EVENT

Amid the event's lively atmosphere, numerous contract and partnership deals were reached. Shri Rajendra Shukla, the Minister for New and Renewable Energy in the Government of Madhya Pradesh, announced the start of the world's largest solar project, Rewa Ultra Mega Solar Project at Intersolar India. The project with a total of 750 MW is to be installed over an area of 1,560 hectares, with completion projected for June 2017. The Chinese company Huawei Technology and the

Indian company Waaree Energies used the exhibition to announce their future partnership: Waaree will procure from Huawei intelligent PV systems and string inverters with a total output of 100 MW.

The industry is experiencing a boost, not least following the Indian government's decision to increase the installed PV output thirtyfold to 100 GW by the year 2022. Four to six GW of additional output are projected for 2016, which would put India in the 4th place among the world's top solar markets. Given its high level of solar irradiation, abundant open spaces, and steadily growing energy needs, India is considered one of the most attractive sites for solar energy. But at the same time, the country still lacks sufficient capacity to produce PV modules and also needs national and international investors. Intersolar India was the perfect arena to discuss objectives and bring together companies, investors, and representatives of science and politics to create the right conditions for meeting these objectives. This year's conference also picked up on these themes with its focus on the Indian market and energy storage.

FORWARD-LOOKING DISCUSSIONS AT THE CONGRESS

Hundred experts from research and industry shed light on current developments in the Indian solar market. The Indian government's growth targets were the subject of such presentation as 'India's PV Market: Driving a New Momentum' or 'Project Financing: Promising Prospects in the Indian Context'. The experts agreed that though the goals were ambitious, they were also thoroughly achievable for the country. However, still more incentives are needed, especially to achieve the goal of installing 40 GW of roof-mounted installations. Visitors and exhibitors were obviously extremely satisfied with the presentations and fresh ideas at the events. "The conference plays a central role in giving us an overview of developments in India's solar industry. It is also a good opportunity to meet and understand opinion leaders in the industry," said Kishor Sharma, Regional Sales Manager North BU Regenerative and Photovoltaic, Bonfiglioli Renewable Power Conversion India Pvt. Ltd.

Particular interest was generated by the sessions titled, 'Field Experience of Ground Mounted PV Power Plants in India' and 'Field Experience of Rooftop PV Power Plants in India' by Rakesh Bohra, Infosys, and Harshita S Kumar, L&T Construction. Visitors were particularly excited about roof-mounted installations, as the Indian government hopes to install around 40 GW of commercial and industrial roof-mounted installations by the year 2022.

For the first time, the 4th Indo–German Energy Symposium took place at the same time as Intersolar India as one of the conference's side events. With workshops such as Making RE and EE Business a win-win for Private and Public and Bankable Business Models to Finance Solar Projects in India, the sessions offered fresh ideas on the profitability and financing of solar technologies.

INTERSOLAR AWARD FOR SOLAR PROJECTS IN INDIA

For the fourth time, the Intersolar AWARD in the category Solar Projects in India was presented at this year's Intersolar India. A panel of judges had nominated eight pioneering projects in advance, three of which were honoured with the Intersolar AWARD. The key criteria for the decision were the social relevance of the winning projects, coupled with their particular benefits to the environment. The decision-makers also praised the degree of technological innovation and the role of the winning projects as models for other regions to follow.

Among the projects honoured was the Solar Power Plant at Cochin International Airport by Bosch Ltd with an output of 12 MWp. Under this project, the company designed and operated a solar power installation at Cochin Airport. This has made the airport the first in the world to run exclusively on solar energy.

Sterling and Wilson Ltd won the award for their 11 MWp Total Turnkey Solar Project in Maharashtra. The solar installation supplies 18,000 households with energy and saves 14,000 metric tonnes of CO_2 annually as compared to conventional energy sources. This makes the plant a model project for the commercial use of renewable energies for educational establishments and the free economy. EF

Source: www.intersolar.in

New Forecasting and Scheduling Regulations

To Cover Solar and Wind Producers

Recently, the Central Electricity Regulatory Commission (CERC) announced the Forecasting and Scheduling regulations for inter-state sale of power. With the intent of having compatible regulations, the Forum of Regulators released a model of regulations as well. The aim is to facilitate large-scale grid integration of solar and wind generating stations, while maintaining grid stability and security. In an interview with ***Sapna Gopal*** *for Energy Future,* ***Vishal Pandya*** *speaks on how these measures will help in the consistent production of renewable energy in India.*

Vishal Pandya is the Co-founder and Director, REConnect Energy Solutions Pvt. Ltd. REConnect Energy is a trading venture in the area of Renewable Energy Certificate (REC)/ Renewable Purchase Obligation (RPO), Energy Portfolio Management & Wind Forecasting and Scheduling. With 36 per cent market share and more than 400 projects over 16 states, it is the largest REC trading company in India. REConnect Energy was co-founded in 2010 by the alumnus of Columbia University, USA and the Indian Institute of Technology, Bombay.

Could you elaborate on how the regulations around forecasting and scheduling have evolved along with its development framework?

The Forecasting and Scheduling (F&S) regulations have evolved at multiple regulatory levels now. The original regulations were framed by the Central Electricity Regulatory Commission (CERC) through Indian Electricity Grid Code (under the Complementary Commercial Mechanism) in 2010, which faced a stiff resistance from the stakeholders due to various operational issues. Keeping the principle regulation still operational, CERC later suspended the penalty mechanism in January 2014.

Subsequent to this, in August 2015, CERC announced a new regulation on F&S covering only inter-state renewable energy (RE) transactions where such RE generation is falling under the control area of the Regional Load Dispatch Centre (RLDC). Following this, the Forum of Regulators (FOR)—a body representing all the state electricity regulatory commissions (SERC) chaired by CERC, announced a Model Regulation on intra-state RE deviation settlement regulation covering all the existing and upcoming wind and solar power producers in India. In line with FOR's model regulation, Karnataka and Madhya Pradesh electricity regulators have already announced their draft regulation on wind/solar forecasting and scheduling. We are expecting all the other state electricity regulatory commissions to follow the similar path and soon, we shall have every wind and solar power producer covered under a similar set of regulations across India.

What are the key provisions listed under the new forecasting and scheduling regulations and also the development framework?

The new regulations broadly cover the following aspects:

- Mandatory forecasting and scheduling of all the existing and upcoming wind/solar power generation at the inter/intra-state level.
- The regional and state load dispatch centres are also mandated to carry out their own parallel forecasting mechanism primarily to manage secure grid operations.
- A wind/solar power producer can either choose to have his own forecast or opt for RLDC/SLDC's forecast for the scheduling purpose. The deviations arising due to a difference between the scheduled generation and actual generation will be settled as per the penalty mechanism adopted under the respective regulations.
- A concept of Qualified Coordinating Agency (QCA) has been introduced to manage the entire exercise of forecasting, scheduling, energy metering, telemetry, deviation management, and penalty de-pooling at every wind/solar pooling station. Each pooling sub-station representing wind/solar power producers must appoint a QCA, which can be either any generator representing the pooling station or any other qualified service provider.
- Unlike the previous mechanism, the deviations and errors linked with deviations are quantified with respect to available generation capacity at the time of scheduling. This will reduce the absolute error magnitude especially during low wind/solar seasons and thus reducing the penalty amount that a generator may have to absorb.
- Among the other key provisions, a RE generator is required to forecast on a day-ahead and week-ahead basis and provide the schedules accordingly. Further, the generator can opt for up to 16 revisions a day where each revision can be effective from 4th time-block.
- Also, deviations and related penalties are de-linked from the Unscheduled Interchange (UI) mechanism, which was a long pending demand from the industry stakeholders.
- A brief comparison between the erstwhile regulation and the new regulations is presented in the table below.

