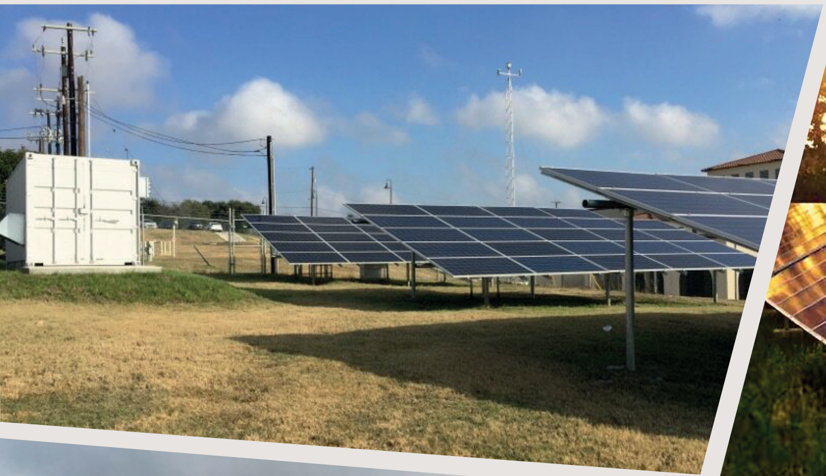
Volume 10 • Issue 6 • June 2017

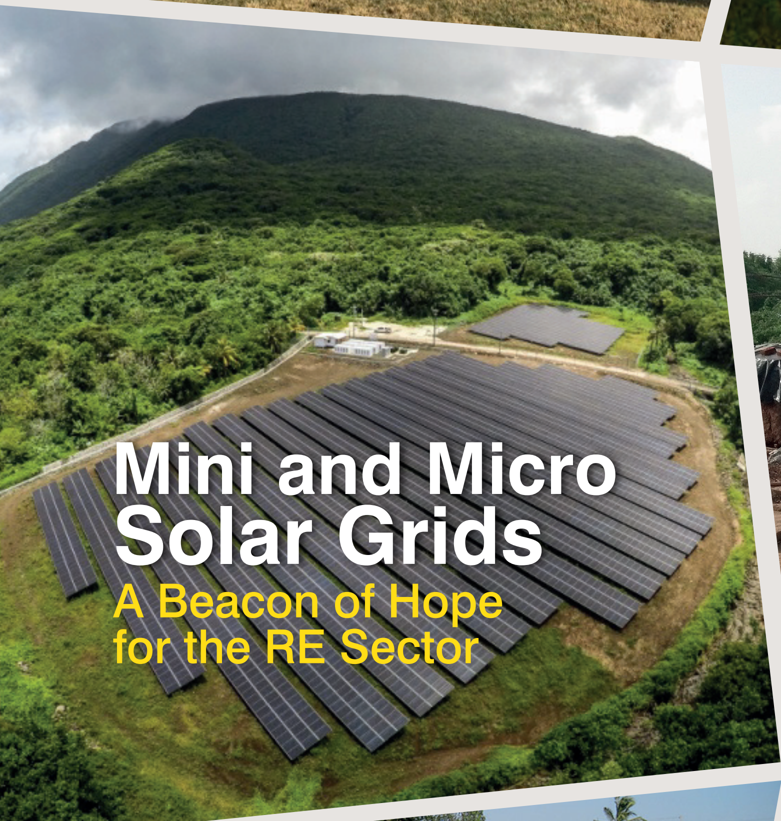
Ministry of New and Renewable Energy
Government of India

Renewable Energy

Akshay Urja

www.mnre.gov.in





Mini and Micro Solar Grids

A Beacon of Hope for the RE Sector

Make your Establishment
green by reducing the carbon foot print

CONCENTRATING SOLAR TECHNOLOGIES

can meet a significant amount of your thermal energy or steam requirement for community cooking & process heat applications

SALIENT FEATURES

- Can provide steam/hot oil/pressurized at 90–350°C
- Integrated with conventional boiler that provides trouble-free operations during non-sunshine hours. Systems with heat storage also available
- Gives economic return in 3-5 years besides getting a green tag
- Around 250 systems of various capacities working in the country.

Interested organizations may contact our Channel Partners (**Ahmedabad:** Taylormade Solar Solutions Pvt. Ltd., Email: dharam@tss-india.com; **Bengaluru:** Unisun Technologies Pvt. Ltd., Email: info@unisun.net; VSM Solar Pvt. Ltd., Email: vsmsolar@gmail.com; **Coimbatore:** Greenera Energy India Pvt. Ltd., Email: valliappan.vk@greenerainda.com; **Hyderabad:** Oorja Energy Engg. Services Hyd Pvt. Ltd., Email: madhu@oorja.in; **Jodhpur:** K energy, Email: sanjeevkachhwaha@gmail.com;); **Mumbai:** Clique Solar, Email: adb@cliquesolar.com; Ultra Conserve Pvt. Ltd., Email: vivek@conserve.co.in; **Nagpur:** GreenLife Solutions Pvt. Ltd., Email: amit@greenlifesolution.in; **New Delhi:** Megawatt Solutions Pvt. Ltd., Email: smalik@megawattsolutions.in; **Pune:** Thermax Limited, Email: kdeshpan@thermaxindia.com; Leveragenet Solutions Pvt. Ltd., Email: contact@energy-guru.com; Forbes Solar Pvt. Ltd., Email: ccmidc@forbesmarshall.com; A.T.E Enterprises Pvt. Ltd., Email: p_dontula@ateindia.com; **Theni, Tamil Nadu:** Sunbest, Email: info@sunbest.in)

सत्यमेव जयते
Government of India

Ministry of New & Renewable Energy
Government of India
Block 14, CGO Complex, Lodi Road, New Delhi-110003. Website: www.mnre.gov.in

JUNE 2017

| Volume 10 • Issue 6|

Renewable Energy Akshay Urja

COVER STORY

12

18

The solar energy utilization varies according to the geographical location. To harness maximum energy from the available sunlight, tracking of PV panels was introduced. **Khyati Vyas** discusses the development and simulation of a PV power pack, servo-based, single-axis solar tracking system prototype.

22

Dr Ram Chandra, Abhinav Trivedi, Bhaskar Jha, Amit Ranjan Verma, and **Dr Virendra Kumar Vijay** present a case study on the utilization of paddy straw for power generation through biomethane production route and bioethanol production on commercial scale and improved biomass cookstove on domestic scale.

28

Dr S S Verma, through this article, presents a detailed description of the two popular solar cells— solar thermophotovoltaics and printed solar cells—such that their technology, challenges in usage, and the future ahead is analysed.

A bi-monthly newsletter of the Ministry of New and Renewable Energy, Government of India (Published in English and Hindi)

CHIEF PATRON
Shri Piyush Goyal
Minister of State (Independent Charge) for Power, Coal and New and Renewable Energy & Mines

PATRON
Shri Anand Kumar
Secretary, MNRE, New Delhi

EDITOR
Shri Dilip Nigam
MNRE, New Delhi

EDITORIAL BOARD
D K Khare
B S Negi
R K Vimal

PRODUCTION TEAM
Anupama Jauhry, Sangeeta Paul, Abhas Mukherjee, Spandana Chatterjee, Anushree T Sharma, Naina Mukerji, Raman K Jha, Shinjini Sen, R K Joshi, Aman Sachdeva, TERI, New Delhi; Nimai Ghatak, MNRE

EDITORIAL OFFICE
Shri Dilip Nigam
Editor, Akshay Urja
MNRE, Block No. 14, CGO Complex, Lodhi Road, New Delhi - 110 003
Tel. +91 11 2436 8911, 2436 0707
Fax +91 11 2436 8911
E-mail: akshayurja@nic.in
Web: www.mnre.gov.in

PRODUCED BY
TERI Press
TERI, Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi -110 003
Tel. +91 11 2468 2100, 4150 4900
Fax: +91 11 2468 2144, 2468 2145
Email: teripress@teri.res.in
Web: www.teriin.org

PUBLISHER AND PRINTER
Ministry of New and Renewable Energy

Published, printed, and edited for and on behalf of the Ministry of New and Renewable Energy, Government of India, from B-14, CGO Complex, Lodhi Road, New Delhi, by Shri Dilip Nigam. Printed at Aravali Printers & Publishers (P) Ltd. W-30, Okhla Industrial Area, Phase II, New Delhi - 110 020, India.

अक्षय ऊर्जा के फरवरी–अप्रैल 2017 में प्रकाशित लेख 'उत्तर प्रदेश के गांवों में मिनी ग्रिडों के लिए मांग आकलन' काफी सारगर्भित लगा। यह पढ़कर काफी अच्छा लगा कि उत्तर प्रदेश के ग्रामीण इलाकों में सौर ऊर्जा, बायोमास आधारित बिजली, लघु पनबिजली, पवन ऊर्जा जैसे नवीकरणीय ऊर्जा स्रोतों में क्षमता के विकास हेतु अविरल प्रयास किए जा रहे हैं। इसके अतिरिक्त नवीन एवं नवीकरणीय ऊर्जा मंत्रालय ने लघु और माइक्रोग्रिड के लिए एक प्रारूपिक राष्ट्रीय नीति जारी की है। इस नीति का लक्ष्य आने वाले पांच वर्षों में निजी क्षेत्र में 500 मेगावॉट तक की क्षमता का सृजन करना है।

डा. आशुतोष सिन्हा,
कानपुर, उत्तर प्रदेश

I am an Academician and Professor in PES Engineering College, Aurangabad. I found *Akshay Urja* of immense intellectual and educational importance. As I teach Renewable Energy to Final Year Electrical Engineering Students, *Akshay Urja* is a very useful teaching aid for me, my students, and my colleagues. It helps all of us to keep ourselves abreast of all the latest happenings in the new and renewable energy world. I request you to kindly subscribe me for the print version of this valuable magazine so that I can share it with all my students, friends, and peers.

Prof Irshad Waheed
Electrical Department,
PESCOE, Aurangabad

''नवीकरणीय ऊर्जा क्षेत्र की राष्ट्रीय समीक्षा' के बारे में जानकारी प्राप्त करके अच्छा लगा। सौर रूफटॉप के लिए मोबाईल एप: 'अरुण' का लोकार्पण भी एक महत्वपूर्ण कदम है। वास्तव में यह एक सरल मोबाइल एप है जिसे इस्तेमाल करना और समझना बहुत सरल है। यह सौर रूफटॉप और इसे स्थापित करने की विधियों की बुनियादी बातों को समझने में बहुत उपयोगी है। 'बायोगैस उन्नयन के लिए वैक्यूम स्विंग एडसॉर्प्शन' लेख में अपशिष्ट से ऊर्जा की संभाव्यता पर प्रकाश डाला गया है, जहां दैनिक दुग्ध प्रसंसाधन प्रचालनों में ताप अनुप्रयोगों के लिए प्राकृतिक गैस का इस्तेमाल किया जाता है। ऐसे बढ़िया लेखों एवं अन्य सामग्री प्रकाशित करने के लिए बहुत-बहुत धन्यवाद।

दीपिका मिश्रा,
नई दिल्ली

In December 2016 issue of *Akshay Urja,* I liked the article in RE Products section on micro solar dome for lighting up households in slum and rural areas. This idea is very good for capturing sunlight and for lighting up households. Particularly PV integrated micro solar dome (MSD) is a unique device; having LEDs fitted in lower dome PV panel. I was glad to know that it is also eligible for subsidy from MNRE. I would also like to buy a few PV micro domes for installing in tribal areas. Thanks to the editorial team of the magazine for publishing such good and useful articles in the RE Products section. Also, the article related to Mobile App for solar rooftop systems 'ARUN' published in the February–April 2017 issue highlights and gives basic knowledge about the installation of solar rooftop in house/premises. It is a brief guide on how to install the solar rooftop system. Also, I came to know that it will give an estimate of installation based on different parameters, such as capacity of budget. To achieve its renewable energy target in rooftop solar, the Government of India has initiated activities, such as promotion of solar power, training, sanction of projects, monitoring of projects, subsidy, disbursement, etc. This new app launched by the Ministry in January 2017 would be very helpful for all.

Er Anant Tamhane
Consulting Engineer Renewable Energy
Nagpur, Maharashtra

इंजीनियरिंग का छात्र होने के कारण मेरी रूचि नवीकरणीय ऊर्जा प्रणालियों के विषय में नवीनतम जानकारियां एकत्रित करने में रहती है। अक्षय ऊर्जा के फरवरी-अप्रैल 2017 अंक में प्रकाशित लेख 'प्रकाशवोल्टीय प्रणाली की निरापदता और दीर्घकालिकता के लिए सौर केबल और कनेक्टर का प्रबंधन' मुझे काफी रुचिकर लगा। 'भारत में भू-तापीय ऊर्जा' संभाव्यता और भावी तथ्य' लेख भी काफी ज्ञानवर्धक है। हालांकि, नवीकरणीय ऊर्जा के इस रूप में अनेक लाभ और हानियां हैं, फिर भी भू-तापीय ऊर्जा में एक स्वच्छतर, अधिक स्थायी प्रणाली की दिशा में किसी एक क्षेत्र विशेष में उल्लेखनीय भूमिका है।

विद्युत कुमार झा,
मधुबनी, बिहार

Dear Reader, Thank you very much for your suggestions and encouragement. The editorial team of *Akshay Urja* will make every effort to make this magazine highly informative and useful to all our readers. We welcome your suggestions and valuable comments to make further improvements in the content and presentation.

Editor, *Akshay Urja*

आनंद कुमार
Anand Kumar

सचिव
भारत सरकार
नवीन और नवीकरणीय ऊर्जा मंत्रालय
SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

Message

With great satisfaction, I want to share with the readers of *Akshay Urja* that in the past three years India's renewable energy sector has seen a paradigm shift as the figures indicate an exponential growth. The period (2014–15 to 2016–17) has been particularly satisfying as the percentage share of renewable power in India's total installed capacity has increased to 17.50 per cent (renewable power capacity of 57.24 GW out of the total installed capacity of 326.85 GW). The growth of 89 per cent has been achieved since April 1, 2015, with capacity addition of 22.26 GW grid renewable power. The Ministry has strived hard to expand solar power generation and as a result, highest ever capacity addition of 5.5 GW in solar power was made in 2016–17, which is 83.0 per cent more than a year's before achievement of 3 GW. The Ministry also set another record in the wind power and solar power capacity additions by adding 5.4 GW and 5.50 GW, respectively in 2016–17. Some of the other milestones achieved during the last three years include notifying all States/UTs for net-metering/feed-in-tariff to encourage solar rooftop plants (the Government has approved ₹5,000 crore for solar rooftops). During the period seven national schemes were launched to promote grid solar power projects. Considering the demand of more solar parks from the State Governments, the capacity of the Solar Park Scheme has been enhanced from 20,000 MW to 40,000 MW.

I am delighted to share with you that MNRE is trying to harness each and every sector of renewable energy to its full potential as the Government aims to fulfill its objective of providing 24x7 power to all households by 2022. India is also playing a pivotal role in international arena as well with the setting up of the International Solar Alliance with its headquarters in India.

I would like to take this opportunity to inform our readers that The Union Cabinet chaired by the Hon'ble Prime Minister of India has given its approval for raising Bonds of ₹2,360 crore for renewable energy. The Bonds will be raised by MNRE through the Indian Renewable Energy Development Agency (IREDA) during 2017–18. The resources raised would be used for developing additional capacity in renewable energy sector, which would result in generation of additional employment. The additional funds would be used by MNRE for the approved programmes/schemes for solar parks, green energy corridors, generation-based incentives for wind projects, CPSU and defence solar projects, viability gap funding for solar projects, rooftop/ off-grid/grid-distributed and decentralized renewable solar power, etc. Such timely investment would boost infrastructure in renewable sector and facilitate achievement of ambitious targets set for the renewable energy sector by 2022.

I look forward to interact with our readers through *Akshay Urja* magazine and request all of you to send your valuable suggestions and innovative ideas for the overall promotion of renewable energy in the country. We must endorse the use of renewable energy in our daily lives. I am sure that the articles and other information published in *Akshay Urja* would inspire everyone to adopt the clean and renewable sources of energy to propel the country towards rapid sustainable development.

With best wishes.

Anand Kumar

From the Editor's Desk

Dear Readers,

I am glad to share with you that India has set another record in the solar and wind power capacity addition by adding 5,526 MW and 5,400 MW in 2016–17, respectively. This year's achievement surpassed the previous highest capacity additions of 3,014 MW and 3,423 MW achieved in the previous year in solar and wind sectors respectively.

Now, moving forward with other sources of renewable energy, in this issue of Akshay Urja we are presenting a blend of various renewable energy initiatives in the country. The special feature in this issue talks about mini and micro solar grids that are really a beacon of hope for the renewable energy sector. Renewable energy (RE) sources-based mini and micro grids (small-scale versions of centralized electric grids) are proving to be one of the biggest rewards for the masses by providing basic electricity facility to the rural and remote networks in underdeveloped and developing countries. Enormous advantages can be availed through new supportive ecosystems by setting up economically-viable and environmentally-benign solar-based mini and micro grids. Rural people are finding a great relief in fulfilling their aspirational needs, such as cooking, clean running water availability, primary rural health and learning centres. Besides meeting the essential energy needs of every household, these mini grid systems are also enabling increase in their income through cottage enterprise-based opportunities.

The current issue also presents an article on analysis of bioenergy models to avoid open field burning of paddy straw in Punjab. The article talks about utilization of paddy straw for power generation through biomethane production route and bioethanol production on commercial scale and improved biomass cookstove on domestic scale. Biomethanation of paddy straw presented in this article consists of actual field experimental data taken from demonstration scale biomethanation plant at Fazilka, Punjab. We have also presented an article in this issue in which the author discusses about the development and simulation of a PV power pack servo-based single axis solar tracking system prototype. The article presents simulation and development of prototype of a single axis automatic solar tracking system using servo mechanism. The solar tracking system significantly improves performance of solar power projects.

Solar energy is abundantly available throughout the year and in order to save fossil fuels, solar energy is one of the most promising solutions and, therefore, needs to be utilized for spraying operation. The practical utility of solar-powered bullock-drawn sprayer has a wide scope in the country. The development and popularization of solar-powered bullock-drawn high clearance sprayer for cotton and red gram crops is essential and has wide scope in Karnataka. Therefore, we have presented a case study on development of a bullock-drawn solar-powered high clearance sprayer, which can be a promising source of renewable energy. The solar energy was used as the power source for the operation of sprayer unit while bullock power was utilized for pulling the cart.

I am sure that all the articles and information in the present issue will be a useful reading material and you will find these informative and interesting as well. Please do not forget to share your views and suggestions.

Happy reading!

DILIP NIGAM
dilipnigam@nic.in

RENEWABLE ENERGY NEWS

Scientists Create Efficient and Low-Cost Solar Cells Using Jamun

Naturally occurring pigment found in jamun as an inexpensive photosensitizer for dye-sensitized solar cells (DSSCs) or Gratzel cells have been used to create more efficient solar cells. Scientists at IIT Roorkee have used jamun fruit to create inexpensive and more efficient solar cells. Gratzel cells are thin-film solar cells composed of a porous layer of titanium dioxide (TiO_2) coated photoanode, a layer of dye molecules that absorbs sunlight, an electrolyte for regenerating the dye, and a cathode. These components form a sandwich-like structure with the dye molecule or photosensitizer playing a pivotal role through its ability to absorb visible light.

"The dark colour of jamun and abundance of jamun trees in IIT campus clicked the idea that it might be useful as a dye in the typical DSSCs," lead researcher Soumitra Satapathi, Assistant Professor at IIT Roorkee, said. Researchers extracted dyes from jamun using ethanol. They also used fresh plums and black currant, along with mixed berry juices, which contain pigments that give the characteristic colour to jamun. The mixture was then centrifuged and decanted. The extracted coloured pigment called anthocyanin was used as a sensitizer. "In principle, we have a large social need for renewable energy, especially solar energy. For quite some time, our lab is actively engaged in low-cost high-efficiency solar cells production," said Satapathi. The research was published in the *Journal of Photovoltaics*.

Source: www.saurenergy.com

Solar Power Tariff Drops to a Historic Low at ₹2.44/Unit

History was created as the record low tariffs achieved in the auction concluded in May 2017 for Bhadla Phase-IV Solar Park, Rajasthan has been broken, with an even lower tariff of ₹2.44 per unit discovered in the auction carried out by the Solar Energy Corporation of India Limited (SECI) for 500 MW capacity in Bhadla Phase-III Solar Park, Rajasthan. The park is being set up by M/s Saurya Urja Company of Rajasthan Limited, a joint venture between the Government of Rajasthan and M/s IL&FS Energy Development Company Limited. This tariff is fixed for 25 years with no escalation and the bidders have sought no VGF from the government. The winners are M/s ACME Solar Holdings Pvt. Ltd. (200 MW) at a tariff of ₹2.44 per unit and M/s SBG Cleantech One Ltd. (300 MW), quoting a tariff of ₹2.45 per unit.

It is understood that this fall in solar tariffs is the result of a combination of various factors, most important being the decision of the Government of India to cover solar power by SECI under the ambit of the Tripartite Agreement for payment security against defaults by state distribution companies. Other factors contributing are about 7–8 per cent higher yield in Rajasthan due to better solar radiation conditions, drop in module prices in international market, and strengthening of Indian rupee against US dollar.

Source: pib.nic.in

Floating Solar PV Plant Installed in Kerala

NTPC has started power generation from India's largest floating solar power plant at Kayamkulam in Kerala. The 100 kWp floating solar generation plant, largest of its kind in India, was indigenously developed as a part of the 'Make In India' initiative, at Rajiv Gandhi Combined Cycle Power Plant (RGCCPP) in Kerala's Kayamkulam district. Solar panels mounted on floating boards that hold them in place saves land usage and has been found to be efficient than the ones installed on land. These floating platforms were indigenously developed by NTPC Energy Technology Research Alliance, the R&D arm of NTPC Ltd, in collaboration with the Central Institute of Plastic Engineering & Technology (CIPET), Chennai.

The system was installed by Swelect Energy Systems Ltd, Chennai with support from NETRA and NTPC Kayamkulam station in a short span of 22 days. "Such systems are fast emerging as an alternative to conventional ground mounted photovoltaic systems which are land intensive. It has various benefits, such as conserving water through reduction of evaporation, increased generation due to cooling effect on the panels and requires lesser installation time than conventional land mounted ones," NTPC said in a statement.

