Furthermore, ecological and biological factors place a stringent limit on the use of hydro sources for power production. (The USA has already developed around 50% of its hydro potential and hardly any further expansion is planned because of ecological considerations.)

With increasing per capita energy consumption and exponentially rising population, technologists already see the end of the earth's non-renewable fuel. A coordinated worldwide action plan is, therefore, necessary to ensure that energy supply to humanity at large is assured for a long time and at low cost and minimum pollution. Some of the facts to be considered and actions to be taken are as follows:

- Curtailment of energy consumption
- Intensification of efforts to develop alternative sources of energy, including nonconventional sources, such as solar, tidal energy
- Recycling of nuclear wastes
- Development and application of anti-pollution technologies

Electric energy today constitutes about 30% of the total annual energy consumption on a worldwide basis. This figure is expected to rise in favour of electric energy as oil supply for industrial uses becomes scarce. Electricity, unlike water and gas, cannot be stored economically (except in very small quantities in batteries); also, electric utility can exercise little control over the load (power demand) at any time. The power system must, therefore, be capable of matching the output from generators to the demand at any time at a specified voltage and frequency. The difficulty encountered in this task can be imagined from the fact that load variations over a day comprise three components—a steady component known as base load; a varying component whose daily pattern depends upon the time of day, weather, season, a popular festival, etc; and purely randomly varying component of relatively small amplitude. The characteristics of daily load curve on a gross basis are indicated by peak load and the time of its occurrence and load factor, defined as

$$\frac{average\ load}{\max imum\ (peak)\ load} = \text{less than unity}$$

The average load determines the energy consumption over the day, while the peak load along with considerations of standby determines the plant capacity for meeting the load.

A high load factor helps in drawing more energy from a given installation. As individual load centres have their own characteristics, their peaks in general have a time diversity, which when

utilized though transmission inter-connection, greatly aids in jacking up load factors at an individual plant-excess power of a plant during light periods is evacuated through long-distance high-voltage transmission lines, while a heavily loaded plant receives power.

Diversity Factor

A high diversity factor could be obtained by the following:

» Giving incentives to farmers and/or industries to use electricity at night or during light-load periods;
» Using day–light saving, as many countries do;
» Staggering office timings;
» Having different time zones in the country, as in the USA, Australia, etc;
» Having a two-part tariff in which the consumer has to pay an amount depending on the maximum demand, plus a charge for each unit of energy consumed. Sometimes, a consumer is charged on the basis of kilo-volt-ampere demand instead of kilowatt to penalize loads of a low power factor. Two other factors used frequently are the plant capacity factor and the plant use factor.

Energy Conservation

Energy conservation is the cheapest new source of energy. A dollar saved is better than a dollar earned as one does not have to pay tax on savings. An important energy-saving concept of co-generation must be adopted. Co-generation is defined as the simultaneous generation of electrical power and process steam. This is now attracting world attention. In fact in the USA, there is a plan for meeting the additional demand of power, not by installing new generating capacities, but by co-generation, other conservation means, and various energy-management strategies. The main advantage of co-generation is its very high thermodynamic efficiency of 80% or more.

Co-generation of steam and power is highly energy efficient and is particularly suitable for chemical, paper, textile, food, fertilizer, and petroleum-refining industries. If these industries have in-plant generation using a co-generation concept, it will help in solving the energy shortage problem in a big way. Further, they will not have to depend on the grid power, which is not very reliable. Of course, they can sell the excess power, if any, to the government for use in deficient areas. They may also sell power to neighbouring industries, a concept called wheeling power.[1]

Conventional Sources of Electricity Generation

Major conventional sources of electric energy generation are (i) thermal (by coal/oil/gas); (ii) hydro; and (iii) nuclear.

Hydro plants do have ecological consideration but there still exists great hydroelectric potential in many developing countries, such as Brazil (90% hydro), and this should be utilized as load grows. Nuclear plants are controversial. There are safety and environmental concerns; yet nuclear energy must be used for power generation.

Fusion is futuristic

The generation of electricity via fusion would solve long-term fuel shortage with minimum environmental problem. Coal is only available for the next 100 to 200 years. With this in mind, there is considerable international effort

1 Kothari DP and Nagrath IJ. 2011. *Modern Power System Analysis*, 4th Edition. New York: McGraw Hill.

being made for the development of alternative/new unconventional/ clean new natural renewable sources of energy.

Energy Storage

Unfortunately, electric energy cannot be stored like gas and water and has to be generated as and when required. However, several ways of energy storage are being tried. They are (i) pumped storage plants; (ii) compressed air; (iii) hydrogen gas; and (iv) secondary batteries.

Nonconventional Energy Sources

Most of the new, alternative sources (some of the them have in fact been known and used for centuries now) are nothing but manifestations of solar energy, for example, wind, sea waves, ocean thermal energy conversion (OTEC), etc.

Geothermal energy

In a geothermal power plant, heat deep inside the earth acts as a source of power. There has been some use of geothermal energy in the form of underground steam in the USA, Italy, New Zealand, Mexico, Japan, the Philippines, and some other countries. In India, feasibility studies for a 1 MW station at Puggy Valley in Ladakh are being carried out. Another geothermal field has been located at Chumantang. There is a number of hot springs in India, but the total exploitable energy potential seems to be very little.

The present installed geothermal plant capacity in the world is about 500 MW and the total estimated capacity is only about 2,000 MW. Since the pressure and temperature are low, the efficiency is even less than conventional fossil-fuelled plants, but the capital costs are less and the fuel is available free of cost.

Wind energy

Wind is essentially created by heating of the atmosphere by sun. Several attempts have been made since 1940 to use wind to generate electric energy and development still continues. However, the techno-economic feasibility has yet to be satisfactorily established.

Wind as a power source is attractive because it is plentiful, inexhaustible, and non-polluting. Further, it does not impose an extra heat burden on the environment. Unfortunately, it is unsteady and undependable. Control equipment has been devised to start the wind power plant whenever the wind speed reaches 30 km/h. Methods have also been found to generate constant frequency power with varying wind speed and consequently varying speeds of windmill propellers. Wind power may prove practical for small power needs in isolated sites; but for maximum flexibility, it should be used in conjunction with other methods of power generation to ensure continuity.

Solar energy

The average incident solar energy received on the earth's surface is about 600 W/m^2, but the actual value varies considerably. It has the advantages of being free of cost, renewable, and completely pollution-free. On the other hand, it has several drawbacks—the energy density per unit area is very low; it is available for only part of the day. Cloudy and seasonal variations reduce the energy received; therefore, harnessing solar energy for electricity generation throws up some challenging technological problems, the most important being that of the collection and concentration of solar energy and its conversion to electrical form through efficient and comparatively economical means.

At present, two technologies are being developed for conversion of solar energy to the electrical form. In one technology, collectors with concentrators are employed to achieve temperatures high enough (≥700°C) to operate a heat engine at reasonable efficiency to generate electricity. However, there are considerable engineering difficulties in building a single tracking howl with a diameter exceeding 30 m to generate perhaps 200 kW. The scheme involves large and intricate structures involving huge capital outlay and, as of today, is far from being competitive with conventional electricity generation.

Electricity may be generated from a solar pond by using a special 'low temperature' heat engine coupled to an electric generator. A solar pond at EinBorek in Israel produces a steady 150 kW from 0.74 ha at a busbar cost of about $0.10/kWh.

Direct conversion to electricity is achieved through photovoltaic generation. This technology converts solar energy to the electrical form by means of silicon wafer photoelectric cells known as 'solar cells'. Their theoretical efficiency is about 25% but the practical value is only about 15%. But that does not matter, as solar energy is basically free of cost. The chief problem is the cost and maintenance of solar cells. With the likelihood of a breakthrough in large-scale production of cheap solar cells with amorphous silicon, this technology may compete with conventional methods of electricity generation, particularly as conventional fuels become scarce.