	New Regulation	Old Regulation
Forecasting & Scheduling	Mandatory for all wind and solar project, regardless of the date of commissioning and capacity	Only for projects commissioned after May 2010
Deviation	Calculated based on total available capacity	Calculated based on scheduled capacity
Payment	Is done based on Actual Generation	Linked with UI charges and Scheduled Generation and deviations thereof
Penalty	Simplified in absolute terms and is based on fixed rate. Introduction of DSM	Complicated calculation as a percentage to PPA rate for different slabs. UI settlement Mechanism
Deviation Slab	Narrowed (+/–10%) for upcoming projects and remains higher (+/–15%) for existing projects	+/–30% w.r.t Schedule
	Maximum number of revisions increased to 16 revisions on a daily basis	Maximum number of eight revisions on a daily basis

What according to you is likely to be the far-reaching implications of these new sets of regulations? Moreover, in what way will it impact the private players in the RE sector?

The development carries far-reaching implications primarily for three reasons. Firstly, it will bring all the existing and upcoming wind/solar power producers under the umbrella of forecasting and scheduling. This will help in providing day-ahead and week-ahead power generation visibility to a grid operator for managing secure and reliable grid operations.

Secondly, the higher and more granular level generation visibly to the grid operator would enable RE generators to seek firm implementation of 'must-run' status of all the wind and solar power projects across India, which many states have failed to provide so far on the account of 'in-firm' nature of power generation linked with wind/solar power. Thus, RE generators would not only benefit from better grid availability in the near-term, but also higher future potential of adding more wind/solar power capacity in India.

Thirdly, the economy of scale will act in favour of the entire industry where the cost of forecasting and scheduling will come down in the near term. Moreover, with aggregation being allowed for a larger geographical area, not only will it bring down the per-unit cost implication for RE generator, but will also enable the next level of technological evolution in managing the plethora of data being created due to the whole exercise.

Will this move help streamline the large scale grid integration and security?

A resounding YES. Metering, telemetry, weather data-access at each wind/solar farm level are few of the pre-requisites under the new regulations. These basic building blocks, which were missing so far, would certainly pave a way for better and larger grid integration of renewable generation.

Is it likely that this initiative will benefit the inter-state sale of power?

Yes. Earlier, a wind/solar power producer would have to worry about very strict energy settlement terms associated with inter-state sale of power. Now, with the new mechanism in place, we can expect an RE generator opting for inter-state sale of power to have far more relaxed and cost-effective solution at his disposal to manage deviations related charges.

Is there a need for a new regulatory framework that effectively makes Regional Load Dispatch Centres (RLDCs) more responsive towards the electricity demand and supply situation at the regional level, rather than putting the entire onus on individual states?

Electricity being a concurrent subject, the State controls the supply contracts, the demand zones as well as the state electricity grid. The role of a regional grid operator so far is limited to balance the inter-state and inter-regional tie-line flows and hence the grid security at macro level. If we have to make RLDCs more responsive towards demand-supply situation, the regulators would be required to empower them more.

Do you believe that power storage options need to be explored and a significant push towards the R&D of these technologies is required?

Electricity—generation and consumption, is an instantaneous phenomenon. So is wind/solar power production where mankind would never have any significant control over in the foreseeable future. Hence, if higher wind/solar penetration is required, suitable storage solutions must evolve along with it.

What are your thoughts on the COP21 summit that was recently held in Paris?

I personally think it is nice to have "development", but it is not a must have. Climate change is real and increasing wind/solar penetration is going to be a reality few decades down the line. Strategically, each country would want to ease out their dependence on energy imports. With the cost of RE becoming cheaper, better, and cost-effective energy storage solutions are in sight now. So, we may not need such developments a decade down the line. Especially when the RE capacity growth is now linked purely with economics and a national strategy. Until then, let us keep enjoying the nice family drama of pollutant grandfathers asking environment-sensitive grandchildren to be more responsive towards climate change! EF

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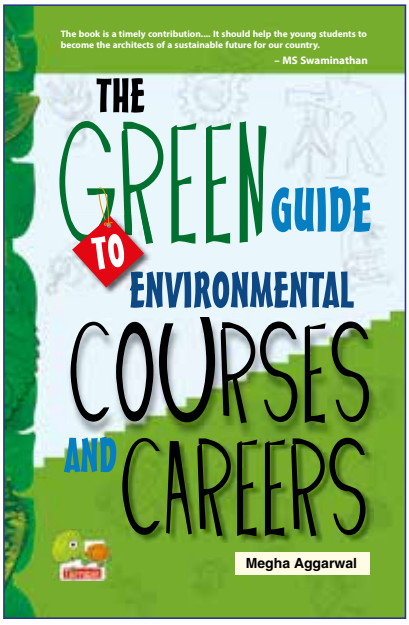

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– **MS SWAMINATHAN**, Father of the Indian Green Revolution

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CURRENT R&D SOLAR

Aqueous Phase Electrocatalysis and Thermal Catalysis for the Hydrogenation of Phenol at Mild Conditions

Applied Catalysis B: Environmental, Volume 182,
March 2016, Pages 236–246
Yang Song, Oliver Y Gutiérrez, Juan Herranz, and Johannes A Lercher

The electrocatalytic hydrogenation (ECH) of phenol on Pt/C, Rh/C, and Pd/C was explored in an H-type two-compartment cell with respect to the impact of electrolyte, pH, current, and catalyst concentration. In all cases, the electric efficiency increased with increasing phenol conversions. Rh/C exhibited the highest hydrogenation rate normalized to the concentration of accessible metal (TOF) followed by Pt/C in terms of mass of metal and intrinsic activities. Therefore, the effect of temperature on ECH and of mild thermal hydrogenation (TH) of phenol was explored on these catalysts. The activation energies for ECH were ca. 23 kJ/mol and 29 kJ/mol on Rh/C, and Pt/C, respectively. TH is much faster than ECH, although both pathways have the same activation energy. Cyclic voltammetry of bulk Pt and Pt/C in the presence of phenol indicated that phenol is adsorbed on the metal and reacted with hydrogen radicals. Hence, ECH was concluded to proceed via a Langmuir-type mechanism where the surface hydrogen is produced by reduction of protons (which occurs when the catalyst contacts the electrode) instead of H_2 dissociation as in TH. Although competitive reactions evolve H_2 during ECH, the involvement of this H_2 in phenol hydrogenation was minor. Thus, ECH and TH are independent processes and do not exhibit any synergy. In both pathways, the reaction path is phenol → cyclohexanone → cyclohexanol. C—O bond cleavage was not observed.