Source: http://energy.economictimes.indiatimes.com/

Dr Arun K Tripathi Takes over as Director General, NISE

Dr Arun K Tripathi has taken over the charge as the Director General of the National Institute of Solar Energy (NISE), Gurugram, on May 18, 2017. He has over three decades of experience in planning, development, and implementation of various renewable energy programmes particularly on biogas development, biomass gasification, solar rooftops, waste to energy, village energy security, solar cities, green buildings, and information and public awareness in the country. He has widely travelled all over India particularly in rural areas, besides, many countries, such as the USA, UK, China, France, Thailand, Japan, etc., on various renewable-energy related assignments. He also acted as the editor of *Akshay Urja* from January 2005 till the previous issue (February-April 2017).

Source: http://nise.res.in/

Record Capacity Addition of Wind Power of 5,400 MW in 2016–17

The Ministry of New and Renewable Energy (MNRE) has set another record in the wind power capacity addition by adding over 5,400 MW in 2016–17 against the target of 4,000 MW. This year's achievement surpassed the previous higher capacity addition of 3,423 MW achieved in the previous year.

The leading states in the wind power capacity addition during 2016–17 were Andhra Pradesh 2,190 MW, followed by Gujarat 1,275 MW, and Karnataka 882 MW. In addition, Madhya Pradesh, Rajasthan, Tamil Nadu, Maharashtra, Telangana, and Kerala have reported 357 MW, 288 MW, 262 MW, 118 MW, 23 MW, and 8 MW wind power capacity addition, respectively during 2016–17. During 2016–17 MNRE took various policy initiatives in the wind energy sector that includes introduction of bidding in wind energy sector, re-powering policy, draft wind–solar hybrid policy, new guidelines for development of wind power projects, etc.

Source: pib.nic.in

India Becomes the Second Most Attractive RE Investment Destination

India has overtaken the US to become the second-most attractive country after China for renewable energy investment, according to a report by a UK accountancy firm EY. In an annual ranking of the top 40 renewable energy markets worldwide in terms of allure, China was ranked at the top, followed by India. According to EY, the US slipped to the third spot from first in last year's ranking. India was ranked third on last year's EY renewable energy country attractiveness index (RECAI) behind the US and China.

"India continued its upward trend on the index to second position with the government's programme to build 175 GW in renewable energy generation by 2022 and have renewable energy account for 40 per cent of installed capacity by 2040. A combination of strong government support and increasingly attractive economics has helped push India into the second place," EY said in a statement.

Solar power tariff has dropped to hit a new low of ₹2.44 per unit in the recent auction conducted for Bhadla Solar Park.

Source: http://www.hindustantimes.com/

IREDA Finances 10,000 Crore Green Projects during 2016–17

The Indian Renewable Energy Development Agency (IREDA) increased its financing of green energy projects considerably in 2016–17, crossing the milestone of ₹10,000 crore in a single year for the first time. IREDA provided loans of ₹10,200 crore through 2016–17 for 112 clean energy projects across solar, wind, small hydro, and biogas. "In the coming year, we plan to do ₹12,500–13,000 crore," said Shri K S Popli, Chairman and Managing Director.

It nearly doubled its support for solar projects to ₹4,785.87 crore in 2016–17 from ₹2,684.68 crore in 2015–16, but its financing of wind projects dropped slightly to ₹2,511.69 crore from ₹2,735.51 crore. The company, currently an NBFC under the Ministry of New and Renewable Energy, with mini navratna status, also hopes to come out with an initial public offering later this year. IREDA has also initiated the process of converting from an NBFC to a green bank. The falling tariffs of solar and wind power, thanks to the auction process initiated by the government, may please discoms and consumers, but financiers of renewable energy projects such as IREDA may have reasons to worry as their borrowers' margins get squeezed.

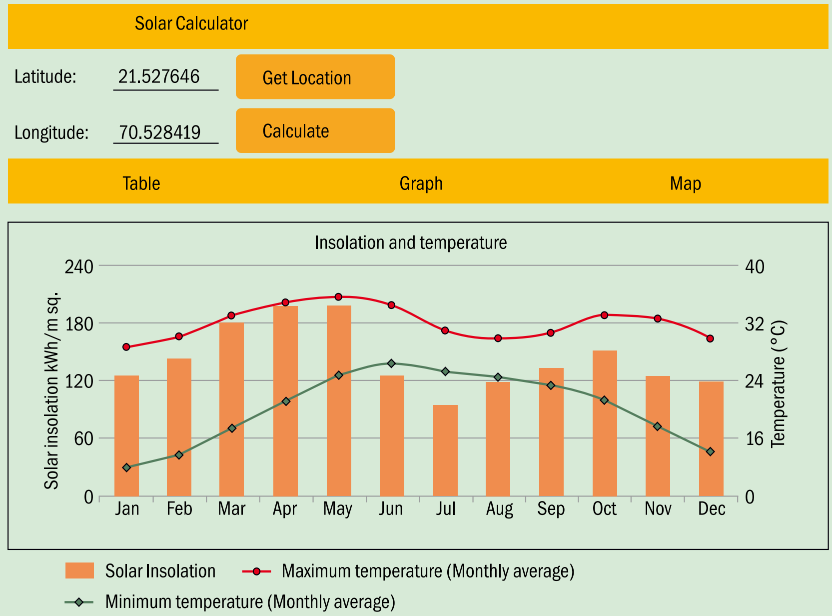
Source: http://energy.economictimes.indiatimes.com/

IREDA's Cumulative Loan Sanction Crosses ₹50,000 crore

IREDA's cumulative loan sanction, since inception crosses ₹50,000 crore. Cumulative loan sanctions towards clean energy projects as on date is ₹50,559 crore. IREDA's cumulative disbursements, since inception is ₹29,172 crore. IREDA over the last 10 years has committed a cumulative loan amount of around ₹40,792 crores for the clean energy sector. During this period, the loan sanctions and disbursements have grown at a CAGR of 32 per cent.

Source: IREDA

ISRO Develops Android App for Computing Solar Energy Potential



The Indian Space Research Organization's (ISRO) Ahmedabad-based Space Applications Centre has developed an android app for computing the solar energy potential of a place. Developed at the behest of the Ministry of New and Renewable Energy, the app is considered to be a 'very useful' tool for the installation of photovoltaic (PV) solar panels that is used for tapping solar energy. The ISRO said the app provides monthly and yearly solar potential and the minimum and the maximum temperatures at any location. It also displays the location of a place on the satellite image as well as the day's length during different periods in a year.

According to ISRO, features of the app include providing solar energy potential at any given location, the required location can be keyed in or can be obtained through GPS. It said it also gives a monthly and yearly solar potential processed using Indian Geostationary Satellite data (Kalpana- 1, INSAT-3D, and INSAT-3DR), and also offers a monthly minimum and maximum temperature to calculate the realistic solar potential. The obstruction of sunlight due to terrain is also calculated using Digital Elevation Model (DEM) with the help of the app which also suggests optimum tilt angle for the solar PV installation.

Source: http://www.hindustantimes.com/

Cabinet Approves Raising of Bonds of ₹2,360 Crore for Renewable Energy

The Union Cabinet chaired by the Prime Minister Shri Narendra Modi has given its approval to raising of bonds of ₹2,360 crore for renewable energy. The bonds will be raised by the Ministry of New and Renewable Energy (MNRE) through the Indian Renewable Energy Development Agency (IREDA) during the 2017–18.

These funds will be used by MNRE in the approved programmes/schemes for solar park, green energy corridor, generation-based incentives for wind projects, CPSU and defence solar projects, viability gap funding for solar projects, rooftop solar, off-grid/grid-distributed and decentralized renewable power, investment in corporations and autonomous bodies, etc. Such timely investment would boost infrastructure in the renewable sector and facilitate achievement of ambitious targets for the renewable energy sector. The resources raised would be used for developing additional capacity in renewable energy sector which would result in generation of additional employment.

Source: pib.nic.in

India's Solar Energy Capacity Expanded by Record 5,525 MW

India's solar energy capacity has expanded by a record 5,525.98 MW in 2016–17, according to the latest figures provided by the Ministry of New and Renewable Energy (MNRE).In comparison, India had added 3,010 MW of solar capacity in 2015–16, which shows that growth nearly doubled over the past year. The Government of India has set a target of 175 GW renewable power installed capacity by the end of 2022. This includes 60 GW from wind power, 100 GW from solar power, 10 GW from biomass power, and 5 GW from small hydro power.

Source: http://energy.economictimes.indiatimes.com/

Shri Upendra Tripathy Appointed as Full Time Interim Director General of ISA

Shri Piyush Goyal, Union Minister for Power, Coal, New and Renewable Energy and Mines, Government of India, and Ms Ségolène Royal, Minister for Environment, Energy and Marine Affairs Government of France jointly decided to appoint Shri Upendra Tripathy, as the Interim Director General (IDG) of the International Solar Alliance (ISA) on a full- time basis.

Shri Upendra Tripathy was the Former Secretary, MNRE from April 1, 2014 to October 31, 2016. The ISA was launched on November 30, 2015 as a coalition of the solar resource-rich countries jointly by Shri Narendra Modi, Hon'ble Prime Minister of India and Mr François Hollande, Hon'ble President of France in the presence of Mr Ban Ki Moon, Secretary General of the United Nations on the first day of the Paris Climate Conference (CoP21).

Source: pib.nic.in

"ISA Can Act as a Medium to Achieve Universal Energy Access Target Set Up Before 2030"—Shri Piyush Goyal

Shri Piyush Goyal, Minister of State (IC) for Power, Coal, New & Renewable Energy, and Mines said that International Solar Alliance (ISA) can act as a medium to spread lessons on energy security which can help achieve universal energy access target set up in SDGs before 2030. He was speaking at the launch of 'Scaling Solar Mini Grids' by France and India on the sidelines of 52nd Annual Meeting of the African Development Bank (AfDB) in Ahmedabad on May 24, 2017.

The President of African Development Bank Group, Mr Akinwumi A. Adesina meeting the Minister of State for Power, Coal, New and Renewable Energy and Mines (Independent Charge), Shri Piyush Goyal, in Gandhinagar, Gujarat on May 24, 2017.

Speaking on the occasion, Shri Goyal called for deeper Indo-African cooperation. He said that the Indian renewable energy sector offers lessons, such as lower and innovative financing models, risk reduction, setting up large scale solar projects through energy parks. "India has achieved grid parity in solar tariffs," he added. Shri Piyush Goyal also said that scaling solar mini grids shall work in tandem with ISA's overall objectives. The main activities under the programme shall include -design and deploy small grids, adopt common standards, aggregate demand, help establish global credit enhancement and de-risking mechanisms, call for expression of interest, assess demand and costs requirement for mini grid projects, identify/develop attractive payment models for consumers, and persuade member countries with overseas assistance budgets to earmark a portion of their soft loan for the Third Programme. Mr Ahmed Said Hassaini Djaffar, Vice President of the Republic of Comoros in his address welcomed the ISA initiative and stated that Africa is a solar resource rich region and can help achieve targets in solar energy.

Source: pib.nic.in

Renewable Energy Jobs Growing Worldwide: IRENA

Employment in the renewable energy sector, excluding large hydropower, increased by 2.8 per cent to reach 8.3 million in 2016, with China, Brazil, the United States, India, Japan, and Germany being the leading job markets. If the large hydropower segment is included, the sector employed 10 million people worldwide in 2016, almost twice as many as in 2012, according to a report by the International Renewable Energy Agency (IRENA). As many as 62 per cent of sector employees worldwide were in Asia where renewable energy projects were on the rise. The agency expects that jobs in the sector could reach 24 million by 2030, more than offsetting fossil-fuel job losses and becoming a major economic driver around the world.

Source: http://economictimes.indiatimes.com/

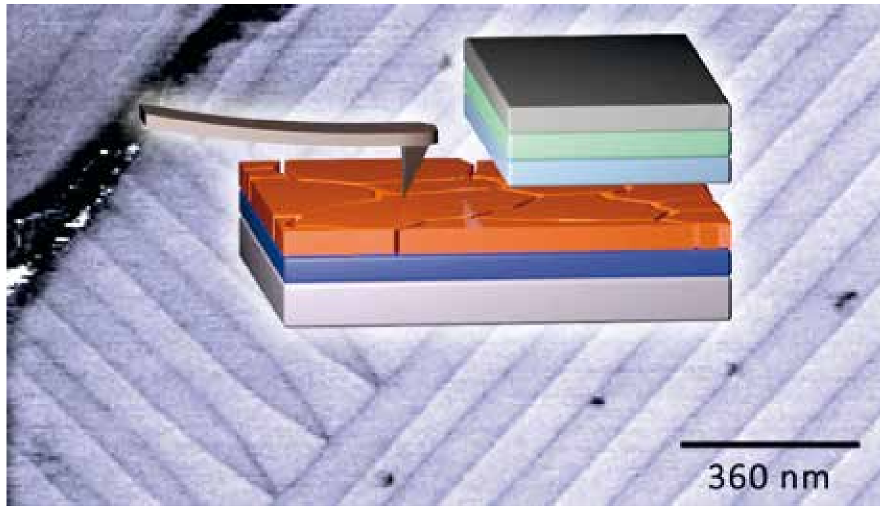
Record for Solar Hydrogen Production

The US Department of Energy's National Renewable Energy Laboratory (NREL) has captured the record for highest efficiency in solar hydrogen production via a photoelectrochemical (PEC) water-splitting process. The new solar-to-hydrogen efficiency record is 16.2 per cent, topping a reported 14 per cent efficiency in 2015 by a team made up of researchers from Helmholtz-Zentrum Berlin, TU Ilmenau, Fraunhofer ISE, and the California Institute of Technology. A paper in Nature Energy, titled 'Direct Solar-to-hydrogen Conversion via Inverted Metamorphic Multijunction Semiconductor Architectures,' outlines how the new record was achieved.

According to NREL, both the old and new PEC processes employ stacks of light-absorbing tandem semiconductors that are immersed in an acid/water solution (electrolyte) where the water-splitting reaction occurs to form hydrogen and oxygen gases. But unlike the original device made of gallium-indium-phosphide grown on top of gallium arsenide, the new PEC cell is grown upside-down, from top to bottom, resulting in a so-called inverted metamorphic multijunction device. Another key distinguishing feature of the new advancement was depositing a very thin aluminum indium phosphide 'window layer' on top of the device, followed by a second thin layer of gallium indium phosphide, NREL said.

Source: http://www.renewableenergyworld.com/

Solar Cells with Nanostripes Detected



Solar cells based on perovskites reach high efficiencies as they convert more than 20 per cent of the incident light directly into usable power. On their search for underlying physical mechanisms, researchers of the Karlsruhe Institute of Technology (KIT) have now detected strips of nanostructures with alternating directions of polarization in the perovskite layers. These structures might serve as transport paths for charge carriers. This is reported in the *Energy & Environmental Science Journal*.

The perovskites used by the KIT scientists are metal organic compounds with a special crystal structure and excellent photovoltaic properties. Since their discovery in 2009, perovskite solar cells have experienced a rapid development. Meanwhile, they reach power conversion efficiencies of more than 20 per cent. This makes them one of the most promising photovoltaic technologies. Research into perovskite solar cells, however, faces two special challenges: The light-absorbing layers have to be made more robust to environmental impacts and the lead contained therein has to be replaced by environmentally more compatible elements. This requires an in-depth understanding of physical mechanisms that enable the high conversion rate of absorbed solar energy into electric power. An interdisciplinary team of researchers headed by Dr Alexander Colsmann, Head of the Organic Photovoltaics Group of KIT's Light Technology Institute (LTI) and KIT's Material Research Center for Energy Systems (MZE) analysed perovskite solar cells by means of piezoresponse force microscopy, a special type of scanning force microscopy, and found ferroelectric nanostructures in the light-absorbing layers. Ferroelectric crystals form domains of identical electrical polarization direction. The KIT scientists observed that, during thin-layer development, lead iodide perovskites form about 100 nm-wide stripes of ferroelectric domains with alternating electric fields. This alternating electric polarization in the material might play an important role in the transport of photogenerated charges out of the solar cell and, hence, explain the special photovoltaic properties of perovskites.

Source: www.sciencedaily.com

Unprecedented Rise in Renewable Energy at Lower Cost

As the cost of clean technology continues to fall, the world added record levels of renewable energy capacity in 2016, at an investment level 23 per cent lower than the previous year, according to a new research published by UN Environment, the Frankfurt School—UNEP Collaborating Centre and Bloomberg New Energy Finance (BNEF). Global Trends in Renewable Energy Investment 2017 finds that wind, solar, biomass and waste-to-energy, geothermal, small hydro, and marine sources added 138.5 GW to global power capacity in 2016, up almost 9 per cent from the 127.5 GW added the year before. The added generating capacity roughly equals that of the world's 16 largest existing power-producing facilities combined.

Investment in renewables' capacity was roughly double in fossil fuel generation; the corresponding new capacity from renewables was equivalent to 55 per cent of all new power, the highest till date. The proportion of electricity coming from renewables excluding large hydro rose from 10.3 per cent to 11.3 per cent. This prevented the emission of an estimated 1.7 gigatonnes of carbon dioxide. Renewable energy investment in developing countries fell 30 per cent to $117 billion, while in developed economies it dropped by 14 per cent to $125 billion. Investment in renewables did not drop across the board. Europe enjoyed a 3 per cent increase to $59.8 billion, led by the UK ($24 billion) and Germany ($13.2 billion). Offshore wind ($25.9 billion) dominated Europe's investment, up 53 per cent thanks to mega-arrays. China also invested $4.1 billion in offshore wind, its highest figure to date. Another positive sign came in winning bids for solar and wind in auctions around the world, at tariffs that would have seemed inconceivably low a few years ago.

Source: www.sciencedaily.com

Mini and Micro Solar Grids

A Beacon of Hope for the RE Sector

Huge advantages can be availed through new supportive ecosystems by setting up economically-viable and environmentally-benign solar-based mini and micro grids. **Dr Om P Nangia** highlights the technical developments and opportunities through mini and micro grids installed with globally proven carbon-neutral technologies. He also discusses the Indian scenario and new developments and growth opportunities in the field of mini and micro solar grids.

More than 1.1 billion people worldwide (about 80 per cent population in rural areas including over 230 million in India) do not have access to electricity. Renewable energy (RE) sources-based mini and micro grids (small-scale versions of centralized electric grids) are proving to be one of the biggest rewards for the masses by providing basic electricity facility to the rural and remote networks in underdeveloped and developing countries. Enormous advantages can be availed through new supportive ecosystems by setting up economically-viable and environmentally-benign solar-based mini and micro grids. Rural folks are finding great relief in fulfilling their aspirational needs, such as cooking, clean running water availability, and primary rural health and learning centres. Besides meeting the essential energy needs of every household, these mini grid systems are also enabling increase in their income through cottage enterprise-based opportunities. Hybrid-based micro grid systems (combination of solar and diesel generator sets) for rural communities can help in meeting their electric load requirements and also increase in their economic activities. The mini grids have enormous potential and are a promising solution to access the energy challenge, especially in developing countries. By setting up these grids, an important milestone is achieved towards the holistic transformation in the lives of the villagers together with boosting of local economy.

All over the globe, the installed capacity of green power systems based on solar energy is expanding rapidly. Decentralized RE systems being eco-friendly and cost-effective, are being deployed to provide electricity in every household in remote areas in many parts of the

Solar micro grid in an Indian village

developing world. Use of clean technologies to generate affordable and reliable power is a high-priority area for the fast upliftment of villagers and in general the economic development of rural areas. New prospects are emerging for installing efficient solar PV systems (using the matured crystalline silicon technology) for energy access through decentralized or distributed mode systems (mini and micro) for multiple applications. Basically, their installation on different scales is relatively easy and can be done in any open, shadow-free ground, or a building rooftop. These systems being modular in nature get quickly installed and the energy produced can instantaneously power the designated applications at the source of consumption. The inherent advantages of solar energy systems have been discussed here.

Solar Power Systems (PV and Thermal)

A solar photovoltaic system (SPVS) is a concept of generating DC electricity from the sunlight falling on a solar array and converting it to AC power with the help of an inverter. The electricity can be used in a variety of applications, such as lighting, pumping, battery charging, etc. The SPV system can store electricity during day time in a battery for use in the night. It is also possible to integrate large solar plants including concentrated solar power (PV technology: CPV and thermal technology: CST) with the grid so that the generated power could be evacuated using a dedicated transmission infrastructure.

The solar PV-based clean power systems are useful for an individual dwelling unit, a community or on grid utility level, besides the space satellite applications. The upcoming technological innovations in mini/micro grids are likely to create new developments and business opportunities.

Solar Mini and Micro Grid Systems

Renewable energy-based mini and micro grids offer the benefits of boosting rural local economy and enterprise development, thereby generating employment opportunities and raising individual/household income, while meeting their day-to-day energy needs. A well-planned and focussed approach is called for scaling up mini and micro grids installations as per the needs of a developing country.

Today, a range of reliable RE technologies to generate, distribute, and manage power for a wide variety of applications are making the installation of micro grids popular. In view of the decreasing costs of delivered solar power including batteries for energy storage, municipalities all over the world are turning to installation of a large number of micro grids.

As per GTM Research report, when it comes to reliability of micro grids as a growth driver, North America is leading the way. The region has reached a tipping point between technology development and commercial deployment.

Policy on Mini and Micro Grids in India

The Ministry of New and Renewable Energy (MNRE), Government of India, has issued a national draft policy on setting up RE-based mini and micro grids in the country. The objective of the policy is to promote decentralized solutions based on RE sources (such as solar, wind, biomass, and small hydro) with its enormous potential, for meeting the lighting needs and other electricity requirements in un-served rural parts of the country. It envisages RE-based micro and mini grid solutions and approaches for overcoming challenges, and being perceived as a durable solution to provide reliable and cost-effective energy access for rural homes, cater to productive and commercial loads, accommodate future loads, and connect with grid and feed surplus power, if needed.