Wave energy

The energy content of sea waves is very high. In India, therefore, with several hundreds of kilometres of coastline, a vast source of energy is available. The power in the wave is proportional to the square of the amplitude and to the period of the motion. Therefore, the long period (–10 s), large amplitude (–2 m) waves are of considerable interest for power generation, with energy fluxes commonly averaging between 50 and 70 kW/m width of the oncoming wave. Though the engineering problems associated with wave power are formidable, the amount of energy that can be harnessed is large and development work is in progress.

Tidal power plants

A tidal power plant is successfully working in France on the river La Rance having tidal height of 9.2 m and tidal flow of 18,000 m^3/sec. Several such sites exist elsewhere, for example, Kutch and Sunderbans, and must be developed.

Ocean thermal energy conversion (OTEC)

The ocean is the world's largest solar collector. Temperature difference of 20°C between the warm, solar absorbing surface water and the cooler 'bottom' water can occur. This can provide a continually replenished store of thermal energy, that is, in principle, available for conversion to other energy forms. OTEC refers to the conversion of some of this thermal energy into work and thence electricity.

Magnetohydrodynamic generation

In thermal generation of electric energy, the heat released by the fuel is converted to rotational mechanical energy by means of a thermocycle. The mechanical energy is then used to rotate the electric generator. Thus, two stages of energy conversion are involved in which the heat to mechanical energy conversion has an inherently low efficiency. Also, the rotating machine has its associated losses and maintenance problems. In magnetohydrodynamic technology, electric energy is directly generated by the hot gases produced by combustion of fuel without the need for mechanical moving parts.

Conclusion

The main reasons for power shortage include delay in commissioning the installed capacity, poor capacity utilization of power plants, poor availability of plants due to bad or unplanned maintenance. In India, the availability is for 3,600 hours as against 5,600 hours in Japan.

Now, people are also thinking of decentralized (distributed/dispersed) power generation, integrated and hybrid energy systems consisting of grid power in combination with biomass, wind, solar, and micro/mini hydel plants, especially for rural areas. Centralized grid power will of course continue to be there, but it must be made available economically, reliably, and with minimum possible environmental effects. EF

Suggested Readings

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Kothari DP and Nagrath IJ. 2007. *Power System Engineering*, 2nd Edition. New Delhi: Tata McGraw Hill.

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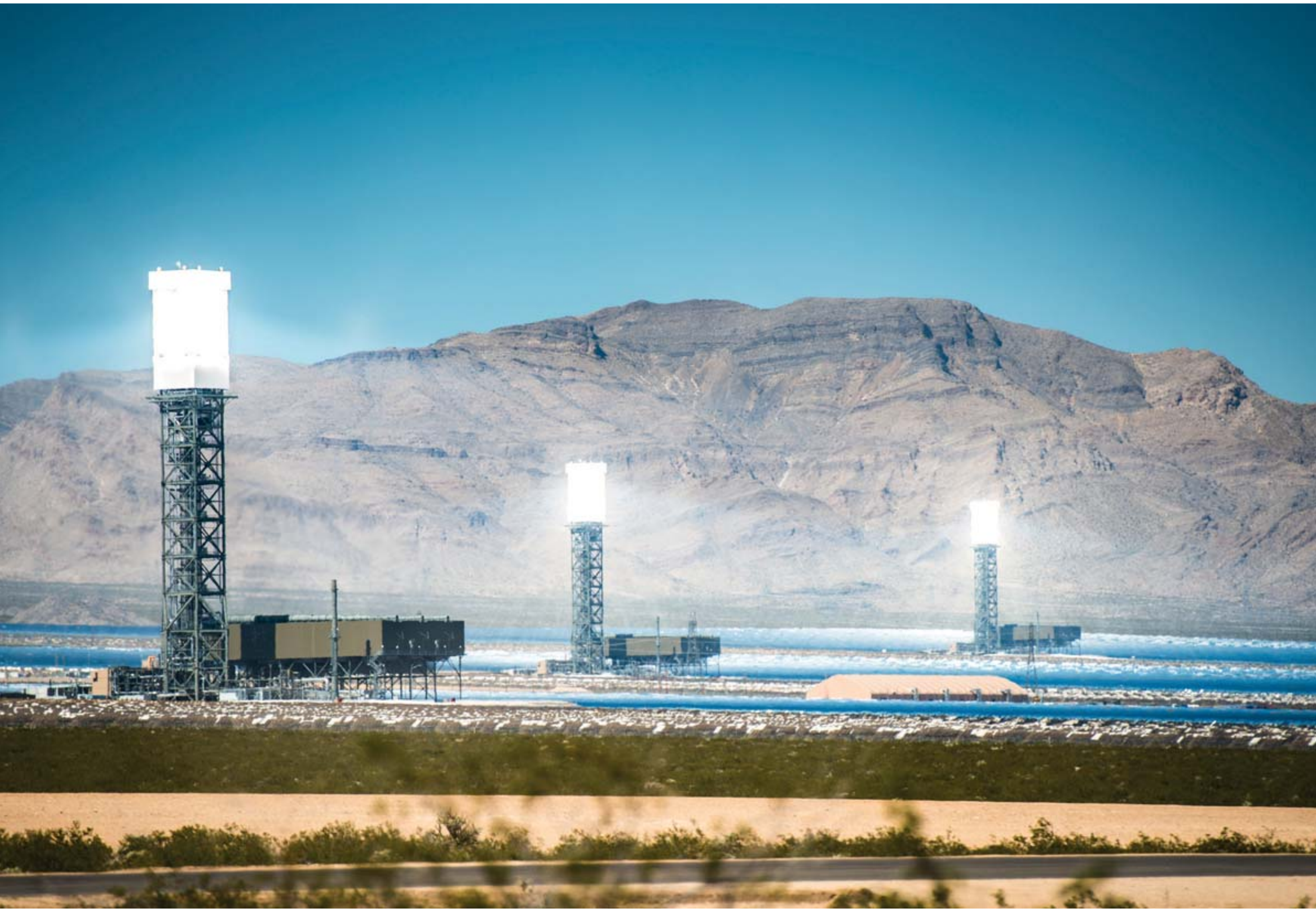
D P Kothari, Director, Research, Gaikwad-Patil Group of Institutions, Nagpur, Maharahtra, India.

CSP TECHNOLOGY IN INDIA

Barriers in widespread expansion



India's solar target is 100 GW by the year 2020. This, however, does not include CSP, that is, concentrated solar power. Owing to India's geographical position just north of the equator, India has a huge potential to develop CSP. **Sarvesh Devraj** talks about the problems facing the advancement of this technology in the country.

Concentrating solar power (CSP) technologies use different mirror configurations to concentrate the sun's light energy onto a receiver and convert it into heat. The heat can then be used to create steam to drive a turbine to produce electrical power or used as industrial process heat. CSP, which is commonly termed as solar thermal electricity, has attained 110 MW global capacity addition in year 2016/17, bringing global capacity to more than 4.8 GW by year's end (2017). Globally, the pace of CSP installations in 2016 was observed to be slow.

India has daily average 4–7 kWh/m^2 solar insolation with daily average direct normal irradiance (DNI)[1] of 4.3–4.54 kWh/m^2 (Figure 1). With aggressive Government solar policies by the end of 2017, India is expected to achieve total installed capacity of 18 GW. It has been a great year so far, around 8.8 GW has been added in 2016/17. India is expected to become a major player in CSP by the year 2050 (Figure 2). The techno-commercial potential of CSP in India is believed to be more than 2,800 GW in India.