Photocatalytic Overall Water Splitting Promoted by SnO_x–$NiGa_2O_4$ Photocatalysts

Applied Catalysis B: Environmental, Volume 182,
March 2016, Pages 220–228
Xiao-Jun Lv, Shixiong Zhou, Xing Huang, Chuanjun Wang, and Wen-Fu Fu

Overall water splitting is a huge challenge for the semiconductor photocatalysts. Herein, the researchers investigated the high effective photocatalytic overall water stoichiometrically splitting into H_2 and O_2 activity using the SnO_x–$NiGa_2O_4$ (SNG) composites photocatalysts. Because of the effective charge separation and transfer in SnO_x–$NiGa_2O_4$ composites, the photocatalytic activity of the optimized composites photocatalysts can reach up to more than one order of magnitude greater than that of $NiGa_2O_4$ (NGO) or SnO_x alone, respectively. In addition, under visible light irradiation the photocatalysts also displayed well both photocatalytic hydrogen evolution and pollution degradation potentials. More importantly, the researchers further elucidated the essential band gap relation between the SnO_x and $NiGa_2O_4$ in the heterostructure, and a deep understanding of the charge separation mechanism based on the band alignment in such system. The study demonstrates great potential of the SnO_x–$NiGa_2O_4$ composites to be an attractive photocatalysts for the overall water splitting or pollution degradation under visible light irradiation.

Biomolecule-assisted Self-assembly of CdS/MoS_2/Graphene Hollow Spheres as High-efficiency Photocatalysts for Hydrogen Evolution without Noble Metals

Applied Catalysis B: Environmental, Volume 182,
March 2016,Pages 504–512
Xuelian Yu, Ruifeng Du, Baoying Li, Yihe Zhang, Huijuan Liu, Jiuhui Qu, and Xiaoqiang An

Despite the great potential of hollow nanomaterials for energy applications, most approaches rely on hard template-based multistep process for tailoring the interior structure, while the template-free self-assembly synthesis still remains challenging. In this work, the researchers developed a facile biomolecule-assisted one-pot strategy towards the fabrication of novel CdS/MoS_2/graphene hollow spheres. The molecular structure of cysteine was found to be crucial for controlling the morphology of composites. Due to the unique hollow-shaped structure and improved charge separation ability, CdS/5 wt% MoS_2/2 wt% graphene hollow spheres exhibited superior high activity for visible-light-

driven water splitting without noble metals. The synergistic effects of graphene and MoS_2 on the photocatalytic hydrogen production were further investigated by time-resolved fluorescence, electrochemical impedance and Mott–Schottky measurements. This method opens promising prospects for the rational design of high-efficiency and low-cost photocatalysts for hydrogen evolution based on graphene and MoS_2.

The Climatological Relationships between Wind and Solar Energy Supply in Britain

Renewable Energy, Volume 87, Part 1, March 2016,
Pages 96–110
Philip E Bett and Hazel E Thornton

The researchers used reanalysis data to investigate the daily co-variability of wind and solar irradiance in Britain, and its implications for renewable energy supply balancing. The joint distribution of daily-mean wind speeds and irradiances shows that irradiance has a much stronger seasonal cycle than wind, due to the rotational tilt of the earth. Irradiance is weakly anticorrelated with wind speed throughout the year ($-0.4 \lesssim \rho \lesssim -0.2$): there is a weak tendency for windy days to be cloudier. This is particularly true in Atlantic-facing regions (western Scotland, south-west England). The east coast of Britain has the weakest anticorrelation, particularly in winter, primarily associated with a relative increase in the frequency of clear-but-windy days. The researchers also considered the variability in total power output from onshore wind turbines and solar photovoltaic panels. In all months, daily variability in total power is always reduced by incorporating solar capacity. The scenario with the least seasonal variability is approximately 70 per cent—solar to 30 per cent—wind. This work emphasizes the importance of considering the full distribution of daily behaviour rather than relying on long-term average relationships or correlations. In particular, the anticorrelation between wind and solar power in Britain cannot solely be relied upon to produce a well-balanced energy supply.

Field Tests of Multiple 1/10 Scale Tidal Turbines in Steady Flows

Renewable Energy, Volume 87, Part 1, March 2016,
Pages 240–252
Penny Jeffcoate, Trevor Whittaker, Cuan Boake, and Bjoern Elsaesser

Queen's University Belfast and Wave Barrier Ltd have developed a tidal testing platform to test hydrokinetic turbines at medium scale. Multiple turbines can be pushed through still water conditions, in steady-state pushing tests. Experiments were conducted to evaluate the interactions between two identical, mono-strut, horizontal axis tidal turbines (HATTs) of 1.5 m diameter (D) rotor. Their relative performance when located individually, in-plane and in-line are investigated. The data shows a high consistency in the power curves at different flow speeds, which indicates high repeatability in this Reynolds range. For an individual turbine, there is no performance difference when the rotor is mounted either upstream or downstream of the supporting structure. When placed in-plane, the turbines have no adverse effect on one another. When spaced in-line with 2D separation, there is a 63 per cent reduction in the performance of the downstream turbine. At 6D downstream, this performance reduction is still 59 per cent, indicating some wake recovery between 2D and 6D, though the influence from the upstream rotor persists to at least 6D downstream of the first device. In contrast, the performance of the downstream turbine when placed at 1.5D offset of the upstream device at 6D downstream is approximately recovered to the individual turbine performance.

Self-Constructed Carbon Nanoparticles-Coated Porous Biocarbon from Plant Moss as Advanced Oxygen Reduction Catalysts

Applied Catalysis B: Environmental, Volume 181, February 2016,
Pages 635–643
Lihua Zhou, Peng Fu, Dehuang Wen, Yong Yuan, and Shungui Zhou

The development of inexpensive metal-free catalysts with high activity and stability as substitutes for carbon-supported platinum catalysts (Pt/C) in the oxygen reduction reaction (ORR) remains a great challenge. In this paper, the researchers report a novel type of self-constructed, carbon nanoparticle (CNP)-coated porous biocarbon prepared from a natural, readily available, and renewable plant moss (*Weisiopsis anomala*) with a single precursor using template-free heat treatment. The CNPs were self-sponsored from the moss, which were simultaneously self-packed on the moss-derived carbon matrix via strong interactions between the hydroxyl and carbonyl functional groups of the CNPs and the moss-derived carbon matrix during the hydrothermal treatment. After being further carbonized at 900°C, the moss-derived, CNP-coated biocarbon material had a larger surface area than that of the CNP-free, moss-derived biocarbon material. Electrochemical characterization

showed that the CNP-coated biocarbon had a high activity in the ORR with an onset potential of 0.935 V versus the reversible hydrogen electrode (RHE); this value is close to that of a commercial Pt/C catalyst (0.962 V vs. RHE) and is more positive than that of a CNP-free biocarbon material. The CNP-coated biocarbons also displayed a high limited current density, excellent long-term stability and resistance to methanol crossover, offering performance characteristics superior to those of Pt/C. Moreover, a microbial fuel cell (MFC) equipped with a CNP-coated biocarbon cathode outperformed an MFC with a Pt/C cathode in terms of energy output. This study presents a new approach for the production of inexpensive nanostructured carbon materials that exhibit high performance in the ORR from a natural resource.