The government equally encourages active participation from energy service companies (ESCOs) in the RE-based mini and micro grid programme for providing clean power to rural households. They are being empanelled as rural energy service providers (RESPs). The Ministry has set a goal to deploy at least 10,000 RE-based micro and mini grid projects in India. An estimated capacity of 500 MW RE-based mini/micro grids (average size 50 kW) are proposed to be set up to provide energy to every household beyond the basic needs during the next five years to attain a sustainable growth in the country.

The underlying principles of the policy are as follows:

- Mainstream RE mini grids for enhancing access to affordable energy services and improving the local economy;
- Streamline project development procedures for ESCOs;
- Provide operational frameworks to operate along with the distribution company (DISCOM) grid;
- Optimize access to central financial assistance and other incentives.

ESCOs interested to deploy micro grids (less than 10 kW) are recommended to install projects in a cluster format (in contiguous areas) to improve operational and cost efficiency. The cluster format offers the possibility of interconnecting projects in the future. The policy favours deploying large-sized mini grid projects and permit ESCOs to deploy projects with capacities above 10 kW.

The International Scenario

Besides India, a few other countries (Tanzania, Nigeria, etc.) have also formulated policies to accelerate mini grid market growth. Internationally, the deployment of distributed

renewable energy is getting an appreciable investment from utilities. Another online platform created by the International Renewable Energy Agency (IRENA)—The Project Navigator, facilitates access to project planning and financing. Through this platform, the navigator guides project developers with the help of guidelines and tools. The detailed technical information on off-grid, mini and micro grid technologies is provided. Based on the IRENA report, with the guidance, the developer achieves the optimal technical solution by considering three major components: site and resource assessment, technology assessment, and logistics and construction. Additionally, the IRENA Project Navigator offers financial help for the mini and micro grids, which supports project developers in evaluating the financials, sustainability, and reliability impacts of the project.

But the biggest technological change in recent years has been a rapid rise in the use of solar PV generation in both standalone home energy systems and mini-grids. Diesel- or gasoline-fuelled mini-grid hybrid with renewable and standalone off-grid generation systems are well established in many countries such as Mali, which has probably more success in the development of isolated mini-grids with more than 200 numbers small diesel mini-grids supplemented with renewable technologies in operation.

Technology Capabilities and Criteria

During the last few years, as the prices of PV and energy storage are plummeting, micro grids are becoming cost-effective and attractive for a variety of power applications. Mini and micro grids using highly efficient/smart grid inverters are more than an alternative way to maintain energy supply or cut operational costs for any facility or municipality. These grids generally operate in isolation to the electricity networks of the DISCOM grid (standalone), but can also interconnect with the grid to exchange power. In general, the grids enable key power system operational and which in turn can benefit developers in achieving a variety of added objectives, such as grid reliability, resilience in the face of harsh climate or natural disasters, and in meeting emissions reduction targets. The technology capabilities and criteria of the mini and micro grids are discussed here.

Mini Grids

An RE-based electricity generator with a capacity of more than 10 kW used for supplying electricity in a community in a rural area or island for household usage, commercial, productive, institutional, and industrial set up, etc., through a public distribution network. Combination of both alternative current (AC) and direct current (DC) systems are acceptable. Electrical parameters of an AC mini grid system are given here and include components, such as generation plant, storage systems (batteries), inverters, distribution network.

AC mini grids:

(i) 220 V 1 phase -- up to 10 kWp

(ii) 440 V 3 Phase -- beyond 10 kWp

Micro Grids

An RE-based system with a capacity below 10 kW, supplying clean electricity to a cluster of houses in a remote area. DC generally generated through solar power is normally preferred where the loads are of low voltage/power, such as lighting, fans, radio, etc., and is closely located.

DC micro grids:

(i) 24 V DC -- up to 1 kWp

(ii) 72 V DC -- above 1 kWp to 10 kWp

Quality Standard of Systems

All the components for a mini and micro grid systems, such as PV panels, charge controller, inverter, storage battery, cables, circuit breakers, junction boxes, etc., shall conform to the technical specifications/requirements and quality standards specified by MNRE across its various programmes.

Case Studies

- A Pacific island Ta'u in American Samoa (4,000 miles from California) has power with solar mini grid from M/s Tesla Solar city, US. The island has three villages (average population of about 400 people) and were earlier powered by 100 per cent diesel generated (requiring 11,000 L of diesel as fuel). Located

Picture 1: Mini grid solar power plant used on Ta'u Island

on seven acres of land on the northern coast of the island, the system includes 5,328 solar panels, generating 1.410 MW of electricity (Picture 1). The energy can be stored in 60 Tesla Power packs that allow the island to stay powered for up to three days with no sunlight.

- In the Ladakh region in India, there are about 100 villages on harsh mountain terrains at an altitude ranging between 2,900 m and 5,900 m, with no access to grid electricity. The region receives incredible solar irradiance—1,250 W/sq. m on a clear day in summer and in winter it touches–30°C temperature. The habitants sustain their livelihood from the limited crops and animals. The Global Himalayan Expedition (GHE), a non-profit NGO along with volunteers from IEEE smart village volunteers have installed 110 solar micro grids (total capacity about 21 kW) in monasteries, homes, elementary schools, and dormitories in 25 villages (Picture 2). Energy access intervention has acted as a tool for further development and growth in these remote areas and has led to increase in income.

As per a report (GHE website), each micro grid of 24 V DC includes a 150 W– 250 W PV panel, a pair of 12-V lead-acid deep-discharge tubular batteries and 2.5 W LED lamps. A schematic diagram of the micro grid system is shown in Figure 1. Each PV panel of 250 W can support 30 LED lights. Each LED lamp is energy efficient and provides 250 lumens. All micro grids are automatic in operation and switch ON and OFF as per the sunlight levels.

Picture 2: Solar electrified mini grids across Ladakh villages

New Developments and Growth Opportunities

In the current scenario, economics and customer preferences are driving micro-grid owners to integrate higher concentrations of non-dispatchable renewable energy of varying capacity into their system. Several key factors, such as resilience and reliability, influence commercial-scale expansion in the micro-grid. For remote industrial operations, fuel prices and access to electricity via weak grids continues to drive specialized solutions, especially in developing countries. This leads to technical and operational challenges, including intermittencies, system-balancing problems, and power quality issues. However, with proper planning and use of appropriate technologies (automated controls and storage), micro-grid operators can effectively address the challenges.

As per GTM Research and ABB report, "The future of micro grids is bright and getting increasingly powered by renewable resources. Catalysed by dramatic decreases in the cost of deployment, the share of renewable energy generation and storage will continue to make up an increasingly larger portion of the growth. Although renewable energy production is variable and often intermittent, it provides long-term certainty on operating costs by offsetting fuel consumption and reducing engine run times."

Hybrid Solar–Diesel–Wind Micro Grid Projects

M/s ABB has installed around 40 installations all over the world serving remote communities, islands, utilities, and industrial campuses with micro grid technology. The report highlights that these factors enhance the economics of high-renewable micro grids while improving system reliability and flexibility. This can enable both grid-connected and off-grid systems to support wide-reaching benefits, such as minimizing fuel and net energy costs, reducing peak demand or emissions, etc. Figure 2 shows the micro grid market till date in the USA (ABB Report). It has relied primarily on conventional resources, specifically diesel- and natural-gas-fired generation, however, advances in PV generation technologies are initiating a rapid change to the future scenario for micro grids.

In the near future, it is expected there will be a large volume (in millions) of distributed energy renewable (DER) connections in the US (California) and elsewhere. To meet the growing requirements, M/s Southern California Edison (SCE) is planning to invest capital (about $ 9 billion), over the next three years on upgrades in its electric distribution system in California. SCE expects that as DER adaption upgrades, behind the meter solar deployment together with energy storage systems will take lead.

Installation of the new RE-based mini/micro grids for remote off-grid location, may offer a reliable and

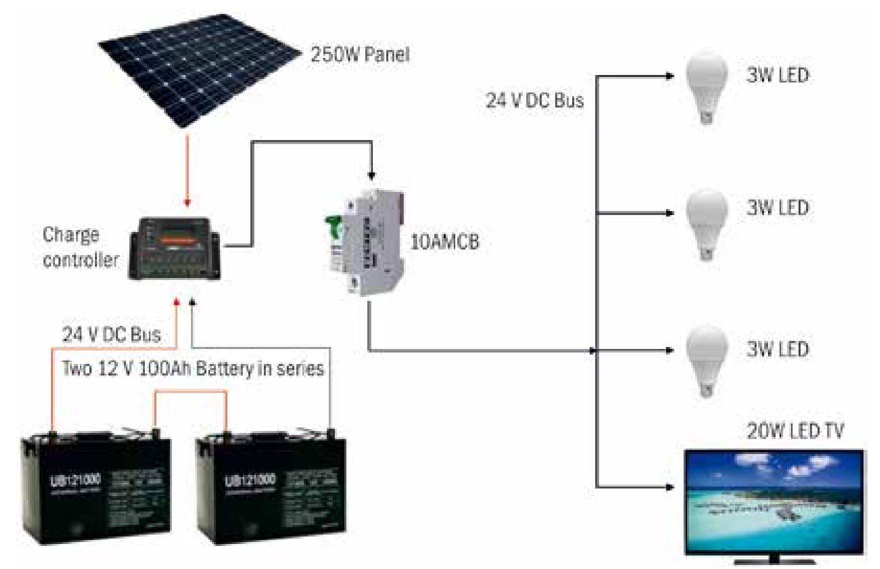


Figure 1: The schematic diagram of the circuit in micro grids deployed in Ladakh

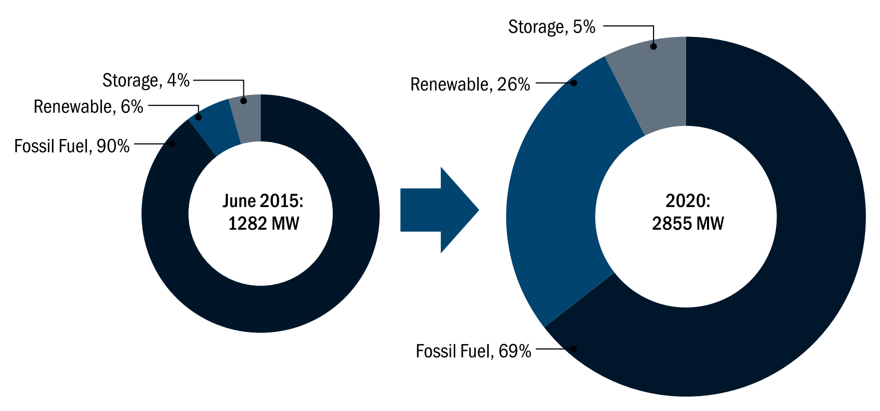


Figure 2: Present and 2020 cumulative operational micro grid capacity

cost-effective alternative to building additional generation or transmission and distribution capacity. If a feeder or substation upgrade is required to meet an increasing demand or address power quality concerns, a local micro grid with on-site generation could meet the need without significant capital investment. Similarly, the grid-connected micro grids can also reduce projected costs of service for local utility purposes.

WWF-India & CAT Projects Australia's micro solar power station at Rajat Jubilee in Sundarbans. Picture source: WWF India

Conclusion

Globally, the micro grid capacity is likely to grow rapidly. Looking in to the future, the momentum and focus on mini and micro grids shall be more with renewable technologies. With the selection of a suitable technology and equipment for setting up micro grids, especially with high-renewable portfolio, the technical challenges such as inherent intermittences of renewable sources can be adequately overcome. Considerable decline in solar technology and energy storage costs have mainly triggered the growth while changing the economics of installing mini and micro grid systems. These systems with the integration of solar offer tremendous potential to enhance reliability, resilience, and long-term energy security while decreasing both fossil-fuel dependence and overall energy costs.

The integration of micro grids with the distributed systems shall continue to grow in future and take care of capacity enhancements with cost effectiveness and power quality issues. As micro grid technologies are taking up a leapfrog from niche application to viable advance systems, commercial projects are beginning to fructify in recognition of the tremendous benefits these systems offer in terms of energy cost reductions, both to the remote communities and the project developer. New technical challenges may surface, but with the right approach and tools, mini and micro grid projects are surely to continue increasing in number and size and with a decrease in system's costs. AU

Acknowledgements: The author thankfully acknowledges all the referred sourced material reports, and websites.

Dr Om P Nangia , Senior Consultant–Solar Energy, Director at New Era Solar Solutions Pvt. Ltd., New Delhi, India.

Ministry of New and Renewable Energy

"PRAKRITIK URJA PURASKAR YOJNA"

Ministry of New and Renewable Energy, Government of India, is operating 'Prakritik Urja Puraskar Yojna' to encourage original book-writing in Hindi/translation of books in Hindi in the field of New and Renewable Sources of Energy. Under the scheme, there is a provision to award a first prize of Rs. 1,00,000/- (Rs. One Lakh), second prize of Rs. 60,000/- (Rs. Sixty Thousand) and a third prize of Rs. 40,000/- (Rs. Forty Thousand) for the books originally written in Hindi. For the books translated into Hindi, the amount of first, second and third prize is Rs.50,000/- (Rs. Fifty Thousand), Rs.30,000/- (Rs. Thirty Thousand) and Rs.20,000/- (Rs. Twenty Thousand) respectively. All authors, whether Government employees or Non-Governmental persons, can participate in the scheme. Entries are invited for the award for the calendar year 2016. Under the Scheme, books originally written in Hindi or translated into Hindi should be published from the year 2012 to 2016. The last date of receipt of entries is Aug. 31st, 2017. Entries will be accepted in prescribed proforma only. For further details, please contact Under Secretary (OL)/Hindi Section, Ministry of New and Renewable Energy, Block No. 14, C.G.O. Complex, Lodi Road, New Delhi-110003 (Phone N0 011 24360707/1002) or visit this Ministry's website www.mnre.gov.in

नवीन और नवीकरणीय ऊर्जा मंत्रालय

'प्राकृतिक ऊर्जा पुरस्कार योजना'

नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार, ऊर्जा के नए एवं नवीकरणीय स्रोतों के क्षेत्र में हिंदी में मौलिक पुस्तक लेखन/हिंदी में अनूदित पुस्तकों को प्रोत्साहन देने के लिए 'प्राकृतिक ऊर्जा पुरस्कार योजना' संचालित कर रहा है। इस योजना के तहत हिंदी में मूल रूप से लिखित पुस्तकों के लिए 1,00,000/- रु. (एक लाख रू.) का प्रथम, 60,000/- रु. (साठ हजार रू.) का द्वितीय तथा 40,000/- रु. (चालीस हजार रू.) का तृतीय पुरस्कार दिया जाता है । हिंदी में अनूदित पुस्तकों के लिए प्रथम, द्वितीय और तृतीय पुरस्कारों की राशि क्रमश: 50,000/- रू. (पचास हजार रु.), 30,000/- रू. (तीस हजार रु.) और 20,000/- रू. (बीस हजार रु.) है । इस योजना में सभी सरकारी अथवा गैर-सरकारी लेखक भाग ले सकते हैं। कैलेंडर वर्ष 2016 के पुरस्कारों के लिए प्रविष्टियां आमंत्रित की जाती हैं। इस योजना के अंतर्गत मौलिक पुस्तकों/हिंदी में अनूदित पुस्तकों को वर्ष 2012 से 2016 के बीच प्रकाशित होना चाहिए। प्रविष्टियां प्राप्त करने की अंतिम तारीख 31 अगस्त, 2017 है। प्रविष्टियां केवल निर्धारित प्रपत्र में ही स्वीकार की जाएंगी। इस बारे में कृपया विस्तृत जानकारी के लिए अवर सचिव (राजभाषा)/हिंदी अनुभाग, नवीन और नवीकरणीय ऊर्जा मंत्रालय, ब्लॉक सं. 14, केन्द्रीय कार्यालय परिसर, लोदी रोड, नई दिल्ली-110003 (दूरभाष 011-24360707/1002) से सम्पर्क करें या मंत्रालय की वेबसाईट www.mnre.gov.in देखें।

Automatic Solar Tracking System

Development and Simulation

The solar energy utilization varies according to the geographical location. To harness maximum energy from the available sunlight, tracking of PV panels was introduced. **Khyati Vyas** discusses the development and simulation of a PV power pack, servo-based, single-axis solar tracking system prototype.

Energy is the prime factor for the development of a nation. An enormous amount of energy is extracted, distributed, converted, and consumed in the global society daily. Eighty-five per cent of energy production is dependent on fossil fuels. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases (GHGs). To provide a sustainable power production and continuous power resources for the future generations, there is a growing demand for energy from renewable sources, such as solar, wind, geothermal, and ocean tidal waves. Renewable energy (RE) sources are the best-proven sources of energy. Solar energy is one of the most abundant resources of RE. Energy from sun is perceptibly environmentally advantageous in all respects. There are many different ways of generating electricity from the sun's energy. The most popular are photovoltaic (PV) panels, where silicon solar cells convert solar radiation to electricity. Keeping the PV-panels perpendicular to the sun's radiation maximizes the output. The systems that are utilized for this movement are called solar trackers. The solar trackers are also required for concentrating solar power applications to function. The power incident on a photovoltaic (PV) module depends not only on the power contained in the sunlight, but also on the angle between the module and the sun. When the absorbing surface and sunlight are perpendicular to each other, the power density on the surface is equal to that of the sunlight (in other words, the power density will always be at its maximum when the PV module is perpendicular to the sun). However, as the angle between the sun and a fixed surface is continually changing, the power density on a fixed PV module is less than that of the incident sunlight. The amount of solar radiation incident on a tilted module surface is the component of the incident solar radiation which is perpendicular to the module surface.

Development and Simulation of the Prototype

The overall solar tracking system consists of a mechanism that enables the PV panels to follow or track the sun. The mechanical structure consists of one servo motor that drives the mechanism, LDR sensors for measuring light intensity, and a programmable microcontroller responsible for giving electric signals to the motors in accordance to the sun angle in order to achieve solar tracking (keeping the PV panel perpendicular to the sunlight). Based on the system requirement tilt angle is provided of 25° angle southwards. The feedback control system operation is based on servo mechanism principles and the controller is responsible for the solar tracker motion.
The controller coding and servo mechanism is simulated in PROTEOUS 7. In summary, this article presents

the simulation and development of a prototype of a single axis automatic solar tracking system using servo mechanism. The simulation for servo mechanism using PROTEUS 7.0 is described thereafter. This is followed by the description of the development of a proposed solar tracking system.

The mechanism of the discussed system deals with the open loop tracking system in which sensors detect the higher light intensity. The motor actuates in the direction where sunlight is more. Such type of tracking mechanism is called servo mechanism and is also known as real-time tracking. It was resolved that real-time tracking would be necessary to follow the sun effectively so that no external data would be required in operation. The open-loop type is simpler and cheaper but it could not compensate for disturbances in the system and has low accuracy. On the other hand for the closed-loop tracking, the sun trackers usually sense the direct solar radiation falling on a photo-sensor as a feedback signal to ensure that the solar collector is tracking the sun all times and keep the solar collector at a right angle to the sun's rays for getting maximum solar insolation. The closed-loop tracking mechanism can overcome the issues related to (cloudy, rainy) weather conditions using AC antenna motors, and power electronic control circuit to convert DC into AC. However, it causes more losses in the system.

Since the PV module has nonlinear characteristics, it is necessary to model it for the design and simulation of PV system applications. Recently, a number of powerful component-based electronics simulation software package have become popular in the design and development of power electronics applications. It is difficult to simulate and analyse in the generic modelling of the PV power system. To test the operation logic code there is one more software to simulate the servo mechanism, that is, PROTEUS 7. Generally, most of the parameters are given in manufacturer's specifications but sometimes some parameters (such as ideality factor, series resistance, etc.) may not be given and may change due to ageing and other environmental factors. Hence, it is necessary to develop relations to find these parameters.

Simulation for Servo Mechanism

The working of microcontroller and servo is first simulated in PROTEUS 7.0 software (Figure 1). The servo mechanism of the solar tracker is first simulated in the software to determine whether the code generated for servo controlling is correct. This provides the working of servo mechanism before actual implementation.

Solar Tracking System Description

Development of the tracking system was carried out through the following two major steps which were as follows:

- Mechanical structure design
- Control system design

Mechanical structure

The structure of the prototype was prepared using CAD Solid Works 2013 to check the free movement of panel in east–west direction. Realization was accomplished at the workshop of renewable energy engineering department. Figure 2 shows the design prepared for tracking system.

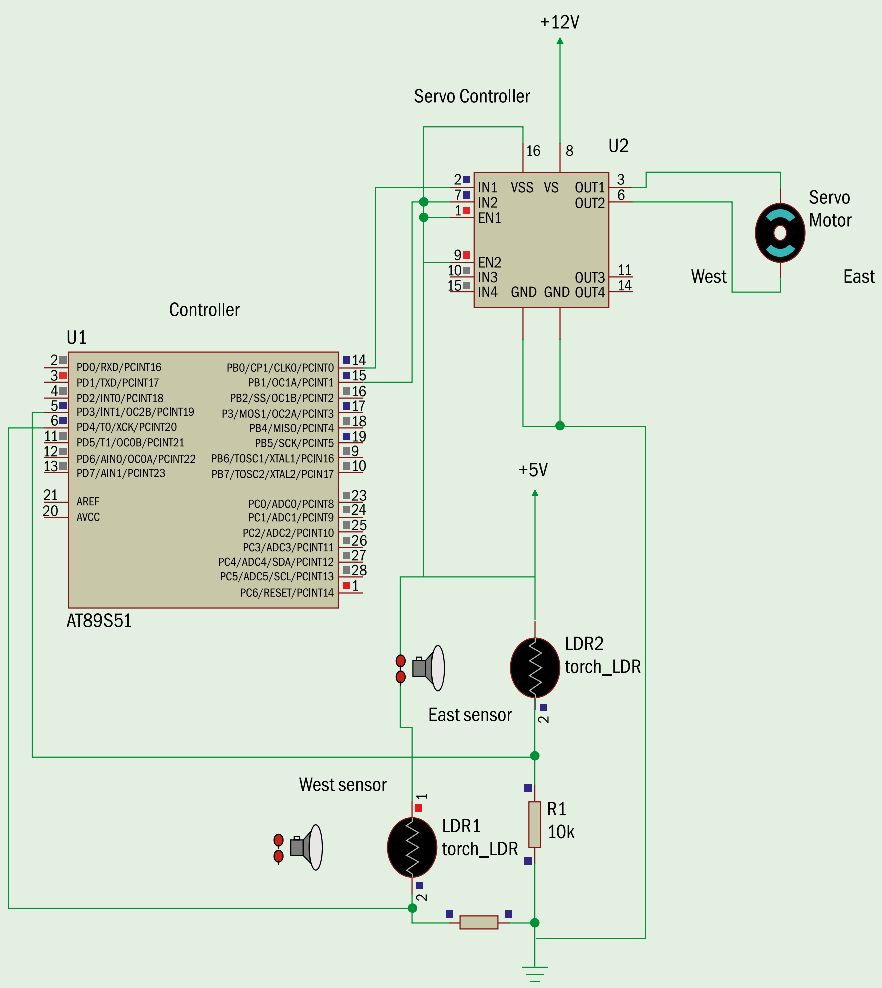


Figure 1: Simulation circuit layout in PROTEUS 7.0

Control system

This can be understood in two parts. First one works with active components which controls the system automation. The second one is to prepare circuit using passive components for charge controller, voltage regulation, and connections of all components.
The active components required are as follows:

» *Light-dependent resistor (LDR):* It is the light-depending resisters that have a particular property that they can detect lightning intensity in which they have been stored. The cell resistance falls with increasing light intensity. The sensitivity of a photo detector is the relationship between the light falling on the device and the resulting output signal. In the case of a photocell, one is dealing with the relationship between the incident light and the corresponding resistance of the cell.