In the year 2010/11 capital cost for photovoltaic (PV) and CSP were 17 crore/MW and 13 crore/MW, respectively. Capital cost of PV for 2016/17 got reduced to 68% of its cost in 2010/11, but CSP capital cost reduced only 7% for the same period. High capital cost also increased the power generation cost leading to high CSP tariff in India (INR12/kWh). Payback period for CSP projects is higher than the solar PV projects. There is need for competitive for smooth acceleration of CSP projects.

Apart from China, India was the only Asian country with CSP facilities under construction by the end of 2016. The major projects under construction in India include 25 MW Gujarat Solar 1 plant (with 9 hours of Thermal Energy Storage [TES]) and 14 MW National Thermal Power Corporation's Dadri Integrated Solar Combined-Cycle (ISCC) plant, 23 (REN21). Only a few

1 https://nsrdb.nrel.gov/nsrdb-viewer

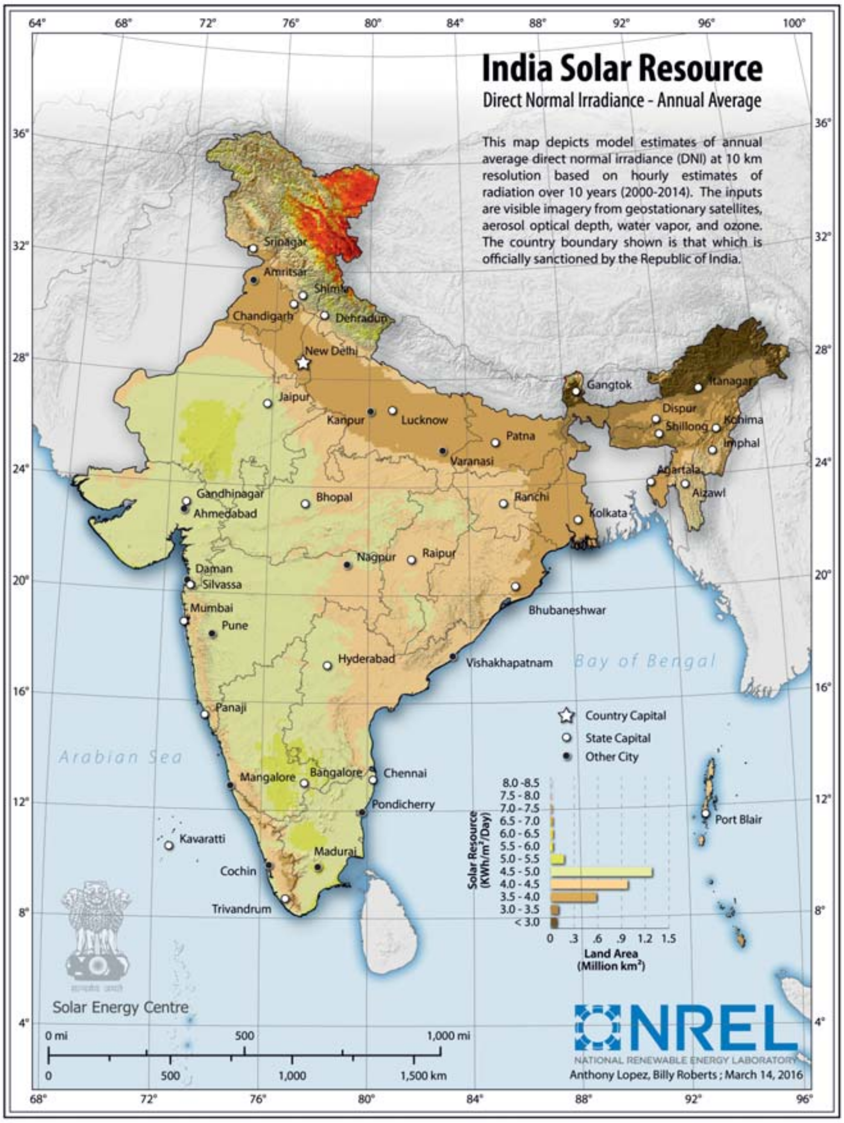


Figure 1 Map showing India's average annual DNI (Source: NREL)

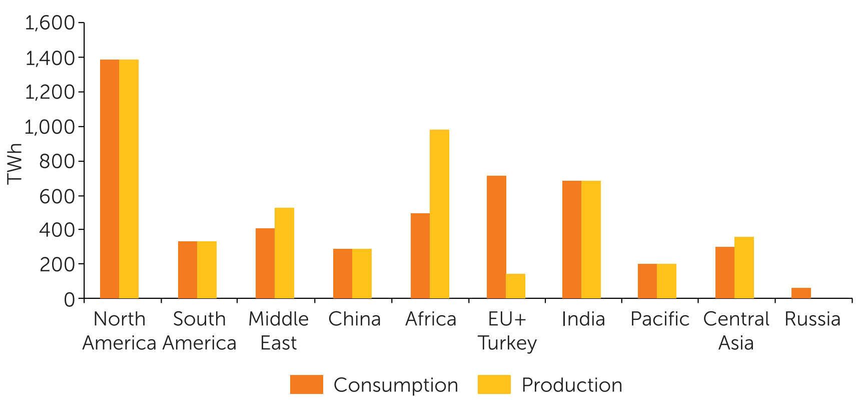


Figure 2 Production and consumption of CSP Electricity by 2050[2]

2 https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/ESMAP%20WB_Development%20of%20Local%20CSP%20Supply%20Chain%20in%20India_Full__Optimized.pdf

CSP projects in India were successful and barriers, such as DNI assessment, high capital cost, manufacturing infrastructure, policy push, etc., have been the key issues.

DNI Assessments

Accurate DNI estimation is very crucial for any CSP projects. The NREL solar DNI map (Figure 1) of Rajasthan and Gujarat have been calculated at value ~5.5–6 kWh/m^2. Actual measured DNI on ground was different than the estimated value from satellites. For instance, Godawari Green Project in Rajasthan was India's first commercial CSP project with 50 MW capacity. The company had reckoned yearly DNI of 1,825 kWh/m^2 but the actual acknowledged DNI was 1,753 kWh/m^2. This inaccurate estimation of DNI had created hurdles for engineers. To achieve 50 MW output, developers had to increase the field area of mirrors significantly, which increased total cost of project. Similarly, first demonstration solar tower project by ACME solar was installed in Bikaner, Rajasthan. Earlier 10 MW plant was proposed but due to overestimated DNI values, only 2.5 MW could be installed.

Issues such as DNI have risked the project and ACME had dropped all the expansions plans. Also, the problem of the desired output with existing solar fields became an issue.

High CSP Tariff in India

A recently announced CSP project awarded to SolarReserve has broken all previous record of low CSP cost. Power generation tariff comes down to around $61/MWh or 6 cents/kWh, which is the lowest till date. The power will be delivered from SolarReserve's 150 MW (135 MW net) CSP Aurora project in Port Augusta will have eight hours of daily solar energy storage to deliver into the late afternoon and evening hours to meet South Australia's peak electricity demand periods.