Wave Energy Conversion through a Point Pivoted Absorber: Numerical and Experimental Tests on a Scaled Model

Renewable Energy, Volume 87, Part 1, March 2016, Pages 317–325

Domenico P Coiro, Giancarlo Troise, Giuseppe Calise, and Nadia Bizzarrini

This paper presents numerical and experimental tests on an innovative wave energy conversion (WEC) system for extracting electrical power from waves. It consists of a point pivoted floater which oscillates due to waves. Linked to the buoyant body, an electromechanical generator based on ball-bearing screw converts floating movements into electrical power. At first, an analytical description of the system arrangement is presented. Then, experimental tests on a scaled model have been performed in wave/towing tank facility and data from tests were used for comparison with data from numerical simulations: both potential flow and Unsteady Reynolds Averaged Navier–Stokes (URANS) numerical simulations were performed. These simulations have been performed in order to identify critical parameters for further WEC developments.

Ultrasonic Radiation to Enable Improvement of Direct Methanol Fuel Cell

Ultrasonics Sonochemistry, Volume 29, March 2016, Pages 363–370

Chaoqun Wu, Jiang Wu, Hao Luo, Sanwu Wang, and Tao Chen

To improve DMFC (direct methanol fuel cell) performance, a new method using ultrasonic radiation is proposed and a novel DMFC structure is designed and fabricated in the present paper. Three ultrasonic transducers (piezoelectric transducer, PZT) are integrated in the flow field plate to form the ultrasonic field in the liquid fuel. Ultrasonic frequency, acoustic power, and methanol concentration have been considered as variables in the experiments. With the help of ultrasonic radiation, the maximum output power and limiting current of cell can be independently increased by 30.73 per cent and 40.54 per cent, respectively. The best performance of DMFC is obtained at the condition of ultrasonic radiation (30 kHz and 4 W) fed with 2 M methanol solution, because both its limiting current and output power reach their maximum value simultaneously (222 mA and 33.6 mW, respectively) under this condition. These results conclude that ultrasonic can be an alternative choice for improving the cell performance, and can facilitate a guideline for the optimization of DMFC.

Development of Nickel Based Catalysts for the Transformation of Natural Triglycerides and Related Compounds into Green Diesel: A Critical Review

Applied Catalysis B: Environmental, Volume 181, February 2016, Pages 156–196

Christos Kordulis, Kyriakos Bourikas, Mantha Gousi, Eleana Kordouli, and Alexis Lycourghiotis

The accumulation of greenhouse gases in the atmosphere resulting from the extensive use of fossil fuels and the depletion of oil reserves due to the increasing demands for energy compel the progressive replacement of fossil fuels by renewable energy sources among which is biomass as well. Triglycerides-based biomass, such as, plant oils, animal fats, waste cooking, and micro-algal oils should be upgraded by transesterification, cracking/hydrocracking and selective deoxygenation (SDO) to provide, respectively, biodiesel (fatty acid methyl esters), the so-called organic liquid product (mixture of hydrocarbons in the range of gasoline, kerosene, and diesel) and green diesel (hydrocarbons in the diesel range). Problems related to the production, storage and use of the already produced biodiesel shifts the research to the second and third upgrading route. Intensive work in the last ten years has shown that the noble metals (mainly palladium) and the NiMo, CoMo, and NiW sulphide catalysts supported on high surface area carriers, are promising concerning SDO for producing green diesel in the context of a stand-alone process of natural triglycerides. EF

MobilHybrid for Power Generators

The Independent, Environment-friendly, Portable Storage System

The MobilHybrid is an innovative storage system, which is connected between power generators and electricity consumers. It enables an economical, environment-friendly, and continuous supply of your electricity demand. The mobile hybrid stores the electricity from the generator and passes it to the consumer, as required in just the right amount without any waste of electricity. It ensures with its innovative technology that the generator can be switched off when the load of electricity consumers is small, less than the rated power of the mobile hybrid in use. If the energy in the batteries ends or the load demand is higher than the power of the MobilHybrid, it automatically turns on the generator. If the load demand is greater than the generator power, the MobilHybrid switches on and the two power sources are added together by the Power-Boost function. The MobilHybrid selects the most favourable energy sources out of multiple (hybrid) supplies for the current load situation. This may be the built-in battery storage, a diesel generator, photovoltaic modules, or a possibly existing grid.

The MobilHybrid supplies your loads with power and controls the power generator when the internal batteries of the MobilHybrid are recharged using its start/stop function. As long as the load is supplied there will be no noise and exhaust gases through the cell hybrid. At high loads, the power of the MobilHybrid and the diesel generator is added by the Power boost function so that the diesel generator can be smaller and more efficient. The MobilHybrid is available in three sizes and six power levels to cover the mobile power needs of all the consumers.

BENEFITS OF MOBILHYBRID FOR THE ENVIRONMENT

- Significant amounts of CO_2 and harmful emissions can be saved
- Silent operation of the power supply, since the diesel generator most of the time is switched off or is no longer needed in some applications
- More CO_2 and money can be saved in addition to the hybrid system by the use of photovoltaic modules
- The lead-acid batteries used are 99 per cent recyclable
- The service life and maintenance intervals of the diesel engine is also extended.

ADVANTAGES OF THE MOBILHYBRID SYSTEM

- Real-time online monitoring system and generation data
- Compatible with existing diesel generator