» *Microcontroller:* The microcontroller is the brain of the tracker, and it controls the tracking system. Basically, it receives input from the sensors, specifying the position of the sun and in response, it sends signal to the motors that are connected to the solar panel to move to the panel to the position of the sun in which optimum solar rays could be received. The microcontroller is made up of software and hardware components.
The software component is basically the computer programmes that decode the input signals and sends out appropriate signal in response to the inputs to control the tracking system. It is connected to the sensors and motors.
The hardware executes the command. It requires 5 V DC.

» Servo motor: Servomotors are handy and practical in today's robotic and mechatronic systems as they provide a high level of accuracy, are simple to wire up, and relatively simple to control. They are also more applicable for certain applications than standard DC motors as they are position controlled rather than rotation controlled. A good application for servomotors is a sun tracking system for solar panels. The system requires a fairly high positional accuracy, therefore, servomotors are ideal for the job. The motor used here requires 4.8 V and an operating speed of 0.18 sec/60° at no load.

» Battery: The tracker needs a power source to keep it running due to the irregularity of the power received from the solar panel. A 6 V and 4.5 Amp rechargeable battery is used; the battery as it is connected to the tracking system is also connected to the output of the solar panel to keep it charging. Figure 3 shows the working of controlling components.

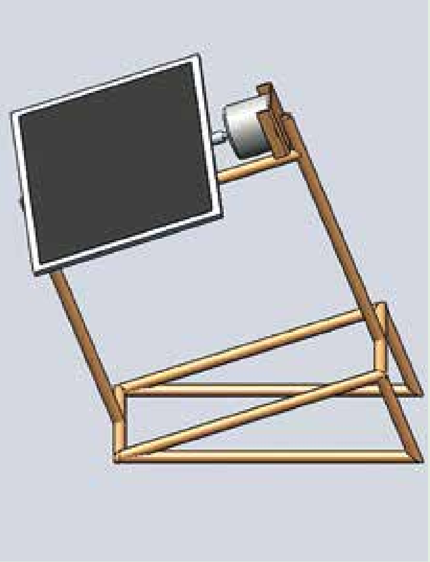


Figure 2: Design prepared for tracking system

Conclusion

In the proposed design and operation of the solar tracker system, the sun was not constantly tracked based on the irradiation. This helps to prevent unnecessary energy to be consumed by the devices and the system stops moving when the night falls. Simulation result shows that the codes generated for servo controlling are working accordingly. The developed system was also tested for performance evaluation.

It was observed that at 15.00 hours, tilted tracking gave 1.27 W of power gain in comparison to the fixed one. The complete calculated data for 12 hours are given in Table 1.

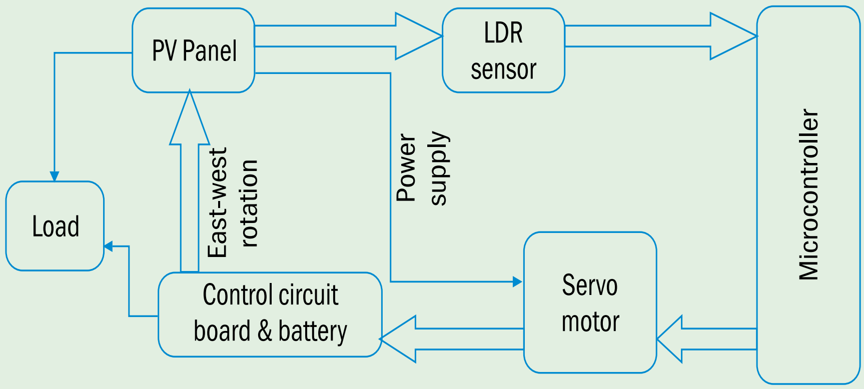


Figure 3: Block diagram demonstrating the working of tracking mechanism

Table 1: Efficiency gain data

Time (Hours)	Efficiency ηf (%)	Efficiency ηt (%)	Efficiency ηt* (%)	Efficiency ηt** (%)	Efficiency gain	Efficiency gain*	Efficiency gain**
7:00	3.64	5.63	6.32	8.43	1.99	2.68	4.79
8:00	4.25	6.97	8.67	8.13	2.72	4.42	3.88
9:00	5.62	6.57	6.78	7.17	0.95	1.16	1.55
10:00	5.74	7.06	6.73	6.97	1.32	0.99	1.23
11:00	6.39	7.05	7.13	6.72	0.66	0.74	0.33
12:00	7.63	7.38	7.61	7.00	-0.25	-0.02	-0.63
13:00	7.09	7.58	7.55	6.84	0.49	0.46	-0.25
14:00	5.69	7.12	7.19	7.27	1.43	1.49	1.58
15:00	2.74	6.45	6.68	5.62	3.71	3.94	2.88
16:00	2.74	5.56	6.48	6.28	2.82	3.74	3.54
17:00	2.80	5.90	9.09	8.21	3.10	6.29	5.41
18:00	0.80	5.68	9.77	9.21	4.88	8.97	8.41
19:00	0.45	2.71	9.64	6.67	2.26	9.19	6.22
Average	4.27	6.28	7.67	7.27	2.01	3.39	2.99

A view of the tracking system

Developed tracking system

Where,
ηf=fixed system efficiency,
ηt=Tracking system efficiency,
ηt*=Tracking at latitude angle efficiency.

$$\eta_{gain}(\%) = \left(\frac{\eta_t - \eta_f}{\eta_t}\right) \times 100$$

$$= \frac{7.67 - 4.27}{7.67} \times 100 = 44.25\%$$

Efficiency Gain = $\eta_t - \eta_f$ = 5.63-3.64=1.99%
Efficiency Gain* = $\eta_t^* - \eta_f$ = 6.32-3.64=2.68%
Efficiency Gain* = $\eta_t^{**} - \eta_f$ = 8.43-3.64=4.79%

An energy efficiency gain of 44.25 per cent relative to the fixed system was obtained. Results showed viability of the tracking strategy. Hence, it can be concluded that tracking system with a location-specific tilt can give better efficiency. The proposed control structure provides the flexibility to accommodate different weather conditions. AU

Source: IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE). Courtesy: Er. Khyati Vyas, Chemtrols Solar Pvt. Ltd, Mumbai, India; Email: khyati.vyas@chemtrolssolar.com

Energy Generation from Paddy Straw

An Analysis of Bioenergy Models

The mechanized harvesting of paddy crop has led to the open field burning of paddy straw. Burning of millions of tonnes of paddy straw releases large quantities of greenhouse gases (GHGs), which creates perturbations to regional atmospheric chemistry. **Dr Ram Chandra, Abhinav Trivedi, Bhaskar Jha, Amit Ranjan Verma, and Dr Virendra Kumar Vijay** present a case study on the utilization of paddy straw for power generation through biomethane production route and bioethanol production on commercial scale and improved biomass cookstove on domestic scale.

In India, paddy is cultivated in about 43.95 million hectares producing about 106.54 million tonnes of rice and approximately 160 million tonnes of straw with a ratio of 1:1.5 for rice grain produced to straw produced. Punjab produced 11.27 million tonnes of rice, which is 10.6 per cent of all India's total production for the year 2013–14 and produced a total of 16.90 million tonnes of paddy straw. Of the paddy straw produced, some part is used as a fuel for modern biomass power plants, brick kilns, cardboard making, mushroom cultivation, and some portion is used to fuel domestic biomass cookstoves in rural areas. Portions of the paddy straw that remain uncollected in the fields due to a combined harvesting technology are not burned and are eventually ploughed back into the fields, which serve as beneficial manure for the upcoming crops. Flooded rice fields also add up additional methane, a potential greenhouse gas produced by the bacterial community under anoxic conditions. But, due to surplus paddy straw and problem associated with its storage, farmers sell paddy straw at an uneconomical price of ₹500 per metric tonne leading to nearly two–thirds of it being burned openly in the fields to quickly prepare it for sowing the next wheat crop.

Paddy Straw Burning Leads to Production of GHGs

Researchers suggest that open field burning of paddy straw contributes heavily towards production of harmful greenhouse gas (GHG) emissions including polycyclic aromatic hydrocarbons (PAHs), as well as polychlorinated dibenzo-p-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), referred to as dioxins. Experimentally, it has been evaluated that one tonne of paddy straw releases 3 kg particulate matter, 60 kg CO, 1,460 kg CO_2, 199 kg ash, and 2 kg SO_2. Local paddy straw burning affects the environment as these air pollutants have significant toxicological properties and are notably potential carcinogens. This article presents experimental evaluation of paddy straw utilization via two bioenergy routes, viz., biomethanation for power generation and paddy straw pellet for household cooking needs. Biomethanation of paddy straw has been explained by actual experimental data from a demonstration scale biogas power of generation scale 3,800–4,000 m^3 of biogas per day. As an alternative to cattle dung cake for cooking application, paddy straw pellets were made and its potential was experimentally validated at lab scale in micro gasifier based forced draft improved biomass cookstove. Further over citing huge potential of biogas from paddy straw, energy and cost–analysis of demonstration scale biomethanation process is presented.

Since renewable energy resources vary according to geographical conditions, bio-energy generation from paddy straw has a wide scope in Punjab and other northern states of India.

Anaerobic Digestion of Paddy Straw

The anaerobic digestion technology is a most efficient way in terms of energy output/input ratio for handling biomass resources to produce energy and bio-fertilizer. Biomethanation of paddy straw presented here consists of actual field experimental data taken from demonstration scale biomethanation plant at Fazilka, Punjab. Paddy straw is received in bales from the entire region of Fazilka, Punjab, and is stored in the storage unit. Further, the paddy straw is manually spread over the width of the conveyer belt, to be fed into the pulverization unit, for its size reduction to a level of 3–5 mm. The proximate analysis revealed that untreated paddy straw contains up to 10.0 per cent moisture and 90.0 per cent total solids on wet weight basis, while 84.0 per cent and 16.0 per cent volatile solid matter and ash matter, respectively on dry weight basis. The ultimate analysis resulted into 40.00 per cent carbon, 5.50 per cent hydrogen, and 0.75 per cent nitrogen content on a dry-weight basis. Upon elemental analysis, it has been found that the amount of nitrogen content present in rice straw biomass is very low, C/N ratio = 54.0. Compositional analysis of paddy straw revealed 39.90 per cent cellulose, 24.0 per cent hemicellulose, and 5.6 per cent lignin.

The average capacity of paddy straw pulverization unit is 1.0 tonne/h. This unit is powered by an electric motor of 75.0 kW, which consumes nearly 94 kWh energy per hour of operation. This unit also consists of a pulverized paddy straw collection system followed by aspirator system for the collection of dust generated during the pulverization process. The aspirator unit is powered through electrical power of 30 kW, which consumes 37.5 kWh energy per hour of operation.

Biomethanation is carried out in two anaerobic digesters (designed in house) of 3,400 m^3 water volume capacity. The prepared paddy straw substrate is fed to the two digesters through the feeding unit using pumps. No external heating source is provided in the digester as the annual mean temperature in the area lies within mesophilic range. Loading rate was kept constant at 6.75 tonne VS/day to maintain 8–10 per cent TS in the digester, while the digester was maintained at a hydraulic retention time (HRT) of 30 days based on previous work done by the authors. The digested slurry was passed through two horizontal solid–liquid separating machines with a slurry-handling capacity of nearly 8.0 m^3/h. The system is able to separate solid material at the rate of nearly 600 kg/h having a moisture content of about 65 per cent. The separated liquid is recycled to prepare paddy straw substrate in a blending tank.

Table 1 shows the initial parameters of conducting continuous feed anaerobic digestion of paddy straw. C/N ratio of the pretreated paddy straw was maintained by adding urea at a rate of 18–20 g/kg of paddy straw on a dry basis. The digester was fully charged with fresh cow dung for start-up and feeding of paddy straw was gradually started.

Table 1: Biomethanation parameters

S.N.	Parameter	Particular detail
1.	Operation cycle	Continuous
2.	Hydraulic retention time (HRT)	30 days
3.	Operating temperature	33–38 ± 1°C
4.	Adjusted C/N ratio	~ 20
5.	Substrate concentration	
	Total solids concentration (TS)	10% (100.0 g/L)
	Volatile solids concentration (VS)	7.5% (75.0 g/L)

The hydrogen sulphide level in biogas has to be reduced below 50 ppm for engine operation. The hydrogen sulphide scrubber unit consists of a 5.5 kW electric motor to power a booster pump, which pumps raw biogas through the scrubber unit. An electric motor having 5.5 kW power is used to circulate the digested slurry in the scrubbing unit. The total power consumption in hydrogen sulphide scrubbing unit has been 11 kW, which utilizes 13.75 kWh energy per hour of operation. Power generation unit consists of 1.0 MW 100 per cent biogas. The generator produces 1.2 MW per hour electrical energy through a three-phase 415 V alternator. Ten tonne/d of paddy straw is pulverized and fed to anaerobic digesters, which produce nearly 3,800–4,000 m^3 of biogas per day with methane and carbon dioxide

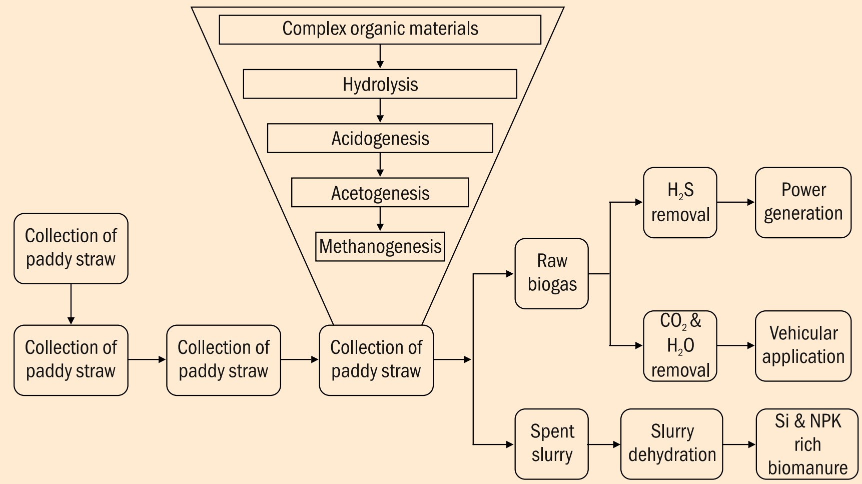


Figure 1: Process flow diagram of biogas production from paddy straw

content in the range of 50–55 per cent and 40–45 per cent, respectively. The hydrogen sulphide content in produced biogas varies from 500 to 600 ppm. Average specific biogas production has been found in the range of 390–440 m^3/tonne of total solids fed to the plant. Specific methane production yield has been observed in the range of 200–220 m^3/ tonne of total solids for standard operation of 12 months. Figure 1 shows the process flow of paddy straw to biogas generation.

Maximum and minimum biogas generated per tonne of total solids in present case is 390 and 440 m^3, respectively after a short, mechanical pretreatment.

Energy and Cost–Benefit Analysis of Biogas Production

For the energy balance, calculations are made from the point of paddy straw pretreatment for biogas production. From Tables 2 and 3, it is evident that the conversion of paddy straw to biogas via pulverization achieves a net positive energy of 655 kWh/tonne and cost benefit of ₹6,916/ tonne of paddy straw. It was revealed that the use of rice straw for biogas production can generate a positive net energy balance between 70 per cent and 80 per cent.

Table 2: Energy analysis of paddy straw-based biogas power production

Unit	Power consumption (kWh/h)	Operating time, h	Total power consumption, kWh/10 tonne
Energy input			
Paddy straw pretreatment (pulverization)	94.00	10.00	940.00
Substrate feeding unit	23.00	10.00	230.00
Hydrogen sulphide scrubbing unit	13.75	10.00	137.50
Bio-fertilizer unit	13.75	10.00	137.50
Total energy input (kWh)			1,445
Energy output (kWh)			8,000
Net energy gain (kWh)			6,555
Output/ Input			5.5

This shows that pretreatment of paddy straw is necessary to reap a higher methane yield. The pretreatment followed by biomethanation will enable the economically competitive use of paddy straw for energy generation. This will lower the negative environmental impact during burning of paddy straw in open fields.

Table 3: Cost–benefit analysis of paddy straw-based biogas power production

	₹/ 10 Tonne paddy straw	Rate (₹/ Unit)
Output electricity (8000 kWh)	60,000	7.5 kWh
Bio-fertilizer (5.0 t)	35,000	7.0/ kg
Input		
Paddy straw cost	-15,000	1,500/ tonne
Paddy straw pretreatment (pulverization)	-7,050	
Substrate feeding unit	-1,725	
Hydrogen sulphide scrubbing unit	-1,031	
Bio-fertilizer unit	-1,031	
Net benefit	69,163	
Output/ Input	3.6	

Total Energy Yield of Biogas and Bioethanol Productions

It is evident from Table 4 that the total obtainable energy yield from biomethanation route is 30 per cent more than bioethanol route. If all the surplus paddy straw biomass, which accounts for 11.70 million tonnes in Punjab, is brought to biomethane production, it will produce energy equivalent to 2.238 Mtoe and upon converting it to bioethanol, it will produce energy equivalent to 1.564 Mtoe.

pelletization. Paddy straw was air dried for five days followed by drying in hot air oven at 105±1°C for 12 hours and pulverized. Pulverized paddy straw was mixed with standard binder and pellets were made by a pelletizer of capacity 100 kg/h.

Water boiling tests were conducted in laboratory for the estimation of thermal performance of improved biomass cookstove fuelled by paddy straw pellets. Thermal efficiency of the cookstove was measured as a ratio of useful heat generated by the combustion of pellets in improved cookstove to the heat (theoretically) produced by complete

CO_2 values in ppm were performed using standard procedure. Total particulate matter was monitored through the stack monitoring system. Thermal efficiency of the improved biomass cookstove was found to be 36.11±0.38 per cent when fuelled by paddy straw pellets which is equivalent when the same stove is fuelled with other fuels. Emissions were calculated on total CO_2 equivalent per tonne of paddy straw pellet fuelled in the aforementioned biomass cookstove. Figure 2 presents the trends in thermal efficiency during laboratory testing and CO_2 equivalent

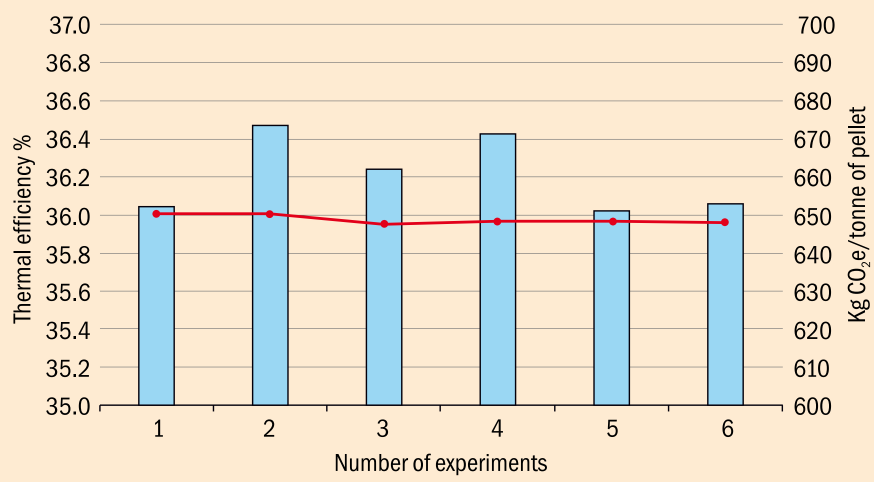


Figure 2: Trends in thermal efficiency during laboratory testing and CO2 equivalent emissions when 1 tonne paddy straw pellets will be combusted in improved cookstove

combustion of a given quantity of pellet in the stove (based on the net calorific value of the fuel).

emissions when 1 tonne paddy straw pellets will be combusted in improved cookstove.

The average value for CO_2 equivalent was found to be 648.76 kg/tonne of paddy straw pellet. The value shows a significant decrease in emissions when compared to CO_2 equivalent emissions from burning 1 tonne of paddy straw in the open field which comes to be 2,150 kg CO_2e/tonne as mentioned in Table 5.