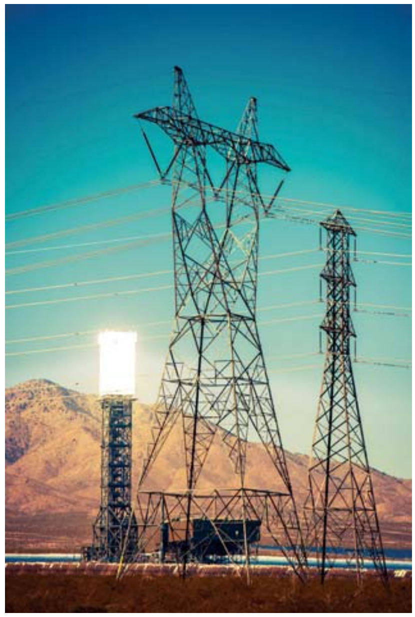
However in India, CSP tariff has constant trends of ~Rs.12/ kWh or $ 0.19/kWh since 2013/14. High power tariff creates low confidence and high risk among CSP vendors.

Financing

Levelized cost of energy (LCOE) of CSP is greater than solar PV. In comparison to other CSP leading countries, India has witnessed less research and development and successful project experience. As there is no successful demonstration project in India, it causes problem for investors to invest their money into CSP projects. Under Ministry of New and Renewable Energy's (MNRE's) Jawaharlal Nehru National Solar Mission (JNNSM), reverse bidding also brought down the generation costs, but due to challenges in technology, investors have shown negligible interest in CSP projects. As per investors, low tariff bids also could not make CSP projects financially viable. This is a significant barrier as financiers are unfamiliar with CSP investments, risk averse, and often focus on the short term. To achieve financial closure, revenue equation must provide investors with an acceptable internal rate of return with all risks appropriately mitigated and allocated. Other barriers also contribute to the risk profile that increases the challenge to securing financing.

Lack of Strong Policy Push

In JNNSM Phase-I (2010/13), total allocation of grid connected solar projects was divided into two equal parts: 50% Solar PV and 50% CSP. During Batch-1(Phase-I), total 470 MW capacity CSP projects were allocated through bidding, but only 50 MW of 470 MW has been commissioned till March 2013. Till date, total CSP installation in India is 250 MWe. Several issues related to technology and design has delayed projects. Seeing the results of Phase-I, government has reduced the CSP target to 30% for Phase-II. The recently announced solar commitment of 175 GW renewable does not consider the CSP. So, a strong policy push and huge



incentives in from of subsidy could only give another birth for CSP.

Acceptable Annual DNI Values

The key challenges in solar thermal power are estimation of correct DNI. In JNNSM Phase-1, most of the CSP projects led towards unpromising results because of overestimation of solar radiation values. An analysis presented by the MNRE shows that DNI values provided by NASA satellites have been overestimated by large variations ~35%.[3] But now, National Institute of Wind Energy (an autonomous body of MNRE) has released Solar Atlas for India, which is more precise for solar thermal power projects.

So to utilize CSP in India, MNRE data could be used. Getting acceptable value and simultaneously vast tracts of land to incorporate big CST collectors always have been key issues for CSP. However, threshold annual DNI for CSP projects can be 1800 kWh/m^2 or 2,000 kWh/m^2.[4]

3 http://wgbis.ces.iisc.ernet.in/biodiversity/sahyadri_enews/newsletter/issue45/bibliography/Assessment%20of%20solar%20thermal%20power%20generation%20potential%20in%20india.pdf

Huge Water Consumptions

Maximum CSP plants utilize Rankine cycle for power generation. The steam production to run the turbine has been catered by quality water. Cleaning of mirrors also demands water; a research explained that around 10% water of total water requirements is for mirror washing and the rest is majorly consumed in cooling and steam generations. Hence, water availability is a crucial factor for solar thermal power projects in India. Generally, DNI values are high in deserts or arid locations, such as Rajasthan, Tamil Nadu, Andhra Pradesh, etc., thus choosing alternatives of water for cooling becomes important.

Table 1 Consumption of water for CSP[4]

CSP Technology	Consumption of Water (Litres/MWh)
Parabolic trough	3,000–3,500
Solar tower	2,300–2,800
Linear Fresnal reflector	4,000–4,500

Indigenous Manufacturing Infrastructure Unavailability

India's deep reliance on CSP component imports from Europe is also one of the reasons for CSP's high capital cost. Developing local production facilities of CSP components, such as mirrors, heat transfer fluids, could slice overall capital cost by halves. Local manufacturing has additional benefits, such as developing indigenous operations and maintenance (O&M) industry supported by local subcontractors, better procurement lead time, and trained local manpower. Promotion of local manufacturing and competitiveness would bring down operational costs significantly. Assuming that local manufacturing would result at best in a 25% reduction of certain equipment costs, this would translate into a reduction of 5%–9% of the project cost. Therefore, in the next round of CSP solicitation, the project bid prices for solar thermal projects are likely to come down to about ₹9 crore/MW, in the best-case scenario, which is very competitive in the CSP field in comparison with global CSP costs. The CSP plants based on the tower technology can come down even further to a level of ₹8.5 crore/MW, since in the case of the tower technology, all items except for the mirrors can be fabricated locally.

4 Dawson L and Schlyter P. 2012. Less is more: Strategic scale site suitability for concentrated solar thermal power in Western Australia. *Energy Policy* **47**: 91–101.

Way Forward

There are so many issues related with CSP deployments in India but like other countries, India is optimistic for further aggressive developments in CSP. A proper long-term vision, research, and developments are definitely capable to make India a leader in CSP technology.

Integration of thermal storage

CSP plants can integrate thermal energy storage systems to generate electricity during cloudy periods or even several hours after the sunset. CSP systems can be also combined with combined cycle power plants resulting in hybrid power plants, which provide high-value, dispatchable power. These attributes make CSP the most attractive renewable energy option in the Sun Belt regions. It was found in a study that capacity utilization factor of CSP plants could reach 40% from average value of 20%–24%.

Local DNI measurements

The unsuccessful stories from JNNSM Phase I have stressed on accurate ground value measurement of DNI solar radiation. So there is a huge requirement for ground-based monitoring stations. National institute of Wind Energy (NIWE), an autonomous body of MNRE, had initiated Solar Radiation Resource Assessment (SRRA) in 2010. According to NIWE, a total of 121 SRRA stations have been planned for installation across the country to record the radiation values along with local metrological parameters. High-regulation radiation values could be instrumental in CSP project designing. Also, validations of ground data with satellite data are the quickest way to solve DNI uncertainty.

Back with alternatives: Hybridizations

CST technology is highly dependent on DNI values; huge variations in solar DNI could affect power generation significantly. During non-sunshine hours, back up with other technologies, such as CNG, biomass, etc., can reduce the capital cost of overall project and increases the efficiency level.

Policy support strengthening

Policy and government support is the biggest factor in promoting CSP technology in India. Spain is the leading CSP powered country in the world; apart from good solar resources, it has been greatly supported by the government. Policy towards developing domestic manufacturing, year-wise targets, and generation-based incentives (GBI) could be the pathway to boost the confidences of project developers.

Local manufacturing of CSP components

The price fluctuations in fossils fuels, such as coal and gas and gas emissions from industries indicate to replace fossils with suitable technologies, such as CSP. Seeing the potential of CSP in country, it becomes necessary to develop local manufacturing of mirrors, storage materials, etc., locally. This would certainly reduce the capital cost and operations cost. Apart from cost reduction, it will create jobs and make India's CSP market more reliable. EF

Sarvesh Devraj, Research Associate, Renewable Energy Technologies, India

USE OF INFORMATION AND MARKET-BASED INSTRUMENTS FOR INFLUENCING ENERGY DEMAND IN THE RESIDENTIAL SECTOR

For transition to a sustainable future, low-carbon growth of the commercial sector alone is insufficient; the residential sector too needs to contribute. The government has formed policies to enhance energy efficiency of this sector but it is still lagging behind. The reasons attributed to this are high upfront costs and information asymmetries leading to market failures. **Nitish Arora** and **Jonathan Donald Syiemlieh** present a stronger case for utilities to undertake information dissemination and market-based instruments to effectively influence the electricity consumption behaviour of households.