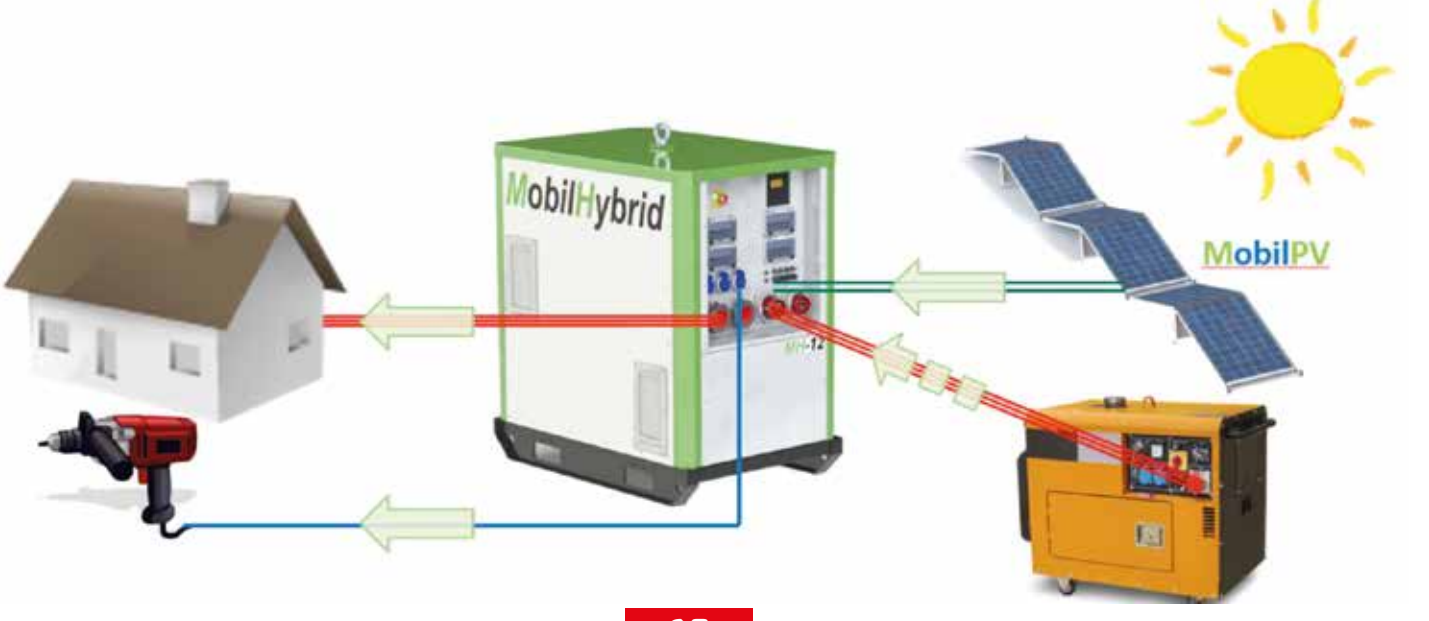
- Fuel efficiency is improved
- Capable of handling and starting current three times of rated capacity
- Diesel savings of up to 50 per cent
- Operating cost savings of up to 60 per cent
- Payback period is less
- Two years in partload operation
- Smaller power generator power with power boost feature
- Less noise emissions
- 30 per cent lower CO_2 emissions
- Dimensions of a euro pallet
- Optional energy supply by photovoltaic.

Dr Michael Seehuber CEO and MD, PV4life GMBH. For more information, kindly contact: PV4Life GmbH, Albstr. 7, 72581 Dettingen a.d. Erms, Phone: +49 (0) 176 42610738 or PV4Life Energy Services Private Ltd, Mumbai-400 088, India, Phone: +91 9867556726. E-Mail: info@pv4life.com, info@mobilhybrid.co.in Website: www.mobilhybrid.net

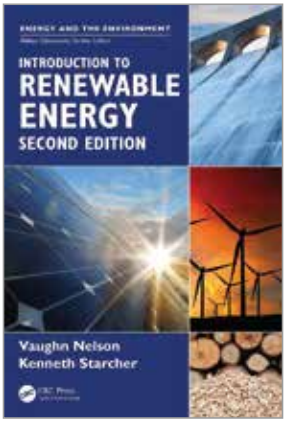
The product range specifications of the MobilHybrid system are presented in Table 1. EF

Table 1: Specifications of MobilHybrid *(subject to change)*

Typ *MobilHybrid*	*MH-3*	*M-4*	*MH-8*	*MH-12*	*MH-18*	*MH-24*
Size	A	A	B	B	C	C
Continuous power VA at 25°C	2,000	3,500	6,000	10,500	15,000	21000
Top performance VA at 25° 30 min	2,600	4,000	7,800	12,000	18,000	24000
Top performance VA 25°C 5 sec	6,500	10,500	19,500	31,500	45,000	63000
Output voltage V AC	230V			230 / 400V		
Input current max. AC	32A			50A		50A
Max. output current (with external AC source) A	11 A (32A)		16A (32A)	28A (44A)	46A (63A)	63A
Protection functions	Overload, over temperature, short circuit, discharged batteries					
Earth fault	40A 1ph 30mA FI			63A 3ph 100mA FI		
Usable battery capacity kWh	3,2		5,5	11,0	16,5	22,0
Input Connector	CEE 32A 1ph		CEE 32A 1ph	CEE 63A 3ph		
Output Connector A	1x Schuko 16A		CEE 32A 1ph	CEE 63A 3ph		
Output Connector B	1x Schuko 16A		3x Schuko 16A IP54			
Charging time at the net to full charge	2,5h		2,5h		2,5h	
Auxiliary contact (remote start Dieselgen.)	Phoenix					
Battery monitoring	LCD Display: Voltage, Power, State of charge, runtime, load cycle					
Battery cycle	1,800					
Protection	IP44					
Operating temperature range	-10°C bis +45°C					
Dimensions W x D x H mm	600 x 800 x 1200		800 x 1200 x 1290		800 x 1200 x 1690	
Weight kg ca.	360		525	750	1360	1380
Optional Photovoltaic loader	Controller with up to 8 kWp connectable module output					



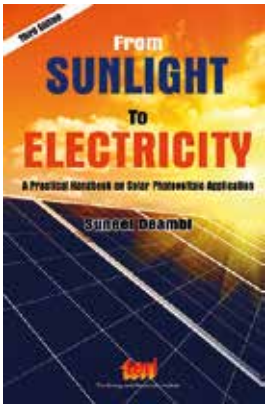
INTRODUCTION TO RENEWABLE ENERGY, SECOND EDITION



Introduction to Renewable Energy, Second Edition covers the fundamentals of renewable energy and serves as a resource to undergraduates in renewable energy courses, non-specialists within the energy industries, or anyone working to support the successful implementation of renewable energy. The second edition discusses developments that have occurred since the publication of the first edition and considers the growing environmental impact of human activity on planet Earth. Dedicated to converging science and technology in a way that ensures a sustainable future, this book outlines the basics of renewable energy and focuses on current and developing policies that support the shift to renewable energy. New in the second edition, the book addresses bioenergy, energy balance, biodiesel, photovoltaic applications, and climate change. The authors take a multidisciplinary approach and share their observations on trending technologies [including neuroscience, artificial intelligence, virtual reality (VR), nanotechnology, and genetic engineering] that they predict will have a significant impact in the next 25 years. EF

Authors: Vaughn C Nelson and Kenneth L Starcher
Publisher: CRC Press; Year: 2015

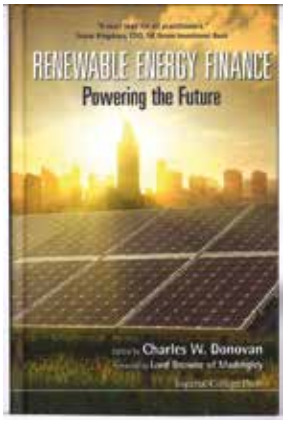
FROM SUNLIGHT TO ELECTRICITY: A PRACTICAL HANDBOOK ON SOLAR PHOTOVOLTAIC APPLICATION, THIRD EDITION