Table 4: Biomethane and bioethanol potential of paddy straw

S. No.	Energy route	Yield/tonne paddy straw (kg/t)	Total energy yield (GJ/t)	Electricity equivalent# (kWh/t)	Petrol equivalent (L/t)
1.	Biomethane	144.32	8.000	777.00	166.60
2.	Bioethanol	188.57	5.600	544.25	116.60

#Power generation efficiency is 35.0 per cent

Paddy Straw Pellet for Improved Biomass Cookstove

Farm-collected paddy straw biomass was dried and pulverized for

The cookstove was tested for its emissions (CO, CO_2, and total particulate matter) simultaneously along with the testing of thermal efficiency. Measurement of CO and

Global Warming Potentials

As a part of life cycle assessment of the technologies for the utilization of paddy straw for bioenergy production,

the global warming potential for biogas (power), improved biomass cookstove, and bioethanol was calculated. Global warming potential (GWP) is an index defined as the cumulative radiative forcing between the present and a chosen later time 'horizon' caused by a unit mass of gas emitted now. It is being used to compare the effectiveness of GHGs to trap head in the atmosphere relative to standard gas, generally CO_2. The GWP for CH_4 (based on a 100-year time horizon) is 21, N_2O is 310, CO is 2, and particulates (PM) is 190. The GHG emissions in terms of kg CO_2e/tonne of paddy straw is presented in Table 5. Emissions from open field burning is considered to be a base case and accordingly calculations were made for each activity. It was found that 1 tonne of paddy straw if diverted from burning in open field can produce 8 GJ for biogas, 5.6 GJ for ethanol, and 5.0 GJ when used as paddy straw pellets with 36 per cent biomass cookstove efficiency. The system boundary taken into consideration while making calculations is depicted in Figure 3. Global warming potential of all three technologies as mentioned in Table 5, suggests that significant emissions can be controlled by diverting paddy straw from open field burning. Since all three routes mentioned here have nearly the same net GWP, these technologies have to be used based on requirement since one technology cannot be the solution provider for mitigating open field burning.

Table 5: Impacts on global warming potential (kg CO_2 e/tonne paddy straw) for biogas, paddy straw pellet, and bioethanol

	Biogas (Power)	Paddy straw pellet (cookstove)	Bioethanol
CO_2e emissions (in kg) for activities (for 1.0 tonne of paddy straw)			
Bailing[a]	165.00	165.00	165.00
Transportation (15 km)[b]	14.35	14.35	14.35
Paddy straw pretreatment[c] (pulverization)	81.78	81.78	81.78
Substrate feeding unit[c]	20.01	N/A	N/A
Hydrogen sulphide scrubber[c]	11.96	N/A	N/A
Biofertilizer unit[c]	11.96	N/A	N/A
Pelleting[c]	N/A	78.00	N/A
Dilute acid pretreatment[d]	N/A	N/A	32.00
Milling and enzymatic hydrolysis[d]	N/A	N/A	32.00
Fermentation and distillation[d]	N/A	N/A	8.00
Total GHG emissions (kg CO_2e/tonne PS)	305.06	339.13	333.13
GHG Credits			
Avoidance of open field burning	-2,150	-2,150	-2,150
Electricity	-870	N/A	N/A
Emissions from cookstove	N/A	-648	N/A
Vehicular emissions from ethanol	N/A	N/A	-377
Emission from petrol vehicles	N/A	N/A	-355
Total GHG credits	-3,020	-2,798	-2,882
Net GWP	-2,715	-2,459	-2,549

[a]kg/tonne CO_2e emissions for bailing paddy straw is taken from a document of International Rice Research Institute Database
[b]kg/km CO_2e emissions for tractor is calculated by calculating total diesel consumption in unloaded and 1.0 tonne load conditions
[c]kg/kWh of CO_2e emissions are calculated using CO_2e emission factor 0.87 kg/kWh. Power consumption of these units are mentioned in Table 3.
[d]kg/tonne CO_2e emission estimations are based on literature data.

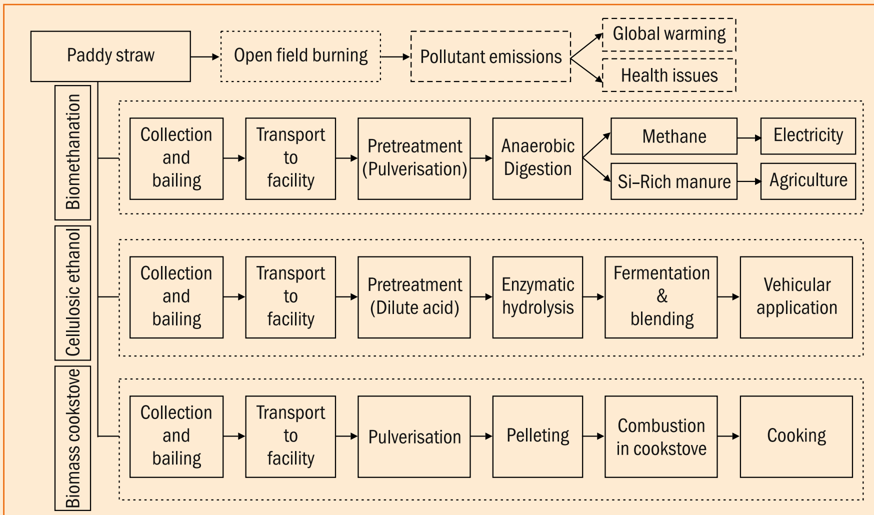


Figure 3: System boundary of paddy straw utilization for energy generation in this assessment

Conclusions

Paddy straw burning is a serious concern in India and has been driving the attention of policymakers and researchers. The authors did in-depth study for best utilization of paddy straw for sustainable energy production and to reduce resulting emissions in terms of GHGs equivalent. The analysis of biomethane production from paddy straw revealed that this route of energy conversion is most efficient in terms of obtainable useful energy and global warming potential. The power generation data showed that the biomethane results into electricity generation of 777.0 kWh/

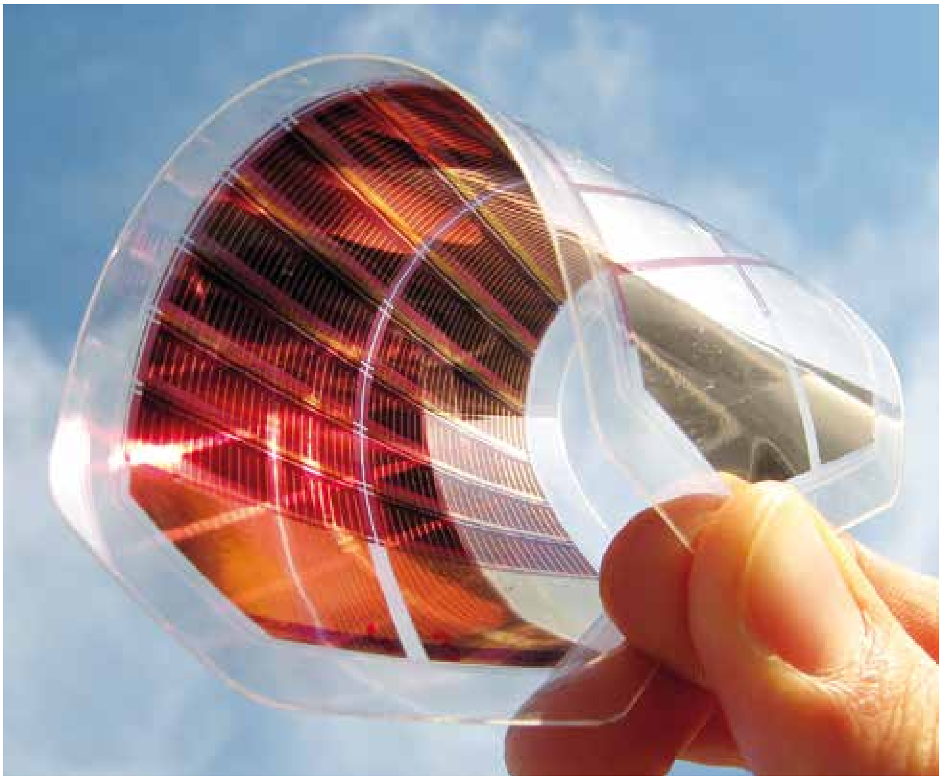
tonne of paddy straw with output/input energy ratio of 5.5. However, bioethanol production potential analysis showed an electricity equivalent of 544.25 kWh/tonne of paddy straw. Nevertheless, bioethanol is a ray of hope in competing with existing petrol-based motor vehicles but biomethane provides an added advantage of reaping extra energy from the same amount of paddy straw and on the other hand providing valuable manure for sustainable agriculture. The pelletized paddy straw can be used in improved biomass cookstoves to meet thermal cooking energy requirement as the results showed in reduction of indoor air pollution as compared to open field burning. The analysis further revealed that biomethanation of paddy straw reduces net global warming potential by 2,750 CO_2e kg emissions/tonne. However, bioethanol production showed net global warming potential reduction of 2,549 CO_2e kg emissions/tonne. The pelletization of paddy straw for improved cookstove showed net global warming potential reduction of 2,459 CO_2e kg emissions/tonne. The overall analysis of conducted study reveals that the utilization of paddy straw for biomethane production through anaerobic digestion route is the best way in terms of energy and environmental economics. Decentralized and centralized system of biogas production commercial plants can be suitably set up at a cluster level of villages to minimize logistic cost. The available energy can be suitably used to supply clean and green cooking fuel, power generation as well as vehicular fuel applications depending upon the need in the vicinity. AU

Dr Ram Chandra, Mr Abhinav Trivedi, Mr Bhaskar Jha, Mr Amit Ranjan Verma, and Dr Virendra Kumar Vijay , Centre for Rural Development and Technology, Indian Institute of Technology Delhi, New Delhi, India; Email: ram.chandra6dec@gmail.com.

New Forms of Solar Cells

Poised for a Breakthrough

Imagine a future where solar cells are present everywhere—from our clothes to our work stations and even our homes. In order to ensure that photovoltaics (PV) make a real difference, they need to become a part of people's lives throughout the world in all possible places and forms. **Dr S S Verma,** through this article, presents a detailed description of the two popular solar cells—solar thermophotovoltaics and printed solar cells—such that their technology, challenges in usage, and the future ahead is analysed.



Paper-thin printed solar cells

Use of solar photovoltaics to generate electricity in terms of solar parks and solar panels on rooftops is growing but even decades after photovoltaics were first developed, the slabs of silicon remain bulky, expensive, and inefficient. Fundamental limitations prevent these conventional photovoltaics from absorbing more than a fraction of the energy in sunlight. Standard silicon solar cells mainly capture the visual light from violet to red. Since 1961, it has been known that there is an absolute theoretical limit, known as the Shockley-Queisser Limit, to how efficient traditional solar cells can be in their energy conversion. For a single-layer cell made of silicon—the type used for the vast majority of today's solar panels—the upper limit is about 32 per cent.

Hot Solar Cells

Photovoltaics to thermophotovoltaics

However, there are some possible avenues to increase the overall efficiency by using multiple layers of cells. In this regard, a widely studied method is solar thermophotovoltaics (STPVs) wherein sunlight is first converted to heat before generating electrical power.

In fact, theory predicts that in principle this method, which involves pairing conventional solar cells with added layers of high-tech materials, could more than double the theoretical limit of efficiency, potentially making it possible to deliver twice as much power from a given area of panels. Scientists have built a different sort of solar energy device that uses inventive engineering and advances in Materials Science to capture far more of the sun's energy. The trick is to first turn sunlight into heat and then convert it back into light, but now focussed within the spectrum that solar cells can use. By converting heat to focussed beams of light, a new solar device could create cheap and continuous power. While various researchers have been working for years on so-called solar thermophotovoltaics, this device is the first one to absorb more energy than its photovoltaic cell alone, demonstrating that the approach could dramatically increase efficiency. The device is still a crude prototype, operating at just 6.8 per cent efficiency but with various enhancements it could be roughly twice as efficient as conventional photovoltaics.

Advantages

The use of such a system could offer a number of advantages over conventional photovoltaics whether based on silicon or other materials:

- The photonic device is producing emissions based on heat rather than light implying that it would be unaffected by brief changes in the environment such as clouds passing in front of the sun.
- If coupled with a thermal storage system, it could in principle provide a way to make use of solar power on round-the-clock basis.
- The biggest advantage is the promise of continuous on-demand power.
- Additionally, due to the way the system harnesses energy (that would otherwise be wasted as heat), it can reduce excessive heat generation that can damage some solar-concentrating systems.

Technology behind STPVs

While current photovoltaic panels efficiently convert part of the solar spectrum directly into electricity, they become significantly less efficient as they get hotter—an inevitable side effect of absorbing sunlight. Unlike traditional photovoltaics, which maintain their efficiency by dispersing the heat away from the panel or cooling the panel in some way, hot solar cell panels will be built from materials that can operate efficiently at temperatures far higher than the typical panel and will integrate with a solar thermal collector that absorbs the unused portion of the light spectrum and converts it into heat. The aim is to make a photovoltaic device that can operate at temperatures as hot as the inside of a brick oven. This is definitely high-risk research, as solar cells have never been run this hot and they will need to be both reliable and efficient at that temperature for a long time. However, the potential payoffs are huge.

The key step in creating the device was the development of an absorber-emitter which essentially acts as a light funnel above the solar cells. The absorbing layer is built from solid black carbon nanotubes that capture all the energy in sunlight and convert most of it into heat. As temperatures reach around 1,000°C, the adjacent emitting layer radiates the energy as light, now mostly narrowed to bands that the photovoltaic cells can absorb. The emitter is made from a photonic crystal, a structure that can be designed at the nanoscale to control the wavelengths of light flowing through it. Another critical advance was the addition of a highly specialized optical filter that transmits the tailored light while reflecting nearly all the unusable photons. This 'photon recycling' produces more heat, which generates more of the light that the solar cell can absorb, improving the efficiency of the system.

The panels will use technology from concentrated solar power—a different method for capturing solar energy used in several large solar power plants—to transfer the heat to high-temperature fluids that can be used to power a steam turbine and generate electricity. These fluids can also be easily stored so that the heat energy can be dispatched when the sun is not shining or whenever electrical demand rises; this method of storing solar energy is more cost-effective than storing energy in batteries. The current high cost of storing solar electricity in batteries, combined with the natural variation of available sunlight, will weaken the economic drive for photovoltaic market growth. Hot solar project addresses both these challenges by taking the best elements of photovoltaic panels and combining them with the best elements of concentrated solar power.

Future of STPVs

A photovoltaic device that converts sunlight into heat to generate power has achieved greater efficiency than previous such devices, thanks to the design of nanomaterials in the light-absorbing layer. The system converts solar heat into usable light, thus increasing the device's overall efficiency. Solar thermal photovoltaics

can exceed photovoltaics output with a direct comparison of the same cells, for a sufficiently high-input power density, lending this approach to applications using concentrated sunlight. The new record for solar means thermal photovoltaics using a solar simulator, selective absorber, selective filter, and photovoltaic receiver, which reasonably represents actual performance that might be achievable outdoors. The next steps include finding ways to make larger versions of the small, laboratory-scale experimental unit, and developing ways of manufacturing such systems economically.

There are some downsides to the approach, including the relatively high cost of certain components. It also currently works only in a vacuum. But the economics should improve as efficiency levels climb and the researchers now have a clear path to achieving the same. Scientists believe they can further tailor the components now that they have an improved understanding of what is needed to get to higher efficiencies. Researchers are also exploring further ways to take advantage of strength of solar thermophotovoltaics. Because heat is easier to store than electricity, it should be possible to divert excess amounts generated by the device to a thermal storage system, which could then be used to produce electricity even when the sun is not shining. If the researchers can incorporate a storage device and ratchet up efficiency levels, the system could one day deliver clean, cheap, and continuous solar power. In addition to converting a portion of the sunlight directly into electricity, the solar cells will use the remainder of the light to heat high-temperature fluids that can drive a steam turbine or be stored for later use.

Printed Solar Cells

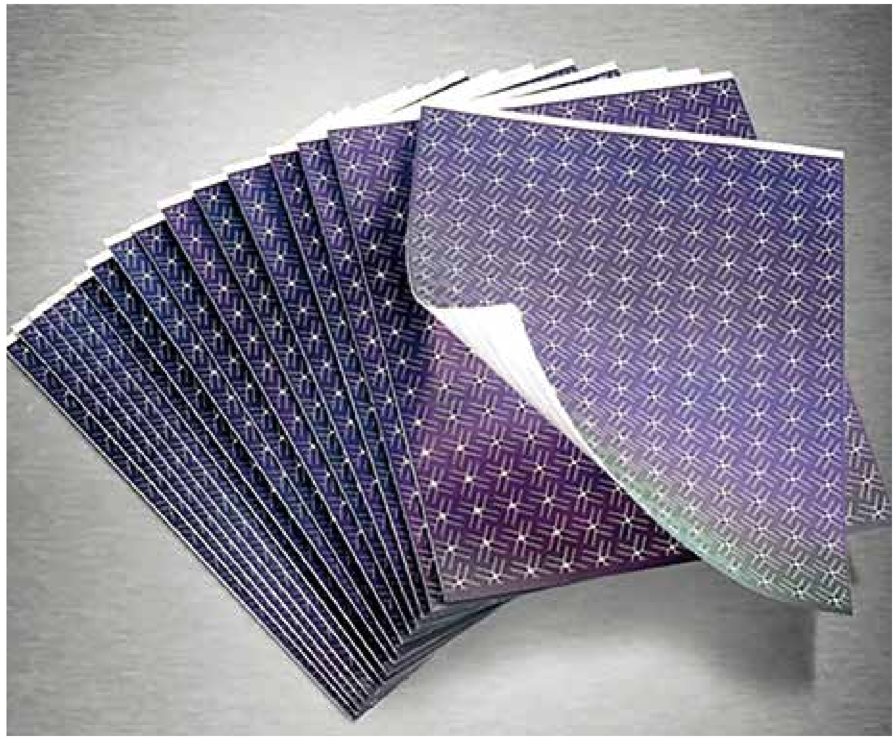
Conventional, silicon-based solar panels are rigid and bulky. The future of solar energy depends on a union of new and old technologies. The most efficient are the perovskite-based cells. The latest of these, with just a few years of research behind them, convert 22 per cent of incident solar power to electrical power. This is more efficient than solar cells made from multicrystalline silicon. But perovskite cells cannot be rolled out commercially yet because they degrade under high humidity and heat. Taking into consideration the importance and growth of solar photovoltaic (PV) power generation in present-day scenario of harsh reality and sincere efforts towards a sustainable environment and depleting conventional energy resources, coming up of printed solar cells will boost the use of solar energy. If photovoltaic (PV) devices that turn light into electricity could be mass produced with printing presses, as if they were newspapers or banknotes, they could be affordable and ubiquitous. Small, thin, and flexible PV devices that are lightweight and translucent on films are already being manufactured. These use little material and can generate electricity in low light, even indoors. The thin, flexible solar cells could offer an affordable solution to meeting the needs of increasing energy demands around the world. Integrating them into phones and watches, as well as walls and windows, could transform the world's energy generation, reduce pollution, and mitigate climate change.

Taking into consideration the importance and growth of solar photovoltaic (PV) power generation in present-day scenario of harsh reality and sincere efforts towards a sustainable environment and depleting conventional energy resources, coming up of printed solar cells will boost the use of solar energy.

Printable solar cells

Printable solar cells that are flexible and lightweight are the need of the hour in order to make best use of solar cells. Printed PV devices are typically made from many layers of material on a substrate of conductive glass

or plastic. Each layer has a function: semiconductors or sensitizers absorb visible light, and other materials carry electrical charges to electrodes. Many types of printed PV devices are being developed; some feature organic semiconductors such as polythiophenes and others use light-absorbing dyes, including ruthenium-based polypyridines. In quantum-dot solar cells, nanoparticles absorb light. Other examples feature semiconductors with a chalcogen element (sulphur, selenium, or tellurium) or contain organic–inorganic light absorbers with a structure similar to that of the mineral perovskite. All of these are classed as thin-film solar cells. At the moment, printable solar cells are made by printing a specially developed 'solar ink' onto a plastic film, similar to the way plastic bank notes are printed. There is a need to develop new materials and processes to enable the production of thin, flexible solar cells based on printable solar inks. These inks are deposited onto flexible plastic films using a range of processes, including spray coating, reverse gravure, slot-die coating, and screen printing. Some techniques for printing PV devices have been demonstrated in the lab over areas of about 10 sq. cm. These include feeding ink through a slit (slot-die printing), spray-coating the substrate, passing the substrate over a rotating cylinder (gravure printing), and moving a blade over the substrate through an ink supply. Interestingly, each technique has a downside. Such drawbacks mean that printed solar cells are less than half as efficient as the best non-printed equivalents.



Solar cells made with 3D printer

To print thin, pinhole-free layers over more than one sq. m will require intelligent, more-precise equipment, and laser processing. An alternative approach would be to develop PV materials that work with existing industrial printing methods. Printing requires that materials can be formed into liquid, solution, or paste. For PV devices, this means using either solutions of chemicals (polymers, dyes or hybrid perovskite, for instance) or dispersions of nanoparticles (such as quantum dots). But many of these can degrade over days to weeks if not properly sealed and more-stable alternatives such as silicon are harder to print. A balance must also be struck between the efficiency of a device and the environmental impacts of its manufacture. The most efficient thin-film solar cells include toxic or rare materials, such as cadmium, ruthenium, and lead, as well as hazardous organic solvents. Indium, another rare element, is a common ingredient in transparent conductive films for PV devices and its use is expected to rise.

Status of Development

Inkjet solar cells are solar cells manufactured by low-cost, low-tech methods that use an inkjet printer to lay down the semiconductor material and the electrodes onto a solar cell substrate. Until recently, inkjet printers have not been used in the printed electronics industry. Industry has decided to move towards inkjet printing because of its low cost and flexibility of use. One of these is the

inkjet solar cell. The first instance of constructing a solar cell with an inkjet printer was by Konarka in 2008. In 2011, the Oregon State University was able to discover a way to create Copper indium gallium selenide (CIGS) solar cells using an inkjet printer. In the same year, MIT (USA) was able to create a solar cell using an inkjet printer on paper. The use of an inkjet printer to make solar cells is very new and is still being researched. Mass production at low cost is what the solar industry sorely needs. The main advantage of printing solar cells with an inkjet printer is the low cost of production. The reason it is cheaper than other methods is because no vacuum is necessary which makes the equipment cheaper. Also, the ink is a low-cost metal salt blend reducing the cost of the solar cells. There is very little waste of material in comparison to other methods such as vapour phase deposition when using inkjet printers to lay down the semiconductor material. However, the efficiency of inkjet solar cells is too low to be commercially viable. Even if the efficiency gets better, the materials used for the solar cells could be a problem. We need to develop new printable solar cells that are flexible, lightweight, and extremely thin such that they can cover most surfaces.