Time and again energy reports (such as by IEA,[1] European Commission,[2] OECD[3]) have suggested that energy efficiency is the best tool to keep energy demand under control and for transition towards a low-carbon future. This consensus extends to the residential sector as well; with many governments attempting to tap this potential by introducing standards and labelling, building codes, and price instruments, such as taxes and subsidies.[4] India is no different with the Electricity Act (2003) providing an overarching framework for enhancing energy efficiency in the residential sector. The government has promoted energy efficiency through initiatives, such as standard and labelling scheme, outreach activities, incentives for adopting and manufacturing energy-efficient appliances (Bachhat Lamp Yojana Scheme, Super-Efficient Equipment Programme [SEEP][5]), and voluntary building codes (with Energy Conservation Building Code [ECBC][6]

1 IEA. 2013. *Transition to Sustainable Buildings*. Strategies and Opportunities to 2050. Paris: International Energy Agency.
2 European Commission. 2011. 'COM (2011) 109 Final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions'. Brussels: Energy Efficiency Plan 2011.
3 OECD. 2003. *Environmentally Sustainable Buildings: Challenges and Policies.* Paris: OECD.
4 Markandya A, Labandeira X, and Ramos A. 2015. Policy instruments to foster energy efficiency. In: Ansuategi A, Delgado J, Galarraga I, Eds., Green Energy and Efficiency. An Economic Perspective (pp. 93–110). Berlin: Springer.
5 SEEP is a programme designed to bring accelerated market transformation for super-efficient appliances by providing financial stimulus innovatively at critical point/s of intervention.
6 The Energy Conservation Building Code (ECBC) was developed by the Government of India for new commercial buildings on May 27, 2007, as a first step towards promoting energy efficiency in the building sector. ECBC sets minimum energy standards for commercial buildings having a connected load of 100 kW or contract demand of 120 KVA and above.

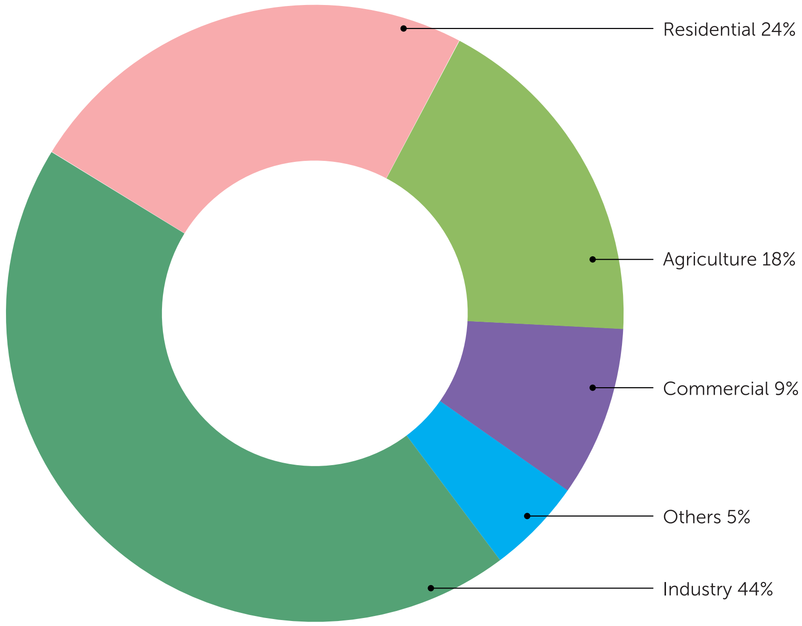


Figure 1 Sector-wise electricity consumption of India, 2016

Source: Garg A, Dhar S, Kankal B, and Mohan P, (Eds.). 2017. *Good Practice and Success Stories on Energy Efficiency in India.* Copenhagen: Copenhagen Centre on Energy Efficiency, UNEP DTU Partnership.

made mandatory for commercial buildings). Occasionally, it has implemented demand-side management (DSM) pilot programmes targeted towards accelerating adoption of energy efficient appliances; however, in spite of the large potential and existing efforts to foster energy efficiency in the residential sector, much remains to be achieved. In particular, informational failures seem to be pervasive and relevant in this area. It is widely acknowledged that behavioural and non-price incentives would be a key factor as far as energy conservation is concerned, whereas monetary or fiscal incentives would be required for accelerating market penetration of energy-efficient products, which underlines the salience of a mix of fiscal and information-based instruments to target improvements in energy efficiency in Indian households.

Status of Residential Electricity Consumption in India

Residential electricity consumption has gone up by 50 times since 1971. Currently, the residential sector consumes 24% of the total electricity in India, making it the second largest next to industry in terms of electricity consumption in India (Figure 1).

Moreover, consumption demand is expected to grow even further on account of rapid electrification, increasing household purchasing power, and technology advancement. Further, the annual consumption growth rate for the states, such as Delhi, Punjab, and Maharashtra, with higher per capita residential electricity consumption was in the range of 5%–8%.[7] State wise, residential electricity consumption data highlights that larger states, such as Maharashtra, Uttar Pradesh, and Tamil Nadu, rank higher. However, based on per capita residential electricity, Delhi ranks on top, which consumes four times more per capita than India's average. This presents a stronger case for utilities to undertake large-scale DSM activities, wherein information and market-based instruments could turn out to be effective in influencing electricity consumption behaviour of households. Although

7 Prayas (Energy Group). 2016. *Residential Electricity Consumption in India: What do we know*? Pune: Prayas.

India does not have a residential energy consumption survey, a few studies have shown that lighting and cooling requirements take up to 75% of the total electricity consumption, the requirements of which are projected to grow by 260% in 2021 (Figures 2 and 3).

Potential for Energy Efficiency

The Bureau of Energy Efficiency (BEE) has attempted a calculation of energy savings made from the star labelling scheme of four common energy consuming appliances in households using the National Sample Survey Office (NSSO) data. From the labelling of four appliances, the estimated saving of electricity consumption by households in the year 2030 is 136.8 billion units (or 24%). Table 1 illustrates these potential savings. BEE has stipulated a reduction of approximately 30% for household electricity consumption, inclusive of both lighting and appliances for the year 2030.

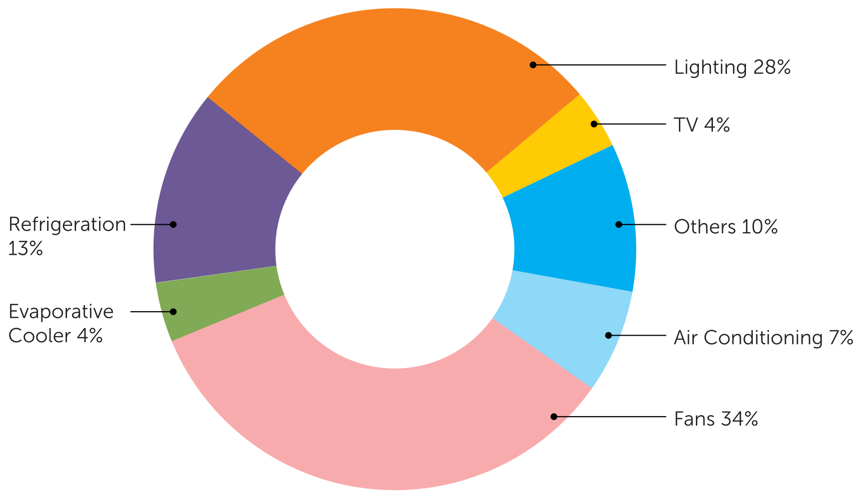


Figure 2 Electricity consumption pattern in residential buildings

Source: Planning Commission[8]