The third edition of the book—*From Sunlight to Electricity: A Practical Handbook on Solar Photovoltaic Application* brings in the latest information about photovoltaic sector in India, designs and applications of specific devices and related benefits, finance, and policies. This edition of the book gives readers an understanding of the photovoltaic technology programme in India, the issues therein, and its future directions. The information has been presented in a format that is easy to understand and apply. In this third edition, the author has included topics, such as 'global development in PV system', 'installation and maintenance of PV systems', and 'application of PV systems for other households'. The target audience for this book is the stakeholders in the PV (photovoltaic) sector—policymakers, government officials, non-governmental organizations, and academic and research organizations. EF

Author: Suneel Deambi
Publisher: The Energy and Resources Institute (TERI); Year: 2015

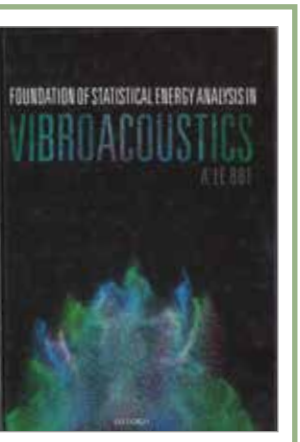
RENEWABLE ENERGY FINANCE: POWERING THE FUTURE



The future of clean energy is no longer about science and technology; it is all about access to finance. The fossil fuel industry has been subsidized for decades with tax breaks and government backing, while renewables have struggled to compete. But now clean energy is the safe bet for investors, as is argued in *Renewable Energy Finance: Powering the Future*, edited by Dr Charles Donovan, Principal Teaching Fellow at Imperial College Business School. With contributions from some of the world's leading experts in energy finance, this timely book documents how investors are spending over $250 billion each year on new renewable energy projects and positioning themselves in a global investment market that will continue to expand at double-digit growth rates until 2020. It documents first-hand experiences of the challenges of balancing risk and return amid volatile market conditions and rapid shifts in government policy. This book provides an insider's perspective on renewable energy transactions, and insight into how countries, such as the US, India, and China are responding to the global energy challenge. Drawing together contributions from senior executives and leading academics, *Renewable Energy Finance: Powering the Future* serves an audience of readers craving intelligent and practical perspectives on the future of clean energy investment. EF

Edited by: Charles W Donovan
Publisher: Imperial College Press; Year: 2015

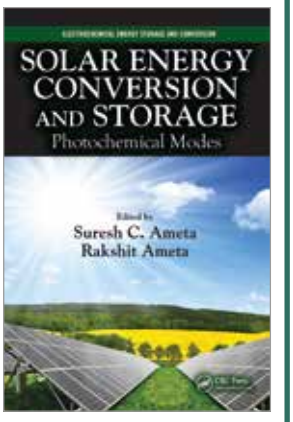
FOUNDATION OF STATISTICAL ENERGY ANALYSIS IN VIBROACOUSTICS



This book provides an in-depth study of the foundations of statistical energy analysis, with a focus on examining the statistical theory of sound and vibration. In the model approach, an introduction to random vibration with application to complex systems having a large number of modes is provided. For the wave approach, the phenomena of propagation, group speed, and energy transport are extensively discussed. Particular emphasis is given to the emergence of the diffuse field, the central concept of the theory. All important notions are gradually introduced—making the text self-contained—to lead the reader to the ultimate result of 'coupling power proportionality' and the concept of 'vibrational temperature'. Further key topics include the analogy between thermodynamics and sound vibration. Applications are concerned with random vibration in mass–spring resonators, strings, beams, rods, and plates but also reverberation in room acoustics, radiation of sound, and sound response. EF

Author: A Le Bot
Publisher: Oxford University Press; Year: 2015

SOLAR ENERGY CONVERSION AND STORAGE: PHOTOCHEMICAL MODES (ELECTROCHEMICAL ENERGY STORAGE AND CONVERSION)

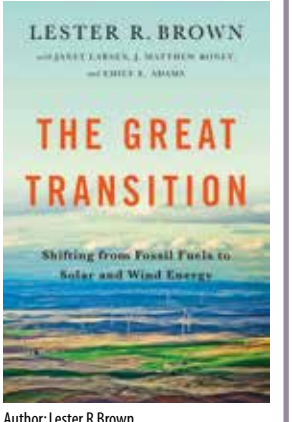


Solar Energy Conversion and Storage: Photochemical Modes showcases the latest advances in solar cell technology while offering valuable insight into the future of solar energy conversion and storage. Focussing on photochemical methods of converting and/or storing light energy in the form of electrical or chemical energy, the book:

- Describes various types of solar cells, including photovoltaic cells, photogalvanic cells, photoelectrochemical cells, and dye-sensitized solar cells
- Covers the photogeneration of hydrogen, photoreduction of carbon dioxide, and artificial/mimicking photosynthesis
- Discusses the generation of electricity from solar cells, as well as methods for storing solar energy in the form of chemical energy
- Highlights existing photochemical methods of solar energy conversion and storage
- Explores emerging trends such as the use of nanoparticles. EF

Edited by: Suresh C Ameta and Rakshit Ameta
Publisher: CRC Press; Year: 2015

THE GREAT TRANSITION: SHIFTING FROM FOSSIL FUELS TO SOLAR AND WIND ENERGY



As oil insecurity deepens and fossil fuel resources shrink, and as air pollution worsens, the extraction risks of fossil fuels rise, and concerns about climate instability cast a shadow over the future of coal, a new world energy economy is emerging. The old economy, fuelled by oil, natural gas, and coal is being replaced with one powered by wind, solar, and geothermal energy.

This book details the accelerating pace of this global energy revolution. As many countries become less enamoured with coal and nuclear power, they are embracing an array of clean, renewable energies. Whereas solar energy projects were once small-scale, largely designed for residential use, energy investors are now building utility-scale solar projects. Strides are being made: some of the huge wind farm complexes under construction in China will each produce as much electricity as several nuclear power plants, and an electrified transport system supplemented by the use of bicycles could reshape the way we think about mobility. This book is a well-written, fast-reading summary of the crucial efforts to phase out coal, natural gas and nuclear power plants and replace them with solar, wind and, geothermal projects. It is useful for all the stakeholders in the renewable energy industry. EF

Author: Lester R Brown
Publisher: W W Norton & Company; Year: 2015

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

SOLAR WATER-SPLITTING TECHNOLOGY DEVELOPED

Rice University researchers have demonstrated an efficient new way to capture the energy from sunlight and convert it into clean and renewable energy by splitting water molecules. This technology relies on the configuration of light-activated gold nanoparticles that harvest sunlight and transfer solar energy to highly excited electrons, which scientists sometimes refer to as 'hot electrons'. Capturing these high-energy electrons before they cool could allow solar-energy providers to significantly increase their solar-to-electric power-conversion efficiencies and meet a national goal of reducing the cost of solar electricity.