Printable solar cells

Key Challenges

Flexible solar panels face several challenges enumerated as follows:

- Currently, printable solar cells have only reached about 10 per cent efficiency whereas traditional silicon solar PV cells are close to 25 per cent efficiency. The huge success of silicon panels has become a hurdle for emerging technologies. The manufacturers of silicon-based PV devices share materials, equipment, and practices with sibling industries, such as computing and this maturity of the silicon industry means there is little urgency to develop alternatives.
- Some solar cells are based on harmful substances such as heavy metals and use of hazardous solvents and others that are quick to degrade and inefficient at converting light into electricity.
- Printers used in the publishing, computing, and electronics industries struggle to print PV materials which are needed to be built with nanometre precision over many square metres.
- Changing materials into viscous pastes alters their physical and electrical properties.
- Printing layers that are nanometres to micrometres thick—uniformly and without pinholes, and over many square meters—is difficult.
- Capital investment and product commercialization are perceived as risky, given that printable PV devices are still being developed.
- the life span of the printed solar cells is also only six months so researchers are working to increase their efficiency, weather-resistance and life span to reach commercial viability.

For all these reasons, printable solar cells are yet to find a foothold in electricity markets. Printed solar cells would not become widespread until they are cheaper and safer to make. Researchers and businesses must work together to improve the efficiency, environmental impact, and stability of these cells, scale up their manufacture, and plan their market penetration.

Future of Printed Solar Cells

Printable solar cells offer exciting potential for generating electricity more flexibly and at a lower cost, wherever the sun shines. Early printable PV devices should target weaknesses in silicon-based technologies, such as their poor performance in low light and their lack of portability. The next wave should complement silicon solar cells and, ideally, be integrated with them. For example, silicon–perovskite devices would harvest a greater fraction of incoming sunlight than silicon devices alone could do. If printed technologies can capture 5 per cent of the PV market, their advantages should ensure that they play an ever-increasing part in meeting the growing demand for renewable energy. Paper thin solar cells or eventually direct 3D printing will allow creating solar cells on blinds, in windows, curtains, and almost anywhere in the home. New developments in printed solar cells could allow solar energy to create electricity almost anywhere, including walls, windows, roller blinds, shade umbrellas, and even tents! Therefore, printing of solar cells is very promising and could bring a great future for the use of solar power.

Acknowledgement: The use of information retrieved through various references/sources from the Internet in this article is highly acknowledged. AU

Dr S S Verma, Department of Physics, Sant Longowal Institute of Engineering & Technology (SLIET), Longowal, Distt.Sangrur, Punjab, India.

WANT TO BE A WRITER ON RENEWABLE ENERGY ?

If yes, here's the opportunity!

Today RE is an established sector with a variety of systems and devices available for meeting the energy demand of urban inhabitants, but there is a need to create mass awareness about their adoption. *Akshay Urja* is an attempt to fulfil this need through the dissemination of 20,000 copies (bilingual) in India and abroad. The magazine publishes news, articles, research papers, case studies, success stories, and write-ups on RE.

Readers are invited to send material with original photographs and statistical data. The photographs should be provided in high resolution files on a CD or through email. Akshay Urja will pay an honorarium of ₹2,500 to the authors for each published article of 1,500 words and above. The publication material in two copies, along with a soft copy on CD/DVD/email may be sent to:

TERI PRESS
TERI, Darbari Seth Block,
IHC Complex
Lodhi Road, New Delhi-110 003
Tel: +91 11 2468 2100, 4150 4900
Fax: +91 11 2468 2144, 2468 2145
Email: teripress@teri.res.in
Web: www.teriin.org

Bullock-Drawn, Solar-Powered, High-Clearance Sprayer

A Promising RE Technology

Dr M Veerangouda, Dr K V Prakash, Dr Jagjiwanram, and **Dr M Din** present a case study of the development of a bullock-drawn, solar-powered, high-clearance sprayer which can be a promising source of renewable energy. The solar energy was used as the power source for the operation of sprayer unit while bullock power was utilized for pulling the cart. The authors also discuss the cost economics of the project.

Renewable energy source such as solar energy is available abundantly, therefore, by utilizing solar energy using solar panels a sprayer can be powered. In order to cover a large area and to overcome the scarcity of labour, the bullock-drawn, solar-powered, high-clearance sprayer was developed to utilize the available solar energy. The sprayer also can be used for spraying huge field crops due to its high clearance. The solar energy was used as the power source for the operation of sprayer unit while bullock power was used for pulling the cart. Significantly, solar energy is abundantly available throughout the year and in order to save fossil fuels, such as diesel and petrol, solar energy is one of the most promising solutions and, therefore, needs to be utilized for spraying operation. The practical utility of solar-powered, bullock-drawn sprayer has a wide scope in the country. The development and popularization of solar-powered, bullock-drawn, high-clearance sprayer for cotton and red gram crops is essential and has a wide scope in Karnataka. The entrepreneurship among farmers/users can also be created by conducting frontline demonstrations in farmers' fields. The revenue generation can also be done by the adoption of custom hiring service centre in villages. Hence, solar-powered, bullock-drawn, high clearance has more scope in India.

Constructional Details and Specifications

The sprayer basically consists of the working components discussed below.

Components of Solar-Powered, Bullock-Drawn, High-Clearance Sprayer

The sprayer consists of the working components, such as solar photovoltaic (PV) modules, spray tank, DC motor pump, battery, wheel, seat, spray boom, nozzle, and pressure control device. The individual components were procured, fabricated, assembled, and developed in the College of Agricultural Engineering, Raichur.

Selection of Solar PV Modules

The solar PV modules were selected based on the power requirement of the motor and the pump. The discharge rate and the operating pressure influence the selection of the solar PV modules. The main parameter which influences the solar PV module is the temperature of the region and maximum sunshine hours. According to the requirement the capacity of solar PV modules selected was 500 W. The specifications of a single PV module is presented in Table 1.

Table 1: Specifications of single PV module

Particulars	Details
Module area	1.64 m^2
Panel capacity	251.9 W
Irradiance	1,000 W/m^2
Ambient temp.	27.2°C
Current	6.99 A
Voltage	36 V
Module efficiency	15.3 per cent

Selection of Motor

The selection of DC motor involves the discharge rate and the operating pressure required for the sprayer. The actual power required to pump the liquid and the power available from the solar PV modules should be matched with the motor. The DC motor is getting power from the PV modules directly and is coupled with the pump. The platform is made for both the pump and motor for uniform rotation of shafts. The specifications of the selected motor is presented in Table 2.

Table 2: Specifications of selected motor

Particulars	Details
Type	Permanent magnet DC motor
Capacity	0.5 hp
Current	15.5 A
Speed	1,500 rpm

Selection of Pump

The gear pump was selected based on the power requirement for operating the sprayer. The selected gear pump is coupled with DC motor to pump the liquid. The speed of both the pump and motor should match with each other. The pumps used are of two sizes, namely, 25 L/m and 50 L/min. The pump was connected to a tank through the suction pipe. The specification of the selected rotary pump is presented in Table 3.

Table 3: Specifications of the selected pump

Particulars	Details
Type	Rotary positive displacement pump
Speed	1,500 rpm
Head	10 m
Discharge	25 and 50 L/min

Suction Pipe

The suction pipe is used to suck the liquid from the tank with the help of X nipple. The 19.05 mm and 25.4 mm flexible plastic pipe of 25 cm was selected to deliver the liquid.

Delivery Pipe

The delivery pipe was selected according to discharge and capacity to withstand the pressure. The flexible hose pipe was selected to deliver the water to spray boom. Tee joint with two sizes of 19.05 mm and 25.4 mm ball valves (flow control valves) were provided in the delivery pipe for diverting the flow. One of the ball valve remains closed during the operation.

Battery

The batteries used here are lead acid dry type. Two batteries of 12 V capacities were used. The PV modules produce 72 V as each panel will produce 36 V. The batteries were kept besides the tank. The current from the PV modules is continuously stored into the batteries in the sunshine hours. The switchboard is provided for batteries and PV modules. The batteries give constant power to the motor due to stored electricity. The PV modules give intermittent power to the motor because of variation in the solar intensity. Because of the higher voltage, the capacity of the PV modules is limited to 500 W. The specifications of the battery is presented in Table 4.

Table 4: Specifications of the selected battery

Particulars	Details
Type	Dry lead acid type
Voltage	12 V
Capacity	100 Ah

The solid diagram and line diagram, front view, side view, and top view of bullock-drawn, solar-powered, high-clearance sprayer is presented in Figures 1, 2, and 3, respectively.

Fabrication of Sprayer

A solar-powered spraying system has been developed for field crops. The spraying system consists of five hollow cone nozzles having discharge of 25 L/min and 50 L/min. The sprayer is provided with 500 W solar panels; five nozzles are provided for spraying

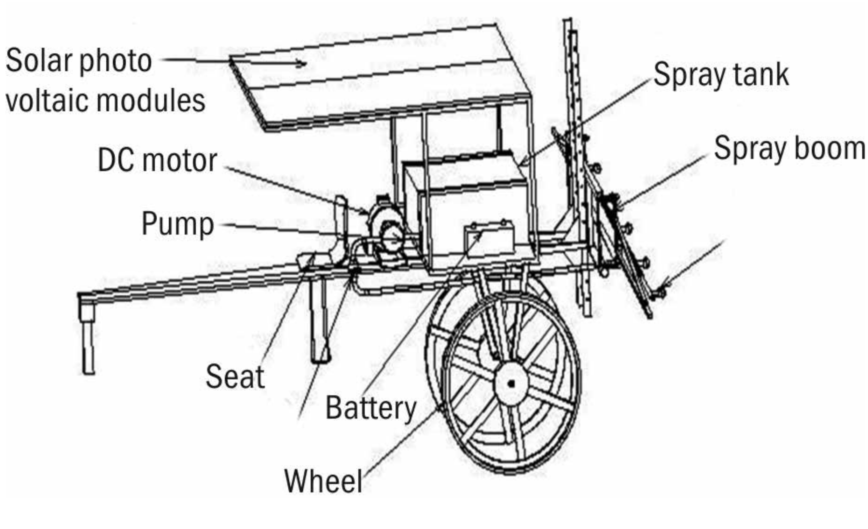


Figure 1: System boundary of paddy straw utilization for energy generation in this assessment

five plant rows. The solar sprayer is provided with DC pump of 0.5 hp and the operating pressure of the pump is 10 kg/cm^2. The pump is coupled with 24 V DC motor having an rpm of 1,500. The sprayer is provided with a water tank of 275 L capacity.

The two solar panels of 250 W are mounted on the frame through nut and bolt system. The frame is made up of mild steel angles. The length of the frame is 1.70 m; width of the frame is 2 m. This frame has 5.08 cm angled mild steel and mild steel flats for supporting the base of the panels. The frame is supported by a four-angled steel from the tank platform. The length of the angles is 92 cm and the size is 2.54 cm. The base of the frame and supporting angles are welded for rigid structure. The pump capacity is designed on the basis of discharge rate and operating pressure. The panel capacity was decided based on the pump capacity requirement. The seat of the operator is placed at the front end of the panels. The specifications of bullock-drawn, solar-powered, high-clearance sprayer is presented in Table 5.

Table 5: Specifications of bullock-drawn, solar-powered, high-clearance sprayer

Sl. No	Parameters	Value
1.	Source of power	Solar PV modules
2.	Pump	25 L/min and 50 L/min of 1,500 rpm speed and 10 kg/cm^2 operating pressure
3.	Motor	0.5 hp capacity, 1,500 rpm speed, and 24 V, DC.
4.	Power transmission	Panel-motor-pump
5.	Number of nozzles	5
6.	Pressure control device	Pressure relief valve
7.	Boom length, mm	4,500
8.	Wheel, mm	Diameter 1,000, width 100
9.	Ground clearance, mm	1,200
10.	Tank capacity, L	275

Components of Sprayer

- Solar PV modules
- Spray tank
- DC motor
- Pump
- Battery
- Wheel
- Seat
- Spray boom

Economics of Bullock-Drawn, Solar-Powered, High-Clearance Sprayer for Selected Field Crops

The cost of operation and the savings are presented in Table 6.

Table 6: Cost of operation and savings for bullock-drawn, solar-powered, high-clearance sprayer for cotton and redgram crop

Sl. No.	Parameters	Cotton	Redgram
1	A) Total fixed cost, ₹/h	22.74	22.74
2	B) Total operating cost, ₹/h	98.36	98.36
3	Total cost (A + B), ₹/h	121.1	121.1
4	Total cost, ₹/ha	128.14	119.66
5	Breakeven point, h/annum	123.61	123.61
6	Payback period, years	3.6	3.6
7	Per cent of financial saving over the manual knapsack sprayer, per cent	56	67.14
8	Per cent of labour saving over the manual knapsack sprayer, per cent	56.6	59.48

The economics of the bullock-drawn, solar-powered, high-clearance sprayer were calculated. It was

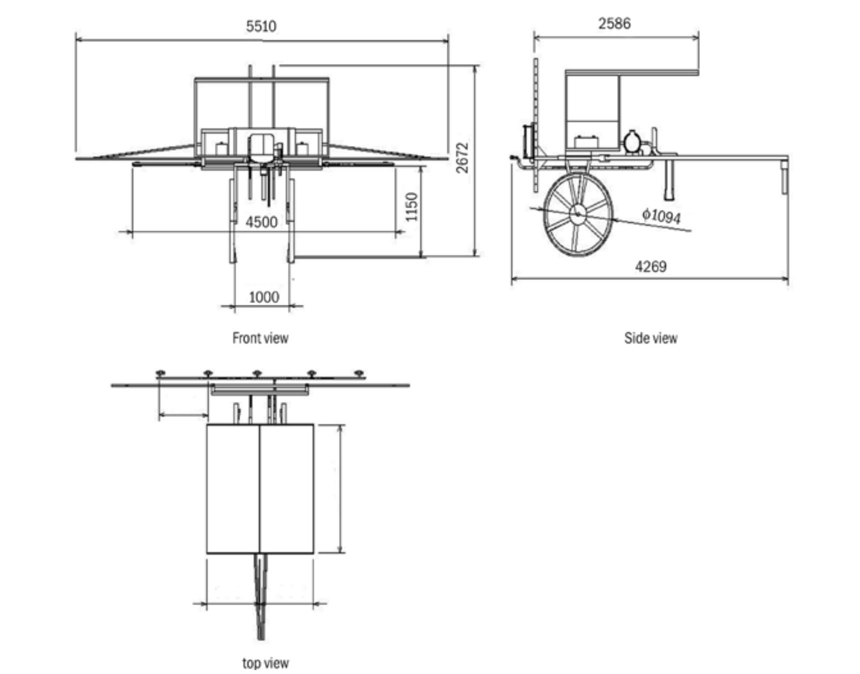


Figure 2: Front view, side view, and top view of bullock-drawn, solar-powered, high-clearance sprayer

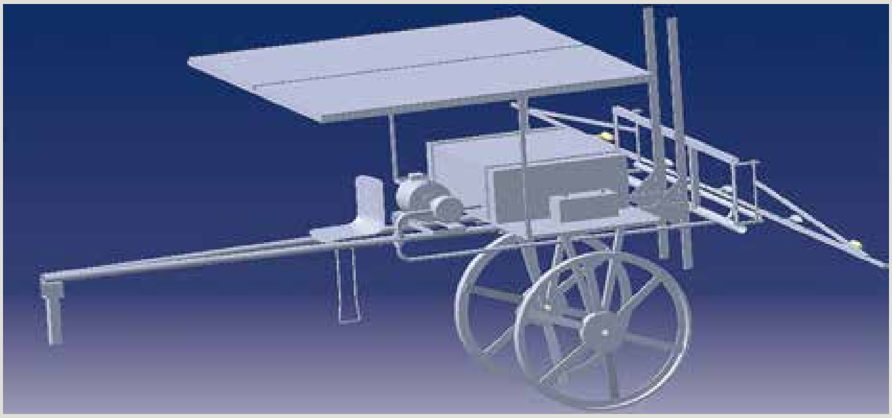


Figure 3: Solid model of bullock-drawn solar-powered high clearance sprayer developed by CATIA software

Picture 1: A view of bullock-drawn solar-powered high clearance sprayer

Picture 2: Spraying operation on cotton crop using the bullock-drawn, solar-powered, high-clearance sprayer

observed that, the cost of operation of this sprayer was ₹121.1/h and it was ₹128.14/ha for cotton and ₹119.66/ha for redgram crop. Breakeven point and payback period were 123.61 h/annum and 3.6 years. Per cent of financial saving over the manual knapsack sprayer was 56 per cent for cotton and 67.1 per cent for redgram crop. Per cent of labour saving over the manual knapsack sprayer was 56.6 per cent in cotton and 59.48 per cent in redgram crop.

In order to create awareness among the users, training programmes and demonstrations were conducted for the farmers, commercial manufacturers, village artisans, and the other users. For fabrication, sale, and service of bullock-drawn, engine-operated sprayer for the farming community, the commercial manufacturers in this region have been identified for further popularization. The safety aspects to be followed for the sprayer have been educated by conducting frontline demonstrations in villages. AU

Dr M Veerangouda, Principal Investigator; Dr K V Prakash, Asst Agril. Engineer; Dr Jagjiwanram, Animal Scientist; and Dr M Din, Project Coordinator, All India Coordinated Research Project on Increased Utilization of Animal Energy with Enhanced System, College of Agricultural Engineering, Raichur, Karnataka, India.

Solar Air Heaters

Large Solar Thermal Air Systems for Industrial and Agro Applications

This article highlights two case studies—one for leather auto spray dryer in Kanpur supported by a UNIDO project and another for chilies drying in Kerala run by a women self-help group.

Solar thermal could play a vital role as clean energy development as well as reduction in the production cost in industrial process heat, especially solar, air, and water heater for temperature ranges of 60 to 80°C applications. The emerging solar air heating technology indicates a potential of 0.92 million m^2 collectors and this is equivalent to savings in 3.52 Mtoe/y (million tonnes oil equivalent/year) in Indian industries and agro-processing sectors, such as leather, pharmaceutical, chemical industry, salt production, processed foods, fruits and vegetables processing, textiles, ceramics, paint-shops, automobile components manufacturing units, hand-made paper products, spices, fish and marine products processing, latex rubber, etc., as per a R&D study carried out by Planters Energy Network—PEN, funded by the Ministry of New and renewable Energy (MNRE R&D project 'Dissemination of Solar Drying Technology for Industrial Sector including Agro-Industries in the Country' sanctioned to Planters Energy Network—2001–2008). To illustrate the potential of solar thermal both air and water, a few case studies have been presented in this article. The author has an experience of 35 years on the design and development of roof-mounted solar air heaters to provide a large volume of hot air in the range of 10,000 to 30,000 m^3/h for applications in industries and agro-processing mostly by retrofitting with the conventional heating unit, a prerequisite for industries.

Solar Air Heaters

A solar air heater is similar to solar flat plate water heater, which uses the greenhouse concept to heat air or water through the accumulated heat in the absorber. Unlike solar water heater, where all 2m^2 panels

are connected externally, the solar air heater modules are fitted together internally to facilitate air to pass through a long path to reach the desired temperature by creating a good heat transfer mechanism within the collector. In a solar water heater, water is recirculated so that at the end of a day the given volume is heated from ambient temperature to say 60–80°C. But in an air heater, the ambient air by passing through the collector should reach 60–80°C in a few seconds. Using the green house basic concept, solar air heaters are installed with integrating multiple modular systems which handles cold air and heats it to 60–80°C.

Solar Auto-Spray Dryer Saves 1,500+ kg of Steam per Day in a Leather Factory

Among many process machineries in a leather factory, auto sprayer dryers consume a large quantity of fossil fuel source of energy either in the form of steam or thermal oil. UNIDO, Vienna under a project for clean leather processing in Kanpur, has selected one air heating project for Calico Leather Company, Kanpur, as a model project with a partial fund support to reduce coal consumption. An auto sprayer has two sections with a conveyer. In the first section, paint is sprayed on the leather placed on a conveyer. The second section has five compartment dryers. Each compartment has steam coils on both sides and its top side is fitted with an axial fan, which blows air over the steam coil creating hot air to pass over the leather, moving in the conveyer leading to drying of paint. A detailed energy audit was done to assess the energy flow with steam consumption in each compartment and total demand. Based on the total demand, a solar air collector of area 270m^2 which could give an average energy delivery of 100–120 kWh was designed. Shadow-free area for 270m^2 was available on the factory terrace roof and a mild steel support stand for the solar collector was fabricated and fitted in the roof. The 270 m^2 collector, consisting of 72 numbers of 3.75 m^2 collectors was installed on the support stand that heats the ambient air to hot air. The solar hot air outlet is connected to an inlet of a 3.75 kW centrifugal blower through an insulated metal duct. The blower outlet duct passes hot air to the auto sprayer with multiple branches to each compartment (Figure 1). The unit is fitted with an energymeter which measures solar energy in kWh based on the air mass flow and temperature difference. Another control regulates the steam flow and also measures the steam consumption. The project was commissioned in January 2017. On a sunny day, it saves around 1,500 to 1,600 kg of steam (or) 300 kg of coal. The estimated ROI for the project is 3.7 years, taking only into account depreciation benefits and fuel savings Subsidy from MNRE will make these projects more viable to the leather industry.