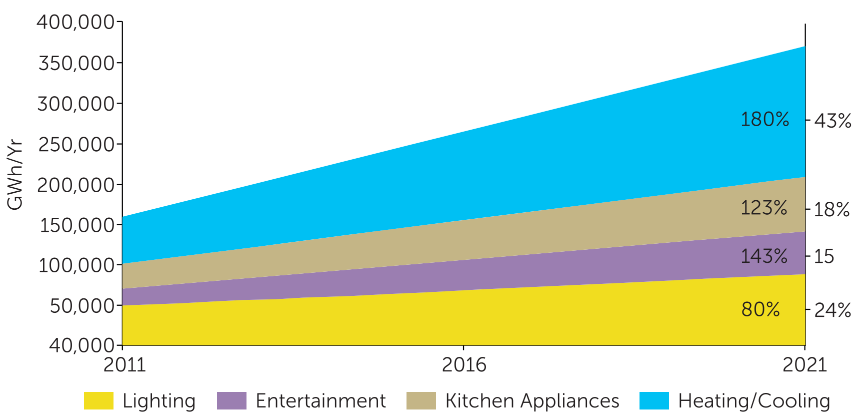


Figure 3 Projected growth in electricity consumption by appliances in residential sector

Source: World Bank[9]

Table 1 clearly presents a greater potential for enhancing the market penetration of energy-efficient appliances. GHG abatement potential by increasing energy efficiency was estimated by McKinsey[10] in terms of cost and ease of implementation, as presented in Table 2. A majority of the GHG reductions from energy efficiency can be achieved either at negative or moderate cost.

Market penetration was somewhat faster in the case of frost-free refrigerators, although one also needs to look at direct-cool refrigerators that have the highest market share, for which no information was available. Moreover, with BEE periodically revising (tightening) energy-efficiency standards, the role of information and market-based instruments becomes extremely critical in acting as the driving force for consumers to switch to more energy-efficient appliances as the technology updates. Recently, the BEE has introduced a new star rating methodology called the Indian Seasonal Energy Efficiency Ratio (ISEER) for air conditioners, such that the Star-5 in 2010 became Star-3 in 2015 and will become Star-1 in 2018 as per the new ISEER methodology. The weighted average Energy Efficiency Ratio of AC has increased from 2.6 in 2006 to 3.26 in 2015, which is an increase of 25% in efficiency due to tightening of standards.

In this context, it becomes necessary to calculate the payback period given the useful lifetime of appliance, high upfront costs and high discount rates of customers. A somewhat similar analysis was done by the IREDA wherein the authors have calculated the present discounted value (PDV) of the savings in electricity bill over the life time of the appliance (which they assume of 10 years) and show how savings outweigh the high upfront cost of star-rated appliances, for details refer to Tables 3–6. Here, useful lifetime of appliance from

8 Planning Commission. 2014. *The Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth*. New Delhi: Planning Commission, Government of India.

9 World Bank. 2008. Residential *Consumption of Electricity in India – Documentation of Data and Methodology*. Background Paper on India: Strategies for Low Carbon Growth. World Bank.

10 McKinsey. 2009. *Environmental and Energy Sustainability: An Approach for India*. McKinsey and Company.

Table 1 Energy saving potentials by appliances in 2030

Households	Appliance	Total No. of Operated Millions	Life in Years	Star Rated	Energy Saving (kwh/ product/year)	Energy Saving by Star-Rated Appliances (Million kwh)	Energy Used by Non-rated Appliance (Million kwh)	Energy Saved (%)
Bottom 5 Deciles	AC	4	7	2*	415	1,660	10,400	16
	Refrigerator	26	10	3*	283	7,358	18,720	39
	Colour TV	60	7	0	0	0	24,000	0
	Ceiling Fans	94	10	0	0	0	21,996	0
Top 5 Deciles	AC	52	10	3*	567	29,484	135,200	22
	Refrigerator	161	10	5*	411	66,171	115,920	57
	Colour TV	247	7	4*	71	17,537	98,800	18
	Ceiling Fans	585	10	4*	25	14,625	136,890	11
All						136,835	561,926	24

Source: Garg A, Dhar S, Kankal B, and Mohan P, (Eds.). 2017. *Good Practice and Success Stories on Energy Efficiency in India*. Copenhagen: Copenhagen Centre on Energy Efficiency, UNEP DTU Partnership.

Table 2 GHG abatement opportunities with energy efficiency in India

GHG Abatement Energy Efficient Opportunities	GHG Abatement Potential (million tonnes CO_2e)	Cost	Ease of Implementation
Equipment and appliances	90	Negative	Moderately challenging
Lighting controls	20	Negative	Challenging
LED Lighting	35	Negative	Very Challenging
New building efficiency	70	Modest (<$30/ tonne)	Challenging
Total	215		

Source: McKinsey

the consumers' perspective is taken into account as they will be making the buying decision on this basis. An assessment of the same would help in designing tailored instruments targeted across the expenditure classes.

Barriers to Energy Efficiency and the Role of Information-Based Instruments

Anecdotal evidence suggests that in general, Indian customers are relatively more cost conscious than their Western counterparts—promptly switching off appliances (e.g., lights, ceiling fans, television sets, etc.) when not in use. Consequently, one would expect higher adoption of energy-efficient technology is more likely to happen in India than in the West. However, the market penetration of energy-efficient appliances is hampered by several barriers in India that are influenced by high upfront costs, heavily discounted future savings, uncertainty associated with energy savings, lack of access to capital, lack of awareness, and inability to assess the lifetime benefits and costs of the decision. In other words, asymmetric and imperfect information on energy efficiency may be a key bottleneck to the faster adoption of energy-efficient solutions in India. This issue is not peculiar to India and several countries are experimenting with information and market-based instruments that are aimed at targeting the behaviour of people through the provision of well-designed information. Information-based instruments can generally be classified as direct and indirect feedback from energy suppliers on household energy consumption and interventions targeted for greater penetration of energy-efficient appliances and technologies.

Direct feedback covers information on real-time consumption provided on the Internet or through dedicated devices and displays, including mobile devices via smart meters. Providing real-time energy consumption information may allow a prompt response from the final energy consumers and increase energy savings. Indirect feedback could include more informative and frequent bills containing historical and/or comparative information on energy consumption. It uses instruments of energy certificates, energy audits, information on energy use and energy efficiency, community-based marketing, peer comparisons, target setting, etc. (for a detailed classification, see Table 7).