The researchers have created a system that uses the energy from hot electrons to split molecules of water into oxygen and hydrogen. That is important because oxygen and hydrogen are the feedstocks for fuel cells, electrochemical devices that produce electricity cleanly and efficiently. To use the hot electrons, they had to find a way to separate them from their corresponding 'electron holes', the low-energy states that the hot electrons vacated when they received their plasmonic jolt of energy. One reason that hot electrons are so short-lived is that they have a strong tendency to release their newfound energy and revert to their low-energy state. The only way to avoid this is to engineer a system where the hot electrons and electron holes are rapidly separated from one another. The standard way for electrical engineers to do this is to drive the hot electrons over an energy barrier that acts like a one-way valve. This approach has inherent inefficiencies, but it is attractive to engineers because it uses well-understood technology called Schottky barriers, a tried-and-true component of electrical engineering.

http://www.sciencedaily.com/releases/2015/09/150904121357.htm

NEW STORAGE CELL FOR SOLAR ENERGY STORAGE, NIGHTTIME CONVERSION

A team from University of Texas at Arlington materials science and engineering has developed a new energy cell that can store large-scale solar energy even when it is dark. The innovation is advancement over the most common solar energy systems that rely on using sunlight immediately as a power source. Those systems are hindered by not being able to use that solar energy at night or when cloudy conditions exist.

The team has developed an all-vanadium photo-electrochemical flow cell that allows for efficient and large-scale solar energy storage even at nighttime. The team is now working on a larger prototype. According to one of the researchers, this research has a chance to rewrite how we store and use solar power. The work is a product of the 2013 National Science Foundation $400,000 Faculty Early Career Development grant awarded to Liu to improve the way solar energy is captured, stored, and transmitted for use.

http://www.sciencedaily.com/releases/2015/07/150701131853.htm

RENEWABLE NRG SYSTEMS LAUNCHES NEW USER INTERFACE FOR TURBINEPHD® CONDITION MONITORING SYSTEM

Renewable NRG Systems (RNRG), a designer and manufacturer of decision support tools for the global renewable energy industry, has completely redesigned its software interface for the TurbinePhD wind turbine condition monitoring system (CMS). TurbinePhD is the only CMS in the wind industry that is engineered for use by wind plant operators at multiple levels of their organization, from technicians to data analysts.

TurbinePhD's powerful automated analysis classifies the health of all turbine drivetrain components, so users don't have to be vibration experts to get actionable information.

And this interface is completely web-based, so users can access all of their turbine health data anywhere with an internet connection. The fleet view allows operators to assess the health of all wind farms at a glance, and graphical health alerts clearly highlight those that need attention. At the wind farm level, users can see which turbines have new alerts or view and download charts of the most critical faults on the farm.

http://www.renewable-energy-technology.net/wind-energy-news/renewable-nrg-systems-launches-new-user-interface-turbinephd-condition-monitoring

CARBON NANOBALLS CAN TRANSFORM THE RENEWABLE ENERGY SUPPLY

Researchers at the Chalmers University of Technology have discovered that the insulation plastic used in high-voltage cables can withstand a 26 per cent higher voltage if nanometer-sized carbon balls are added. This could result in enormous efficiency gains in the power grids of the future, which are needed to achieve a sustainable energy system.

The researchers have shown that different variants of the C60 carbon ball, a nanomaterial in the fullerene molecular group, provide strong protection against breakdown of the insulation plastic used in high-voltage cables. Today, the voltage in the cables has to be limited to prevent the insulation layer from getting damaged. The higher the voltage the more electrons can leak out into the insulation material, a process which leads to breakdown.

The C60 carbon ball is also called buckminsterfullerene. They have unique electronic qualities and have been regarded as very promising material for several applications. Thus far, however, there have been few industrial usage areas. Fullerenes are one of the five forms of pure carbon that exist. The other four are graphite, graphene/carbon nanotubes, diamond and amorphous carbon, e.g., soot. It is sufficient to add very small amounts of fullerene to the insulation plastic for it to withstand a voltage that is 26 per cent higher, without the material breaking down, than the voltage that plastic without the additive can withstand.

http://www.renewableenergyworld.com/articles/2015/02/carbon-nanoballs-can-transform-the-renewable-energy-supply.html

A SOLUTION TO INTERMITTENT RENEWABLES USING PUMPED HYDROPOWER

Pumped storage hydropower plants could ultimately provide one of the most cost-effective means of frequency regulation for the EU grid of the future. Integrating large quantities of renewable generation with low-carbon technology will require the development of large flexible carbon-free generation and storage assets. Over the last 40 years, numerous large capacity pumped-storage hydropower plants (PSPs) have been built worldwide, many of which could be retrofitted to provide grid-balancing services that the grid of the future will need.

Almost all PSPs are equipped with fixed rotating speed units. This technology imposes a fixed power capacity per unit in pumping mode: the pump is either stopped or operating at full capacity. The result of this is that other types of flexible generation plants must be kept online when the pumps are in operation. However, operating this way has a negative impact on the cycle efficiency, literally resulting in the intermittent generation heating up the water in the upper reservoir. The fixed operating speed also limits the ability of the hydraulic unit, when operating in turbine mode, to keep a high efficiency over a large head and flow range.

New variable speed technology for PSPs was recently introduced in Europe. A key benefit of this new technology is that is gives PSPs the ability to regulate power both in pumping and generation modes instead of just in generation mode, like conventional units. Because this new technology allows for additional flexibility for PSPs, once equipped with them, these PSPs are now among the best solutions to provide necessary ancillary services for the grid.

http://www.renewableenergyworld.com/articles/2015/05/a-solution-to-intermittent-renewables-using-pumped-hydropower.html

SOLAR ROOF: NEW HYBRID SOLAR PANEL ROOF SLASHES ENERGY BILLS

Scientists at Brunel University, London have designed a new hybrid roofing system which could halve energy bills in new homes. The patented new system harnesses a unique mixture of technologies to pre-heat domestic hot water for radiators, baths and showers while also generating electricity. More than half of domestic energy use in the UK is to heat water. At its heart is the use of heat pipes—super conductors of heat energy found in high tech devices from PCs to the International Space Station where they prevent it from melting in the heat of the sun on one side and freezing in the vacuum of space on the other.

The new system also addresses a wide range of practical issues in installing solar panels in new properties. Attempts to integrate installing solar panels with conventional roofing techniques have a poor track record. EF

http://www.sciencedaily.com/releases/2015/09/150925085759.htm

INDUSTRY REGISTRY

ATS Automation
ATS offers over 30 years of experience in factory-wide integration including assembly and test automation. Our products include wet bench, wafer handling, cell sorter, laser processing, and module automation.
730 Fountain St. N, Cambridge N3H 4R7, Canada
Tel: +1-519-653-6500
Fax: +519-653-6533
Email: solar@atsautomation.com
Website: www. atsautomation.com

ALD Vacuum Techn. GmbH
Worldwide leading supplier of technology and production equipment for metallurgical and solar applications. Crystallization equipment for multi and mono2tm ingot production.
Wilhelm-Rohn-Str. 35, D-63450 Hanau, Germany
Tel: +496181/307-0
Email: info@ald-vt.de
Website: www. ald-vt.de

Duraluxe Energy Co., Ltd
Duraluxe Energy is a professional PV inerter manufacturer providing excellent and reliable products that range from 1.5 kW single phase to 500 kW three phases, with complete certification.
No. 2288, Cuihu No.5 Rd, Development Zone of Economy & Technology, Tongling, Anhui, 244000, China
Tel: +86/562/2196800
Fax: +86/562/2196880
Website: www.duraluxe.com