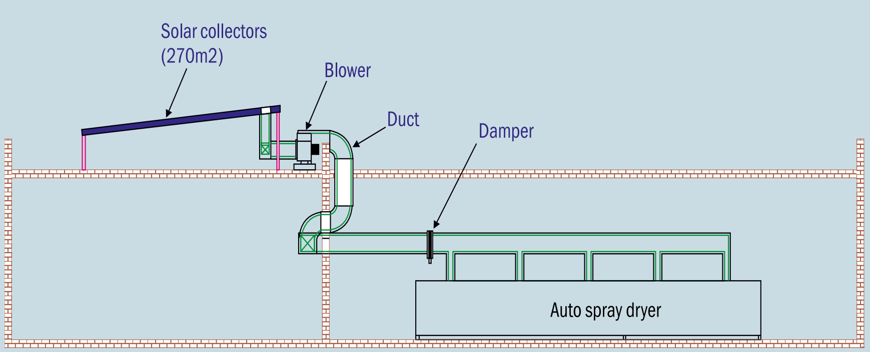


Figure 1: Solar air heater with auto spray dryer

Solar Air Heating Reduces Chilly Drying Time by ~30 Per Cent in a Hygienic Set-Up

Swasthy Food Products, Kerala, has a food processing plant mainly run by womenfolk and manufactures many varieties of dried fruits and vegetables. A special variety of chilly cultivated here is locally dipped in buttermilk and then dried. Dipping and drying are repeated till the given volume of buttermilk is fully absorbed. The construction of the system is shown in Figure 2. It consists of an 18 m^2 solar collector consisting of tempered glass, special black paint coated aluminium absorber, duct for airflow below the absorber and side insulation. A 0.75 kW centrifugal blower draws the hot air from the solar collector. For non-sunny periods, a biomass oven provides hot air. The hot air from solar or from biomass could be passed to the dryer using an electrical operated actuator damper. The dryer is made up of a double-layered SS 304 box with insulation in between. It has multiple vertical trays with SS mesh through which solar hot air passes

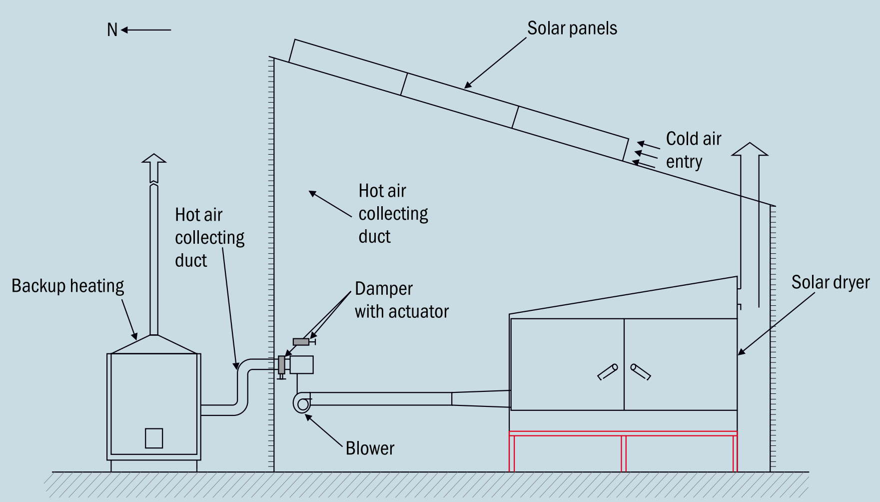


Figure 2: Schematic diagram for solar air heater

and exhausts through a chimney. The dryer has 25 m^2 spreading area for the products to be dried. The exhaust air is taken away from the building through a metal duct. The hot air carrying duct is installed with 50 mm insulation. Prior to the solar installation, open sun drying took around 14 days and also due to intermediate weather, the products also get spoiled. The solar dryer had been successfully installed and the drying time for 100 kg buttermilk chilly is reduced to 10 days. Apart from the drying reduction, the product quality improved with better hygiene.

Diffusing the concept of solar drying with roof-mounted collector with a backup heating to process many cash crops in a hygienic way will help more women entrepreneurs gain employment in rural areas of India, thereby avoiding wastages in fruits, vegetables, fish, and other food products. Also, it will lead to the availability of hygienic and nutritious food. This has been demonstrated in Ladakh, Kargil, Mizoram, and many other regions in India with many installations by our organization. Moreover, more than 12,600 m^2 solar air heater collectors for industrial and agro processing applications have been installed in India and some of the installation done in 1992 in the tea industry still works showing the sustainability of these projects.

Conclusion

The worldwide energy scenario indicates that industry and services consume almost 50 per cent energy in the form of thermal. Often neglected by industry due to a lack of expertise or investment capacity, heat is a powerful vector for financial savings, capable of making a difference in the race for competitiveness. Large-scale adaptation of solar air heating and water heating in industries and agro processing will lead to clean energy processing as well as reducing the production cost for these industries. Solar air heaters have a great potential in saving the fossil fuels. Also, solar dryers could impact our food-processing sector in a great way creating employment as well as nutritious and hygienic food. MNRE's 30 per cent subsidy for the whole solar dryer cost, instead of the collector part only being given now, will go a long way in helping the farmers to adopt this technology for value addition to their farm products, such as chilly, cash crops, spices, etc., especially in the northeastern region of the country where a large quantity of ginger, turmeric, and fruits are being wasted due to a lack of processing facility. A major effort from MNRE and all other stakeholders are needed to take the technology to the farm level so that farmers can enjoy value addition to their products. AU

Mr C Palaniappan, SUN BEST, Theni, Tamil Nadu, India, email: info@pen.net.in,info@sunbest.in Web: www.pen.net.in, www.sunbest.in

Micro Hydropower

An Alternative Way of Energy Generation

Making electricity available is essential to bring opportunity and prosperity to small, marginalized communities. Although large-scale power projects dominate electrification efforts, advancements in renewable technologies and their efficiency have made distributed, decentralized systems increasingly viable. **Anil G** shows the possibilities with a success story of a micro hydropower project in a small tribal settlement called Thayannankudi in the Chinnar Wildlife Sanctuary in Kerala.

Thayannankudi is a very old Muthuvan tribal settlement in the Chinnar Wildlife Sanctuary along the side of River Chinnar in Idukki District, Kerala. There are 48 families and nearly 200 members in this settlement as per the management plan 2012–2022, and there was no electricity or communication facility in the settlement. Most inhabitants of the colony are dependent on agriculture and the forest for their livelihood. Being located in the rain shadow region of the sanctuary, the availability of South–West monsoon in the sanctuary is very poor but retreating South–West monsoon and North–East Monsoon gives an advantage to their agriculture and other livelihood practices. Other than the houses and common gathering places, there are some agricultural farm houses and store houses that needed power back up. Originating from the laps of Eravikulam hill ranges, which flanks in the north–west side of the sanctuary, River Chinnar is a perennial water source for the sanctuary and this colony. Deserving the status of a protected area and owing to the huge investments required, the settlement was not allowed to use utility lines for electric supply. In order to satisfy their power demand, solar power system had been installed long back, when the technology was not that mature. Due to a lack of proper maintenance and management, the system turned out to be a failure with time. In this circumstance, an alternative way of energy generation was suggested taking advantage of the perennial Chinnar River by installing a micro hydropower system availing the government subsidy rate for the electrification in Thayannankudy tribal settlement. Micro hydropower systems are beneficial in terms of cost and simplicity from different approaches in the design, planning, and installation than those that are applied to larger hydro power.

Recent innovations in micro-hydro technology have made it an economic

Underground powerhouse

The school

Check-dam

source of power even in some of the world's poorest and most inaccessible places. Through this means, power can be generated, enabling standard electrical appliances to be used and the electricity to be distributed to the whole colony. The Thayannankudy tribal colony can utilize devices, such as LED bulbs, radios, television, refrigerators and food processors, agricultural machines, etc., which can be powered by micro hydro. This has added to the socioeconomic development of the forest-dependent tribes of this colony and has provided a better livelihood for them to combat the human–wildlife conflict.

Thayannankudi is situated 4 km inside the forest from Chinnar main road near the Chinnar check post under the Forest Department. There is no electric grid connection available for this settlement. There are about 50 houses (around 200 inhabitants) including a school, Anganwady, community hall, and Chathram in and around the colony. The River Chinnar flows near this village. From this river, water is diverted and taken by a channel through the village for irrigation purposes. The existing channel for irrigation was modified and rectified for drawing water into the turbine. Along the channel it was noted that at many places down the channel towards the river, to find the necessary head to generate power, the water can be let off to the Chinnar River. At a place where the channel enters the Kudi, there is a head of approximately 7 m obtained with an underground powerhouse. At this point, an inlet tank cum filtration tank was constructed on the channel with an overflow arrangement and the water is drawn through a penstock and valves to the hydro turbine and the tailrace water is let in to the river again after irrigating the terrain.

Penstock pipe

Mould for draft tube casting

Underground Powerhouse

A turbine shed (underground) measuring 3 m × 3 m was constructed as a powerhouse. From this point, power is evacuated through transmission lines and then distributed to individual houses by proper cable arrangement. The houses are scattered across the settlement and a few of these houses are at a long distance.

Intake

Intake

Intake

Table 1 presents the salient features of 3 kW Thayannankudi pico hydropower project in Kerala.

Turbine

PLC Controller

Generator

Table 1: Salient features of 3 kW Thayannankudi pico hydropower project

S N.	Items Description	
1.	**Location**	
i	State	Kerala
ii	District	Idukki
iii	Nearest town	Kanthalloor
iv	Access	About 7 km from Chinnar
v	Owner	Forest Department
2.	**Details of site**	
i	Name of stream	Chinnar
ii	Head (m)	7
iii	Design Discharge (lps)	100
iv	Installed capacity (kW)	3
3.	**Civil Works**	
i	Power channel	--
ii	Length	300 m
iii	Width	250 mm approx.
iv	Depth	250 mm
4.	**Penstock**	
i	Length	16 m
ii	Diameter	250 mm
iii	Material	GRP
5.	**Power House**	
i	Length	3 m
ii	Width	3 m
iii	Height	3 m
6.	**E&M Work**	
(a)	Runner	
i	Type	Cross flow, steel
ii	Orientation	Horizontal
iii	Runner diameter	300 mm
iv	Runner width	150 mm
v	No. of blades	30
(b)	End use	Electricity
7.	**Cost incurred**	**₹12.1 lakh (i+ii+iii)**
i	Electro mechanical equipment, such as cross-flow turbine, generator, PLC controller, dummy load, flay pulleys and belts, base frame, inlet piece, penstock and valves, and erection and commissioning	₹5.4 lakh
ii	Power evacuation, electrification of houses, Anganwady, school, Chathram and street lights, poles, etc.	₹4.2 lakh
iii	Civil work cost incurred for rectification of channel, weir, gates and construction of fore bay, powerhouse, tail race, etc.	₹2.5.lakh

The power is evacuated from the generating station to the colony through a suitable three-core armoured cable and to the individual houses through distribution cables from the respective poles. Complete electrification of houses and other common amenities, including providing service wires, MCBs, switches, and plug sockets, as well as fixing of a 9 W LED bulbs for lighting and streetlights have been provided. The entire scheme was conceived and implemented by the Energy Management Centre (EMC) with financial support from the Ministry of New and Renewable Energy (MNRE) and the Forest Department.

The electrification carried out successfully is as below.

- A total of 48 house houses with 2 × 9 W LED bulbs
- The community hall with 2 × 9 W LED bulbs and 3 plug sockets
- The school with 6 × 9 W LED bulbs and 2 plug sockets
- The Anganwady with 6 × 9 W LED bulbs and 2 plug sockets
- The Chathram with 6 × 9 W LED bulbs with 2 plug sockets.

Recently, the Forest Department implemented another project making use of the tail race water of this micro hydroelectric plant. The tail race water of this plant is used to refill 'Punarjani' a check-dam deep inside the forest, which is a grass land of the sanctuary, almost 6 km from the powerhouse. Usually, the check-dam goes dry during severe summer months forcing the wild animals to move out of forest to human habitations in search of water, which causes man–animal conflicts. Further, the intervention could prevent the death of small species, such as star tortoise. Earlier, forest personnel used to fill up these ponds periodically, which is a costly and time-consuming affair due the location of the check-dam and the evaporative losses during the summer season. It can be said that the Thayannankudi micro hydropower scheme is a decentralized plant catering to the isolated tribal community with electric power and by drawing the tailrace water to fill up a check-dam inside the sanctuary it quenches the thirst of wild animals and it is also very unique. AU

Mr Anil G, Joint Director, Energy Management Centre (Under Department of Power, Government of Kerala), Sreekariyam, Thiruvananthapuram 17, Kerala, India.

Solar Cabinet Dryers

An Initiative by SEED

Prof. M Ramakrishna Rao and **Mr G Harikrishna** discuss a success story of solar cabinet dryers developed by SEED that achieved a milestone by recording the highest temperature in Leh, Ladakh region of Jammu & Kashmir. In this way, these solar dryers are most suitable for drying apricots and tomatoes to increase their shelf life and to add value to the products.

Solar dryers are devices that use solar energy to dry substances, especially food. Generally, direct solar cabinet driers are used to dry small quantities of food or vegetables in moderate drying temperatures (45–55°C) and airflow rates. Society for Energy, Environment and Development (SEED) was founded in 1987 by a few professionals with expertise in engineering, management, solar energy, law, and social work. The purpose of this NGO is to draw upon the expertise of these fields of study to create awareness about the environment and energy issues and creating devices to enhance the quality of life. SEED promotes community development activities under a four-fold programme of employment, entrepreneurship, health and education.

'SEED' Solar Cabinet Dryers are becoming popular from micro enterprise level to industrial level. The dryers have been designed and developed with different models indicating the different capacities of the products and to different climatic conditions in the country. Table 1 presents the specifications of these dryers.

Table 1: Specifications of solar cabinet dryers

Sl. No.	Model	Loading Capacity (Weight)	Solar Window	Drying Area	Solar Photovoltaic panel 12 V DC	Electrical back-up 220 V AC
1.	SDM-8	8 kg	0.37 sq. m	0.56 sq. m	5 W	1 kW
2.	SDM-50	50 kg	2.23 sq. m	3.6 sq. m	30 W	4 kW
3.	SDM-100	100 kg	4.46 sq. m	7.2 sq. m	60 W	8 kW
4.	SDM-200	200 kg	9.00 sq. m	14.2 sq. m	60 W	16 kW
5.	SDM-400	400 kg	18.00 sq. m	28.8 sq. m	120 W	32 kW
6.	SDM-500	500 kg	22.30 sq. m	36.0 sq. m	120 W	40 kW

All of them are commercialized and 225 solar dryers of different models with varying sizes have been installed in 15 states in India and exported to countries, such as Australia, Mauritius, Malaysia, Saudi Arabia, and Tanzania. Some of the large sizes are to be transported to different places in India for installation in knock-down conditions and two engineers are to be deputed for installation and demonstration of solar dryers at site. These installations are for processing of fruits, vegetables, and fish at different locations in India as well as in other countries.

Installation of Dryers in Leh, Ladakh

Two solar dryers of SDM-200 and SDM-100 models were supplied

and installed at two educational institutions of the same campus, namely, Sher-e-Kashmir University of Agriculture Sciences & Technology and Krishi Vigyan Kendra, Leh, Ladakh. After installation, training was imparted to the staff of the educational institutions of the University. These dryers are used for drying of fruits and vegetables, such as apricots, tomatoes, etc. The performance of SDM-200 and SDM-100 is given in Table 2.

Table 2: Solar dryers: Performance Data (June 2016)

Time	Cabinet Temperature in °C	Ambient Temperature in °C
7 A.M.	20.8	17.6
8 A.M.	31.7	18.8
9 A.M.	45.5	20.8
10 A.M.	55.4	22.9
11 A.M.	58.2	23.7
12 Noon	57.4	26.0
1 P.M.	58.4	28.8
2 P.M.	58.6	29.6
3 P.M.	56.3	28.4

These are high-efficiency solar cabinet dryers whose design was improved by insulating cabinet walls for reducing thermal losses. This enhanced temperature in the cabinet at about 60°C at 1.00 P.M. when the temperatures during day time are 15–18°C in the morning. This was in the month of June in 2016. The temperature between ambient and cabinet dryer are about 41°C at noon in the two places of Sher-e-Kashmir University of Agriculture Sciences & Technology and Krishi Vigyan Kendra, Leh, Ladakh. This is the highest temperature in the cabinet dryers during the season and most suitable for drying of apricot and tomatoes to increase the shelf life and to add value to the products. This gives an excellent performance of the cabinet dryer in areas with difficult terrain and living conditions to give an opportunity for local population to add value to their local produce with zero energy cost.

Table: 3: Impact of solar dryer in mitigating climate change

Solar Dryers Models	No. of solar dryers installed	Total processed fruit bar per annum (MT)	Total fruits for processing per annum (MT)	Total saving from CO2 emission per annum (MT)	Power saving (KWh) per annum
SDM-8	50	8	26.64	54.37	44,800
SDM-50	159	159	529.47	1,080.69	890,400
SDM-100	1	2	6.66	13.59	11,200
SDM-200	1	4	13.32	27.19	22,400
Total	**211**	**173**	**576.09**	**1,175.85**	**968,800**

Impact of Solar Dryer in Mitigating Climate Change

The 'SEED'solar cabinet dryer operates entirely on solar energy, which is eco-friendly. The energy cost of the operation of the dryer is zero. In addition to this great advantage, it operates on zero-carbon emission. Also, it is a clean and non-polluted energy source. The total impact of solar dryer is given in Table 3.

Conclusion

The University authorities certified that the solar dryer performance is the best and very useful for drying of fruits and vegetables. Earlier also, 'SEED'supplied four solar dryers of SDM-50 model to Ladakh Ecological Development Group, Leh, Ladakh. The overall performance of solar dryers is best suitable for drying fruits and vegetables grown in the Himalayan region. AU

'SEED' Solar Cabinet Dryer: SDM-200 model

'SEED' Solar Cabinet Dryer: SDM-200 model with trainees

'SEED' Solar Cabinet Dryer: SDM-100 model

Prof. M Ramakrishna Rao and Mr G Harikrishna, Society for Energy, Environment & Development (SEED), Hyderabad, India.
Website: seed@seedngo.com

Demonstration of Web Portal for RPO Monitoring and Compliance

TERI, in conjunction with the Ministry of New and Renewable Energy (MNRE), has developed a web portal for monitoring and compliance of Renewable Purchase obligation (RPO) in the country. In this context, TERI organized an interactive work session on demonstration of the web-based portal for stakeholders to accelerate grid-connected RE capacity addition in India, on June 28, 2017, at India Habitat Centre, New Delhi.

Various stakeholders including Electricity Regulatory Commissions (ERCs), DISCOMs, State Load Dispatch Centres (SLDCs), State Nodal Agencies (SNAs), Energy Exchanges, Captive Power Producers, energy think tanks and research institutions from across the country participated in the workshop.

The objective of the demonstration of the portal was to align and collate compliance data, and to implement it at the national level. The success of the proposed mechanism will depend on the adoption of precise definition of the roles and responsibilities of the institutions, as well as adoption of the appropriate governance structures and capacity building to undertake defined roles and responsibilities. It intends to create a common portal for filing and compiling information for all the obligated entities and their percentage of solar RPO compliance.

President Shri Pranab Mukherjee confers SCOPE award to IREDA CMD

Indian Renewable Energy Development Agency Limited (IREDA) CMD Shri K S Popli was awarded the 'SCOPE Award for Excellence and Outstanding Contribution to the Public Sector Management-Individual Leadership Category III (Other Profit Making PSEs)'.

The award was presented by Shri Pranab Mukherjee, Hon'ble President of India to Shri Popli, Chairman and Managing Director, IREDA, at an award ceremony in Vigyan Bhavan, New Delhi on April 11, 2017. The awards function saw the felicitation of organizations who work tirelessly towards India's sustainable growth.

The award function was also graced by Shri Anant G Geete, Hon'ble Heavy Industry and Public Enterprises Minister and Shri Babul Supriyo, Hon'ble Minister of State for Heavy Industries & Public Enterprises. SCOPE Excellence Awards have been instituted by the Standing Conference of Public Enterprises (SCOPE) and conceptualized to recognize the contribution of public enterprises. AU

Hon'ble President of India, Shri Pranab Mukherjee presenting the SCOPE Award to Shri K S Popli, CMD, IREDA. Shri Anant G Geete, Hon'ble Heavy Industry and Public Enterprises Minister and Shri Babul Supriya, Hon'ble Minister of State for Heavy Industries & Public Enterprises also seen in picture

IREDA bags India Pride Award

Indian Renewable Energy Development Agency Limited, (IREDA) was awarded the India Pride Award 2016–17 by Dainik Bhaskar Group of Publications under the category – CSR/ Environment Protection and Conservation.

The Award was presented by Shri Manoj Sinha, Minister for Communication (Independent Charge) and Minister of State for Railways to Shri K S Popli, Chairman and Managing Director, IREDA at an award ceremony at New Delhi on March 27, 2017. The awards function saw the felicitation of organizations who work tirelessly towards India's sustainable growth.

Shri Manoj Sinha, Minister for Communication (Independent Charge) and Minister of State for Railways presenting the India Pride Award to Shri K S Popli, CMD, IREDA

Build a Solar-Powered Airplane

Innovative Aeromodelling

In this article, we shall explain the fabrication of a small aircraft fly on solar power. The aircraft is radio controlled using the usual transmitter-receiver pair used in aeromodelling. The aircraft has a wing of span 2.5 m and chord of 30 cm with no tapering or sweep angle. The model weighs approximately 1,500 g out of which 400 g is the weight of the 18 solar cells, which are installed in the plane. The solar cells produce about 50–60 W@9–11 V under normal conditions. For construction of the airplane, balsa wood is used, which is then covered by heat shrunk model aircraft covering. The length of the fuselage is 200 cm which is also completely built of balsa wood and uses trusses to reduce weight and retain strength. The airplane uses a brushless DC motor and a direct drive slow fly propeller for producing thrust. Two-bladed propeller is used for more efficiency. Along with this a system is also developed for emergency landing in case of dim sunlight or to handle any other power failure situation. After fabrication, flights were taken and necessary improvements were done to enhance its performance. The key feature of this design of solar airplane is the solar cells which initially charge a battery and when these cells discharge during flight—these were subsequently made to continuously charge during the flight. It removes the need for using a heavy battery for storage, thus improving efficiency and reducing the weight considerably.

The distinguishing quality of solar aircrafts is the long duration of flight without the need of refuelling. A solar plane theoretically can remain in air for any duration of time that, too, with zero emission. This aeromodel uses electric motor to run a propeller and is powered by several solar cells installed on them which either provide electricity to run the electric motor directly or charge a battery pack that later discharges during flight. A solar plane gains altitude and recharges its batteries during daytime; after sunset it flies on batteries or simply glides until sunrise.

The fabrication can be completed in three stages:

Stage-I

In this stage the aircraft was designed, keeping in mind the available resources.

Stage-II

Constructing the ribs and spar; then parts for the fuselage were cut and glued together followed by the tail and fin sections. Then solar cells were soldered and their installation on wing and tail was undertaken and electrical components were installed.