Note that determining net savings—because of these behavioural interventions, excluding the effect of other demand reduction programmes of standards, labelling, and financial incentives—can be difficult. Other considerations include the 'rebound' effect, that is, reductions in energy costs

Table 3 Air conditioners: Initial cost, energy consumption, and economic attractiveness

Star Rating	Cost (INR/ unit)	Energy Consumption (kwh/year)[a]	Energy Saving over 1* (kwh/year)	PDV of Saving @ ₹4/kwh and Discount Rate of 20%	PDV of Saving @ ₹6/ kwh and Discount Rate of 10%
Window Acs: (1.5 Tonne, operated 1200 h per year, life 10 years)					
1	18,190	2,258	0	0	0
2	19,000	2,101	157	3,159	6,367
3	24,990	2,061	197	3,964	7,989
4	27,000	2,004	254	5,111	10,301
5	30,000	1,856	402	8,090	16,303
Split Acs: (1.5 Tonne, operated 1200 h per year, life 10 years)					
1	23,000	2,100	0	0	0
2	26,000	1,981	119	2,395	4,826
3	29,000	1,926	174	3,502	7,056
4	31,500	1,849	251	5,051	10,179
5	33,500	1,786	314	6,319	12,734

[a] From BEE-rated data for 148 window and 309 split ACs of 1.5T, (BEE, 2015)

Table 4 Refrigerators: Initial cost, energy consumption, and economic attractiveness

Star Rating	Cost (INR/ unit)	Energy Consumption (kwh/year)[a]	Energy Saving over 2* DC and 1* FF (kwh/ year)	PDV of Saving @ ₹4/ kwh and Discount Rate of 20%	PDV of Saving @ ₹6/kwh and Discount Rate of 10%
Direct cool (DC) refrigerators (175–225 litres, life 10 years)					
1	0				
2	9,000	419	0	1,661	3,085
3	10,500	322	96	2,786	5,173
4	13,000	258	161	2,786	5,173
5	16,000	207	211	3,651	6,780
Frost free (FF) refrigerators (235–265 litres, life10years)					
1	9,000	500	0		
2	11,000	400	100	2,012	4,055
3	14,000	310	190	3,824	7,705
4	17,500	240	260	5,232	10,544
5	20,000	190	310	6,238	12,572

[a] From BEE rated 305 DC and 175 FF models (BEE, 2015) of these capacities.

Table 5 Colour TV: Initial cost, energy consumption, and economic attractiveness

Star Rating	Cost (INR/unit)	Energy consumption (kwh/year)[a]	Energy Saving Over 1* (kwh/year)	PDV of saving @ INR 4/kwh and discount rate of 20%	PDV of saving @ INR 6/kwh and discount rate of 10%
CRT televisions – 55 cm screen size – operating hours 2190 per year - life10 years					
1	7,800	235	0	0	0
2	8,200	208	27	543	1,095
3	8,500	188	47	946	1,906
4	10,000	167	68	1,368	2,758
5	13,500	140	95	1,912	3,853
LCD televisions – 55 cms screen size – operating hours 2190 per year – life 10 years					
1	16,500	158	0	0	0
2	17,000	135	23	463	933
3	17,500	108	50	1,006	2,028
4	18,500	92	66	1,328	2,677
5	23,000	71	87	1,751	3,528

[a] From BEE rated models (BEE, 2015) of 55 cms.

Table 6 Ceiling fans, minimum air delivery 210 cubic metre/minute, operating hours 3600, Life 10 years.

Star Rating	Cost (INR/ unit)	Energy Consumption (kwh/year)[a]	Energy Saving Over 2*(kwh/year)	PDV of Saving @ ₹4/kwh and Discount Rate of 20%	PDV of Saving @ ₹6/kwh and Discount Rate of 10%
1	0	0	0	0	0
2	1,600	222	0	0	0
3	1,750	209	13	266	535
4	1,900	197	25	503	1,014
5	2,100	180	42	845	1,703

[a] From BEE rated 138 models (BEE, 2015) of this capacity

Table 7 Types of Feedback

Type of Feedback	Sub-type of Feedback	Medium	Type of Information	Communication
Indirect Feedback	Standard Billing	Paper	- Historical Energy consumption -Historical comparison	One-way communication
	Enhanced Billing	- Paper -Electronic environment (ebill)	-Energy consumption, rewards - Energy Efficiency Advice -Social comparison -Historical comparison	One-way communication
Direct Feedback	Direct feedback with IHD	- In-House Display - Web environment	-Real-time information -Social comparison -Historical comparison	One-way communication
	Direct with Connected Devices	- In-House Display - Web environment - Smart Meter	-Real-time information -Appliance disaggregation -Social comparison -Historical comparison	Two-way communication

Source: ACEEE Summer Study on Energy Efficiency in Buildings, 2016

resulting in customers to increase their energy use, diminishing the actual energy savings achieved.

Evidence from the World

Country experiences of using information and market-based instruments targeted towards influencing household behaviour on energy saving and energy efficiency are shown in Table 8.

After having looked at the efficacy of information-based instruments, it becomes essential to look at the complimentary role played by monetary rewards in influencing consumption behaviour of electricity .

Incentives for Adopting Energy-Efficient Products

Subsidies and fiscal incentives are popular means for increasing home energy efficiency. Countries that offer financial incentives for sustainable household energy investments include Canada, France (equipment such as boilers), Denmark (energy-efficient windows), and the United Kingdom (insulation, water and space heaters). Germany offers interest-free ten-year loans as well as a guaranteed price for household solar heating installations (UNDESA, 2007). Ontario, Canada; Italy; and UK provide rebates on provincial sales taxes for purchases of select energy-saving appliances and replacing out-dated energy-intensive products.

Table 8 Cross-country experiences

Geographic Location	Intervention	Impact/Observation	Source
EU Member States	Direct and indirect feedback	Combining direct and indirect feedback from energy suppliers has so far been the most successful in influencing consumer behaviour and achieve energy savings	EEA Technical Report 2013
USA	Direct and indirect feedback	Energy savings due to direct feedback generally fall within the range of 5% to 15%. Energy savings from indirect feedback can reach 10% but success depends on context and quality of information delivered to households	Ehrhardt-Martinez, Donelly et al. (2010)*
UK	Direct and indirect feedback	Average measure of energy consumption from local area was the most effective benchmark for consumers for energy savings	Ipsos MORI, 2011
UK	Direct and indirect feedback	Provision of historical feedback combined with a direct feedback measure is likely to have higher benefits	Raw and Ross (2011)[#]
USA	Feedback coupled with target setting	Showcased that energy consumption with feedback reduced by 15.1% as compared to 4.5% for those who did not receive the feedback set at a target of 20%. Where the energy-saving target was set at 2%, the energy consumed with feedback reduced by 5.7% as compared to 0.6% for those who did not receive feedback	Becker (1978)[+]
USA	Peer group comparisons	Evidence suggests that informing households how their electricity consumption compares to the average consumption of their peers can lead to small but economically significant reductions (of the order of 1%–3%) in average electricity consumption	Allcott, 2011
UK	Smart meters	Interventions using smart meters were often successful and resulted in larger energy savings compared to other measures. The combination of smart meters and real-time displays (RTDs) consistently resulted in energy savings of around 3% on average. The customer surveys on RTDs also exhibited that cost information was used and valued more than unit (kW) information	Raw and Ross (2011)16

* https://www.smartgrid.gov/files/ami_initiatives_aceee.pdf

\# https://www.ofgem.gov.uk/ofgem-publications/59105/energy-demand-research-project-final-analysis.pdf

\+ Becker L. 1978. Joint effect of feedback and goal setting on performance: A field study of residential energy conservation. *Applied Psychology* 63: 428–33.

Consumer reward points/Green Loyalty Point System

This innovative approach aims to promote low-carbon lifestyles by encouraging consumers to buy energy-efficient appliances. Consumer get awarded with reward points, which can be redeemed for discounts on public transportation, basic utility charges, and purchases of other efficient appliances. The programme was a huge success in Japan. The share of products shipped that had four or more stars increased from 20% to 96% for air conditioners, from 30% to 98% for refrigerators, and from about 84% to 99% for televisions. This resulted in estimated savings of 2.7 million tonnes of CO_2 per year.[11] Other countries running similar programmes include South Korea, the Netherlands, and France. For a detailed list of the programmes, refer to Table 9.

Evidence from India

However in India's context, there aren't many studies assessing the feasibility of information and market-based instruments in influencing the end-users of electricity in the residential sector. A study by Mohit Jain and others[12] surveyed nearly 1,700 residents around Delhi and did not find any link between culture and energy conservation; however, the drive for energy conservation was mainly due to the desire to save money. They also found that comfort and convenience was a major barrier in promoting energy conservation practices. However, these households were willing to adopt home energy monitors and share their energy data with others.