Laplace System Co., Ltd
Development and sale of PV simulation (Solar Pro) measuring software (Solar link), various kinds of technology calculation software.
A-1 Toyozono 2-1 Yawatashinade, Yawata City, Kyoto 614-8001, Japan
Tel: +81/75/9831237
Fax: +81/75/9722218
Email: laplace@ lapsys.co.jp
Website: lapsys.co.jp

JRT Photovoltaics GmbH & Co. KG
JRT is offering an optimal service spectrum in the sector of metallization and handling technologies, and the partial coating of crystalline solar cells.
Riegeler Strasse 4, 79364 Malterdingen, Germany
Tel: +49-7644-92797-0
Fax: +49-7644-92797-110
Email: info@jrt-pv.de
Website: www. jrt-pv.de

Martifer Solar S.A.
Martifer Solar is a leading player in the global photovoltaic market focussed on Development, EPC and O&M Service. The company is based in Portugal and has presence in Europe, North & Latin America, Africa and Asia. In 2013, Martifer Solar's revenues reached a high level and, to date, the company has implemented more than 500 MW of photovoltaic solar energy worldwide.
Tel: +351/232/767-700
Fax: +351/232/767-779
Website: www.martifersolar.com

RITEK Solar
An expert manufacturer of PV-Modules from polycrystalline, mono-crystalline, to BIPV certified by TUV, UL, CEC, and MCS.
No. 42, Kuan-Fu N. Rd, Hsin Chu, Industrial Park, 30316, Hsinchu, Taiwan
Tel: +886-03-598-7298
Fax: +886-03-599-8449
Email: ritsolar@ritek.com
Website: www.riteksolar.com

Semco Engineering
Enhanced processes and automation systems for diffusion and AR coating which drastically increase throughput and cell efficiency.
Lydop® diffusion: 400 cells/tube/HR, 625, rue de la Croix Verte, 34196 Montpellier, France
Tel: +33/467/610990
Fax: +33/467/526963
Email: info@semco-engineering.com
Website: www.semcoeng.com

SAMIL Power Co., Ltd
Manufacturer of grid-connected PV power inverters and other PV system accessories for residential use and commercial power stations.
No. 52, Huigu Innovation Park, Huishan District, Wuxi, Jiangsu Province 214174 P.R.C., China
Tel: +86/510/83593131
Fax: +86/510/83593136
Email: info@samilpower.com
Website: www. samilpower.com

Victron Energy
True sinewave stand-alone inverters and combined inverter chargers. Modular systems 200W+ 45 kW. Unique grid and generator parallel operation features. Also battery chargers, battery monitoring, and DC/DC converters.
P.O. Box 50076, 1305 AA Almere-Haven, The Netherlands
Tel: +31/535-9700; Fax: +31/535-9740
Website: www.victronenergie.com

NATIONAL AND INTERNATIONAL EVENTS

INTERNATIONAL

International Conference on Future Environment and Energy

Jan 23–24, 2016

Pattaya, Thailand
Website: http://www.icfee.org

International Conference on Sustainable Energy and Environmental Sciences

Feb 22–23, 2016

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

7th Solar Power PV Conference & Expo

Feb 24–25, 2016

Boston, MA, USA
Website: www.events.solar/pvconferenceexpo

International Conference on Environment and Renewable Energy

Feb 24–25, 2016

Ho Chi Minh, Vietnam
Website: http://www.icere.org

Conference and Exhibition: Solar Middle East

Mar 1–3, 2016

Dubai, UAE
Website: www.solarmiddleeast.ae

ASIA 2016: Water Resources and Hydropower Development in Asia

Mar 1–3, 2016

Vientiane, Lao Peoples Democratic Republic
Website: http://hydropower-dams.com

International Conference on Green Energy and Applications

Mar 23–25, 2016

Singapore
Website: http://www.icgea.org

5th Intersolar China 2016: Conference and Exhibition

Mar 29–31, 2016

Beijing, China
Website: www.intersolar.asia

Future of Energy Summit

April 4–6, 2016

New York, USA
Website: http://10times.com/bnef-summit

13th Green Energy Expo Korea: Conference and Exhibition

April 6–8, 2016

Daegu, South Korea
Website: www.energyexpo.co.kr/eng

NATIONAL

Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy

Jan 21–23, 2016

Bengaluru, Karnataka, India
Website: https://www.amrita.edu/site/pestse2016

International Conference on Conservation of Biodiversity and Sustainable Energy: Law and Practice

Feb 12–14, 2016

Delhi, India
Website: http://clc.du.ac.in/full-Event.aspx?id=30

World PetroCoal Congress & Expo-2016

Feb 15–17, 2016

New Delhi, India
Website: http://worldpetrocoal.com

International Conference on Energy and Infrastructure Management

Feb 18–19, 2016

Gandhinagar, Gujarat, India
Website: http://spm.pdpu.ac.in/iceim2016.html

Biofuels & Bioenergy: International Conference and Exhibition (BICE 2016)

Feb 23–25, 2016

Bhopal, Madhya Pradesh, India
Website: www.weentech.co.uk

International Conference on 'Recent Advances in Bio-energy Research'

Feb 25–27, 2016

Kapurthala, Punjab, India
Website: http://icrabr.com

EnerTech World Expo

Mar 3–5, 2016

Mumbai, Maharashtra, India
Website: http://www.chemtech-online.com

International Conference on Sustainability

Mar 17–19, 2016

Shillong, Meghalaya, India
Website: http://www.iimshillong.in/sus-con/sus-con.asp

International Conference on Energy Efficient Technologies for Sustainability 2016

April 7–8, 2016

Nagercoil, Tamil Nadu, India
Website: http://iceets16.com/site/index.php/home

Renewable Energy World India

May 18–20, 2016

New Delhi, India
Website: http://10times.com/renewable-energyworld-india

Renewable Energy at a Glance

Programme/Scheme-wise Physical Progress in 2015–16 (Up to the month of November, 2015)			
Sector	FY 2015–16		Cumulative Achievements
	Target	Achievement	(as on 30.11.2015)
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	2,400.00	1,315.71	24,759.32
Solar Power	1,400.00	922.61	4,684.74
Small Hydro Power	250.00	106.55	4,161.90
Bio-Power (Biomass & Gasification and Bagasse Cogeneration)	400.00	132.00	4,550.55
Waste to Power	10.00	12.00	127.08
Total	**4,460.00**	**2,488.87**	**38,283.59**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	0.50	146.51
Biomass (non-bagasse) Cogeneration	60.00	10.50	602.37
Biomass Gasifiers -Rural -Industrial	2.00 6.00	0.20 8.67	18.15 160.72
Aero-Generators/Hybrid Systems	0.50	0.13	2.67
SPV Systems	50.00	46.50	280.85
Water Mills/Micro Hydel	2.00	0.00	17.21
Total	**130.50**	**66.50**	**1,228.48**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (numbers in lakh)	1.10	0.22	48.34
Solar Water Heating – Coll. Areas (million m^2)	-	0.00	8.90

Source: www.mnre.gov.in

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