Stage-III

The first flight of the plane has to be taken on battery power so as to check the stability of the plane and to find out its behaviour during take-offs, turns, and landings. Based on this flight, further improvements on the design is to be taken up.

It is advisable to use polycrystalline solar cells, since these cells are comparatively less costly, sufficiently efficient, and have light weight.

Size: 156×156mm, Thickness: 200μm±30μm

Power: 4.28 Watts, Voltage: 0.628 V

The airplane requires a minimum of 45–55 W of electricity to remain in a levelled flight under no wind conditions. Considering the available space on the aircraft, 18 solar cells could be placed on wings and horizontal stabilizer (14 on wing and remaining 4 on the tail), which could supply 50–60 W. Since each solar cell produces 0.6 V and 18 solar cells are used, all of which are connected in series, an output voltage of 9–11 V is generated which is then directly

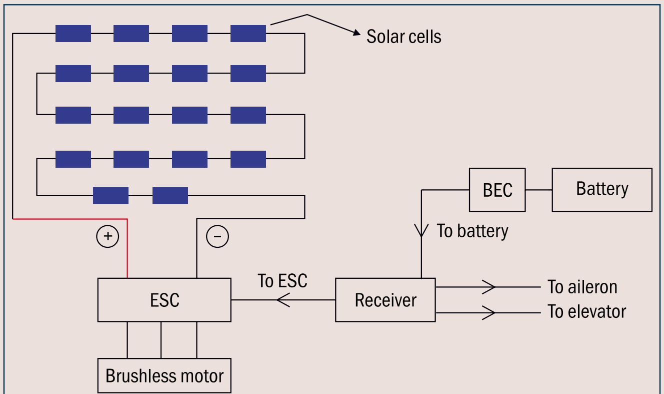
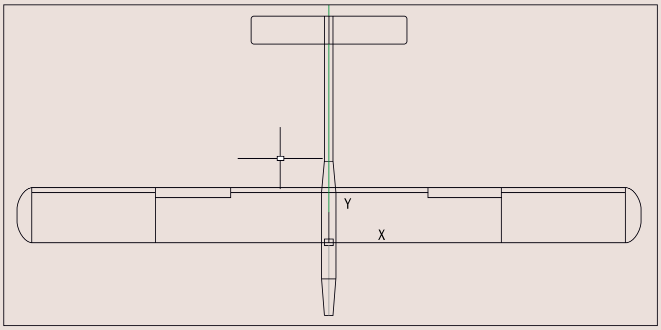


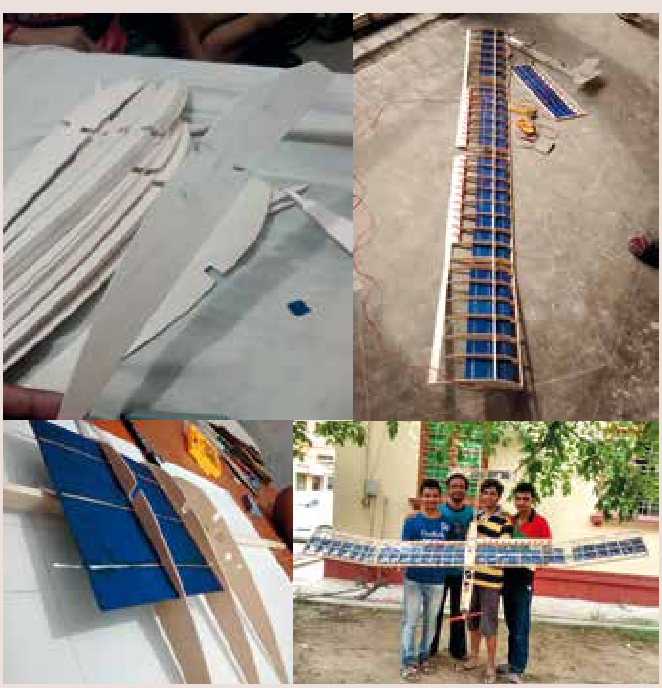
Figure 1: Circuit of Electrical Connections

fed into the electronic speed controller (ESC), which powers the brushless motor. The following electronic components are used in the aircraft apart from solar cells: electronic speed controller (ESC), small brushless DC motor, 2.4 GHz transmitter and receiver, servo motors, and battery eliminator circuit (BEC). Figure 1 is a block diagram showing the connections between different electrical components.



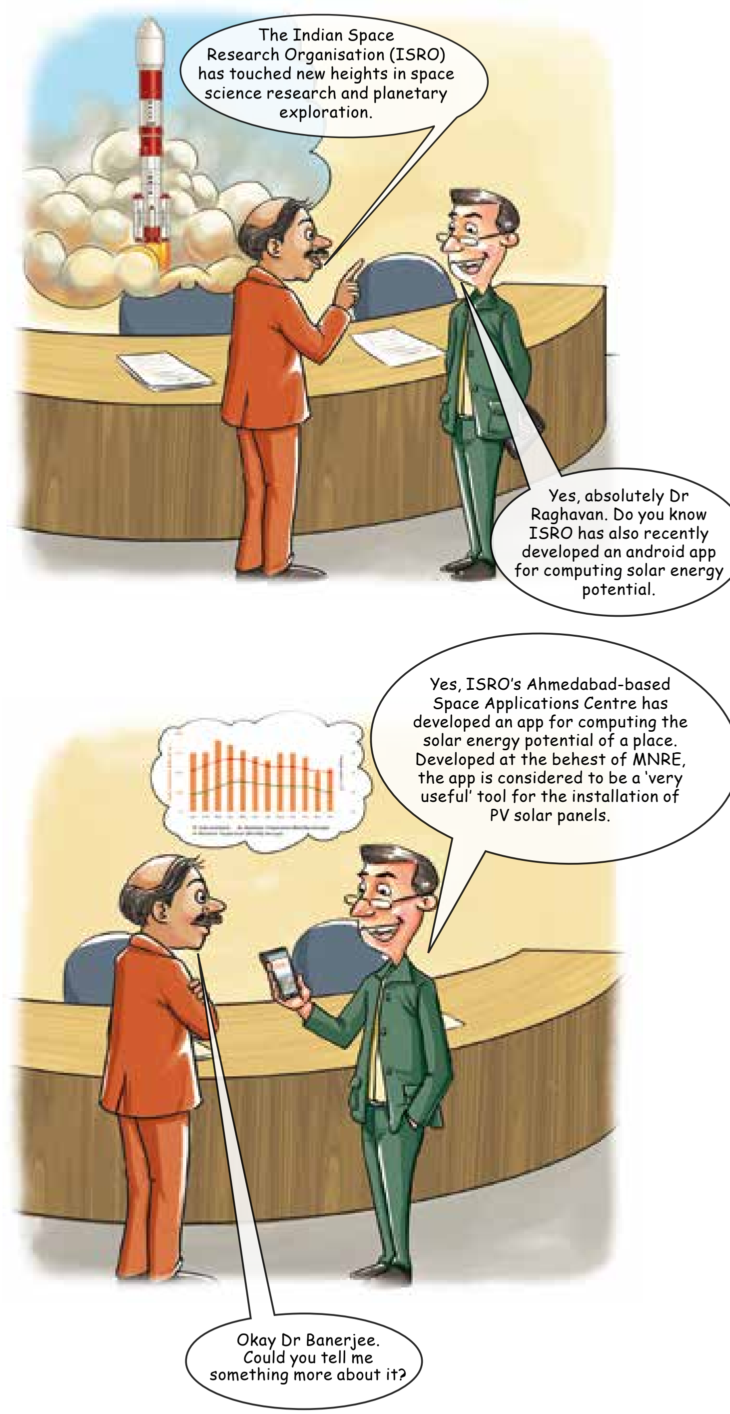
Drawing of solar plane

The most important part of this airplane are wings. They need to be light in weight, must accommodate the required number of solar cells, must have sufficient strength, and most importantly they must produce sufficient lift at very low air speed. NACA 7313-63 airfoil was chosen. This airfoil possesses qualities required for slow flying. Wings of span 2.4 m and chord 30 cm and aspect ratio as 8 and mass of aeromodel is about 1.5 kg. It uses 1400 kV motor which turns a 10-inch propeller. Figure 2 gives the drawing of a solar plane. AU



Contributed by Mr Ahmed Shams, Part III IDD Civil Engineering, IIT(BHU), Varanasi-221005, Uttar Pradesh, India.
Email: shams.ahmed.civ14@itbhu.ac.in

CON 2 PRESERVE



http://ec.europa.eu/

iAcharya Solar Courses on Photovoltaic Power Generation

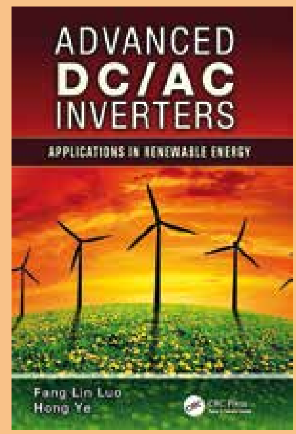
| https://www.iacharya.in/site/

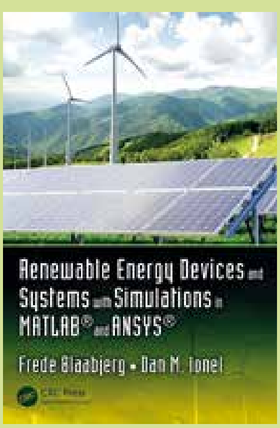
iAcharya Silicon Limited (ISL) has been actively involved in education and training in the Renewable Energy Innovation and Technology Sector being authorized by the Solar Radiation Resource Assessment wing under the Ministry of New and Renewable Energy (MNRE), Government of India. Training has been provided to over 3,000 people in solar PV installations. The trainings are aimed at various segments from basics in solar to advanced design practices. iAcharya offers Government of India Certification from MNRE, India from SRRA (Solar Research and Resource Assessment wing) and NISE (National Institute of Solar Energy).

Advanced DC/AC Inverters: Applications in Renewable Energy

Fang Lin Luo, Hong Ye; CRC Press, 322 pages

DC/AC inversion technology is of vital importance for industrial applications, including electrical vehicles and renewable energy systems, which require a large number of inverters. In recent years, inversion technology has developed rapidly, with new topologies improving the power factor and increasing power efficiency. Proposing many novel approaches, *Advanced DC/AC Inverters: Applications in Renewable Energy* describes advanced DC/AC inverters that can be used for renewable energy systems. The book introduces more than 100 topologies of advanced inverters originally developed by the authors, including more than 50 new circuits. It also discusses recently published cutting-edge topologies. The book supplies design examples to illustrate how to use these inverters in renewable energy systems such as wind turbine systems.





Renewable Energy Systems: Simulation with Simulink® and SimPowerSystems™

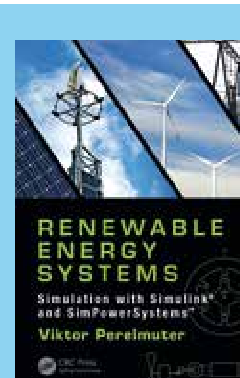
Viktor Perelmuter; CRC Press, 389 pages

The development of renewable sources for electrical energy has become a mainstream focus in the field of electrical engineering. This book can be used by both engineers and researchers working to develop new electrical systems and investigate the existing ones. Additionally, it can serve as a guide for undergraduate and graduate students during their study of electrical fields. The electrical devices that are used in renewable sources have complicated inner structures, and methods of computer simulation make the development of these systems easier and faster. Simulink, and its toolbox SimPowerSystemss, is the most popular means for simulation of electrical systems. This book covers an in-depth exploration of the simulation of WG systems, systems with batteries, photovoltaic systems, fuel elements, microturbines, and hydroelectric systems.

Renewable Energy Devices and Systems with Simulations in MATLAB® and ANSYS®

Frede Blaabjerg, Dan M Ionel; CRC Press, 402 pages

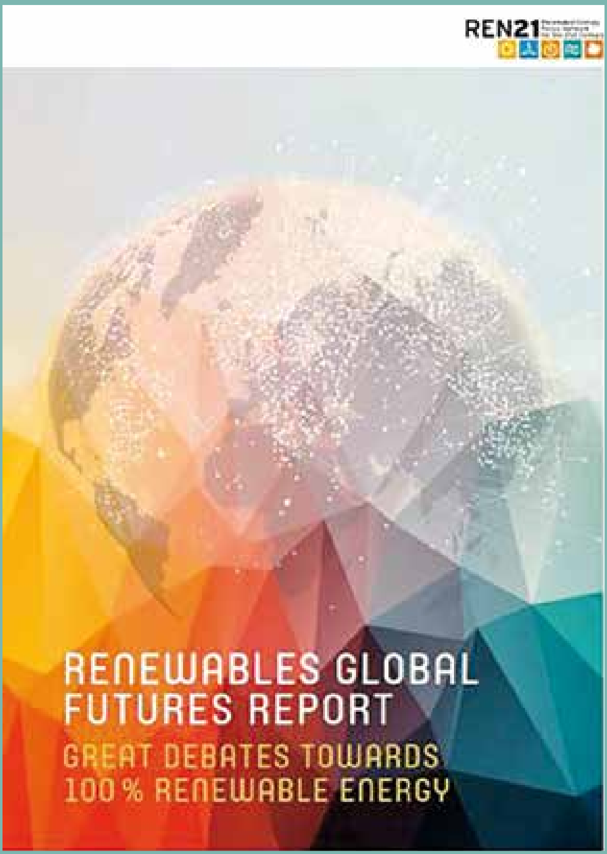
This book introduces wind power system concepts including: fix speed generators, DFIGs, full-scale converter systems with squirrel cage induction or PM generators. Both the modelling and the control principles for these wind power systems and their associated power electronics converters are discussed. It also covers renewable energy technologies, such as PV and solar concentrators, fuel cells, wave energy, and batteries and explains how to integrate the technology into micro-grids and into the grid power system. This book allows the reader to design a small-scale PV and a wind turbine system. It includes information on energy storage with batteries and ultra-capacitors and micro-grids.



REN21 Renewables 2017 Global Status Report

The REN21 Renewables 2017 Global Futures Report presents the views of 114 renowned energy experts from around the world, on the feasibility and challenges of achieving a 100 per cent renewable energy future. Their thoughts are grouped into 12 Great Debates ranging from the future of heating and transport, the interconnection of sectors, the role of mega-cities, and what utilities of the future could look like. The report does not predict the future but should spur debate about the opportunities and challenges of a 100 per cent renewable energy future. The report analyses the views of 114 renowned energy experts from every region of the world, interviewed over the course of 2016. The results are clustered as '12 Great Debates':

1. 100% Renewables: A logical consequence of the Paris Agreement?
2. Global Energy Demand Development: Efficiency on a global level?
3. Renewable Power Generation: The winner takes all?
4. The Future of Heating: Thermal or electrical applications?
5. Renewables for Transport: Electrification versus biofuels?
6. Interconnection of Sectors: System thinking required
7. Storage: Supporter or competitor of the power grid?
8. Technology versus Costs: Which should come first?
9. Scaling-up Investments and Work Force: 100% renewables for socio-economic change
10. Utilities of the Future: What will they look like?
11. Mega Cites: Mega possibilities
12. Energy Access Enabled Through Renewables: How to speed up connections?



The 2017 edition of the REN21 Renewables Global Status Report (GSR) reveals a global energy transition well underway, with record new additions of installed renewable energy capacity, rapidly falling costs, particularly for solar PV and wind power, and the decoupling of economic growth and energy-related carbon dioxide (CO2) emissions for the third year running. Innovative and more sustainable ways of meeting our energy needs—through better-integrated sectoral planning, the adoption of exciting new business models and the more creative use of enabling technologies—are accelerating the paradigm shift away from a world run on fossil fuels. Newly installed renewable power capacity set new records in 2016, with 161 GW added, increasing the global total by almost 9 per cent relative to 2015. Solar PV was the star performer in 2016, accounting for around 47 per cent of the total additions, followed by wind power at 34 per cent, and hydropower at 15.5 per cent. For the fifth consecutive year, investment in new renewable power capacity (including all hydropower) was roughly double the investment in fossil fuel generating capacity, reaching $249.8 billion. The world now adds more renewable power capacity annually than it adds in net new capacity from all fossil fuels combined.

Cost for electricity from solar PV and wind is rapidly falling. Record-breaking tenders for solar PV occurred in Argentina, Chile, India, Jordan, Saudi Arabia and the United Arab Emirates, with bids in some markets below $0.03 per kWh. Parallel developments in the wind power sector saw record low bids in several countries, including Chile, India, Mexico, and Morocco. Record lows in offshore wind power tenders in Denmark and the Netherlands brought Europe's industry closer to its goal to produce offshore wind power more cheaply than coal by 2025.

Source: REN21, 2017, REN21 Renewables Global Futures Report (GFR), Paris, REN21 Secretariat

NATIONAL

July 14–16, 2017 | New Delhi, India
Govt. Achievements & Schemes Expo
Website: http://nnsevents.com/exhibitions/govt-achievements-schemes-expo/

August 03–05, 2017 | Rourkela, India
National Conference on Waste to Energy-Carbon Capture and Storage-NCWECCS– 2017
Website: https://www.mypadnow.com/ncweccs2017

August 21–23, 2017 | New Delhi, India
World Renewable Energy Technology Congress (WRETC) & Expo - 8th Edition
Website: www.wretc.in

August 31–September 01, 2017 | New Delhi, India
The Business & Climate Summit
Website: http://www.businessclimatesummit.com/

September 20–22, 2017 | Greater Noida, India
Renewable Energy India Expo (REIE)
Website: http://www.renewableenergyindiaexpo.com/

INTERNATIONAL

August 21–23, 2017 | Toronto, Canada
ICCE2017: 6th International Conference & Exhibition on Clean Energy
Website: http://icce2017.iaemm.com/

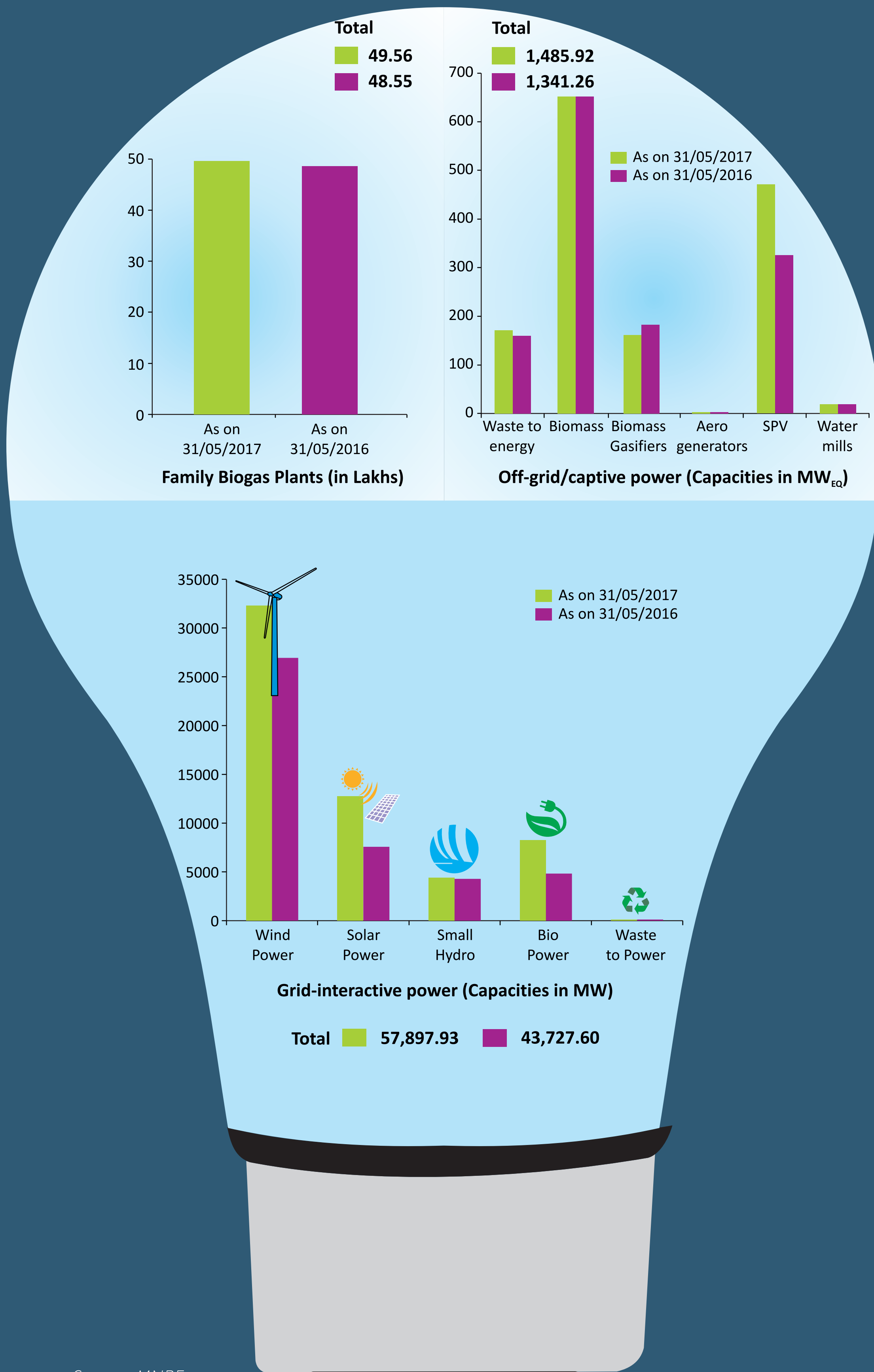
August 29–31, 2017 | Bremen, Germany
Offshore Wind Powers Substations Conference
Website: https://offshore-windpower-substations.iqpc.de

September 18–20, 2017 | New York, USA
International Conference on Sustainable Development
Website: http://ic-sd.org/

September 27, 2017 | London, UK
Renewable and Low-Carbon Energy Planning
Website: https://www.rtpiconferences.co.uk/briefings-and-workshops/renewable_and_low_carbon_energy_planning

September 28–29, 2017 | London, UK
2nd World Congress on Wind & Renewable Energy
Website: http://windenergy.conferenceseries.com/

RENEWABLE ENERGY AT A GLANCE: INDIA



Source: MNRE

RNI No. DELENG/2007/22701