Another interesting study by Sudarshan[13] assessed the effectiveness of (i) behavioural nudges using peer comparisons; (ii) nudges augmented with financial incentives, and (iii) price changes. The author surveyed 500 upper-middle class households in Delhi and found that comparing household's monthly electricity bill with that of neighbours resulted in a reduction of 8% in its electricity consumption. However, the study further found that peer comparisons when coupled with financial incentives led to a net increase

Table 9 Incentive programmes for adopting energy-efficient products

Country	Programme	Time Frame	Form	Recipient	Administrator	Funding	Energy-Efficient Product
France	Sustainable Development Tax Credit	2005 to present	Tax Credit	Consumers	Government	General Budget	Boilers, home insulation, heat pumps, windows, renewable energy
Italy	Tax Deduction for Energy Savings	2007 to present	Tax deduction replacement	Consumers	Government	General Budget	Efficient equipment and home insulation
UK	Reduced VAT	1998 to present	VAT reduction	Consumers	Government	General Budget	Insulation material, heating control systems, heat pumps, wood fueled boilers
South Korea	Carbon Cashbag	October, 2008	Eco-points	Consumers	Local Government	General and local budget	Home electronics, appliances
Japan	Eco-points	2009-2011	Eco-points	Consumers	Local Government	Stimulus Package	Air conditioners, refrigerators, TVs
Mexico	PNSEE	2009-ongoing	Replacement on-bill	Consumers	Government	International Institution	Refrigerators, air conditioners

11 Mizobuchi K and Takeuchi K. 2012. Using economic incentives to reduce electricity consumption: A field experiment in Matsuyama, Japan. *International Journal of Energy Economics and Policy* 2(4): 318–32.

12 Jain MC, Chabra D, Mankoff J, and Singh A. 2014. *Energy Usage Attitudes of Urban India*. Available at https://www.iiitd.edu.in/~amarjeet/Papers/ICT4S-2014-IndiaSurvey.pdf, last accessed August 22, 2017.

13 Sudarshan A. 2014. Nudges in the marketplace: Using peer comparisons and incentives to reduce household electricity consumption. *Journal of Economic Behavior & Organization* 134: 320–35.

in electricity consumption because these incentives are low powered and the price elasticity is low. Although price increases remained effective in reducing consumption, the author concluded that isolated DSM incentives in practice are less likely to be successful; however, a bundle of variety of different interventions would be an effective tool. These results suggest that behavioural instruments may interact in complicated ways with incentives and market prices.

Recent Initiatives

The scenario seems to be changing with the success of UJALA and Streetlight National Programme schemes being implemented by EESL, wherein efficient devices are promoted in the market through a programme. Under the UJALA scheme, families can pay for their LED bulbs through their utility bill at ₹10 per month making energy efficiency affordable to everyone. This has helped in reducing average household electricity bills by 15%—one year's savings is equivalent to a week's average earnings. Moreover, typically one LED lamp can last as long as 20 incandescent bulbs, saving family's money on incandescent bulb purchases. Extending the scheme to energy-efficient fans and LED tube lights, EESL found that by distributing 230 million LED bulbs, 800,000 energy-efficient fans, and 2.3 million LED tube lights have cumulatively helped India save 32 billion kWh electricity annually, the production of which would otherwise have consumed 19 million tonnes of coal. This has led to an annual reduction of 25 million tonnes of CO_2, which is equivalent to growing approximately 600 million trees over a period of 10 years. Adding to that, consumers are saving over ₹124 billion on their electricity bills annually.

By far, the State Electricity Regulatory Commission (SERC) and DISCOMs have implemented several schemes to lower the transaction costs for higher penetration of energy-efficient appliances and alter consumption behaviour. SERCs have mostly relied on tariff mechanisms, such as the time-of-day tariff, incentives, and surcharges, based on the power factor and load factor as well as kVAh billing. The SERCs in Maharashtra, Gujarat, and Tamil Nadu have issued DSM regulations, while Delhi has put out draft DSM regulations that are yet to be notified. Further, DISCOMs in Delhi and Mumbai have launched appliance exchange programmes for their consumers. Under these programmes, the DISCOMs provide a substantial rebate to the consumers (to the tune of 40%–50%) to replace their old, inefficient appliances with new, 5-star-rated appliances. The old appliances are scrapped in an environment-friendly manner. However, the programmes have remained at the pilot scale as scaling up these programmes will require significant budget outlays and can have a substantial tariff impact, especially for the non-participating consumers who cannot avail the benefits from energy-efficient appliances. Also, one of the major barriers DISCOMs faced is the lack of availability of 5-star-rated products that comply with the latest standards; thus creating uncertainty among the consumers regarding its performance and potential energy savings.

Behavioural change is seen as a combination of both conscious effort and habitual behaviour; therefore, it is essential to develop innovate marketing campaigns to trigger the right impulse. For example, for impacting decision on energy consumption, some questions need to be raised and answered, such as how energy is used (intensity and mode), what appliances to buy or upgrade, why buy star-rated appliances, and many more. Specific actions need to be developed to turn them into new routines or habits that would then influence their long-term behaviour. A review of the literature suggests that market-based instruments, such as green loyalty point system and interest-free EMI option on purchase of energy-efficient appliances are likely to work in India's context. Similarly, quantifying monetary benefits of energy units along the star rating label might address consumer misconceptions. Thus, tailored information strategies can solve problems of imperfect information in markets by disclosing the unobserved costs of individual consumption decisions to consumers. Moreover, because electricity demand is relatively price inelastic, non-price information strategies using normative, intrinsic, or social motivations might prove to be effective alternatives. EF

Nitish Arora, Research Associate, and Jonathan Donald Syiemlieh, Associate Fellow, Resource Efficiency & Governance, TERI

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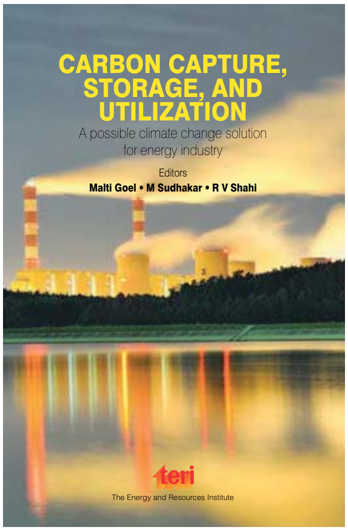

CARBON CAPTURE, STORAGE, AND UTILIZATION

A possible climate change solution for energy industry

Editors
Malti Goel, M Sudhakar, and R V Shahi

Carbon Capture and Storage (CCS) is among the advanced energy technologies suggested to make the conventional fossil fuel sources environmentally sustainable. It is of particular importance to coal-based economies.

Carbon Capture, Storage, and Utilization deals at length with the various aspects of carbon dioxide capture, its utilization and takes a closer look at the earth processes in carbon dioxide storage. It discusses potential of carbon capture, storage, and utilization as innovative energy technology towards a sustainable energy future. Various techniques of carbon dioxide recovery from power plants by physical, chemical, and biological means as well as challenges and prospects in biomimetic carbon sequestration are described. Carbon fixation potential in coal mines and in saline aquifers is also discussed.

Key Features

- Analyses how current research on carbon capture, storage, and utilization is being pursued throughout the world.
- Presents details of earth process in carbon sequestration such as saline aquifers, minerals, rocks, and coal mines.
- Describes the new cost-effective processes being developed in carbon dioxide utilization for value-added products.

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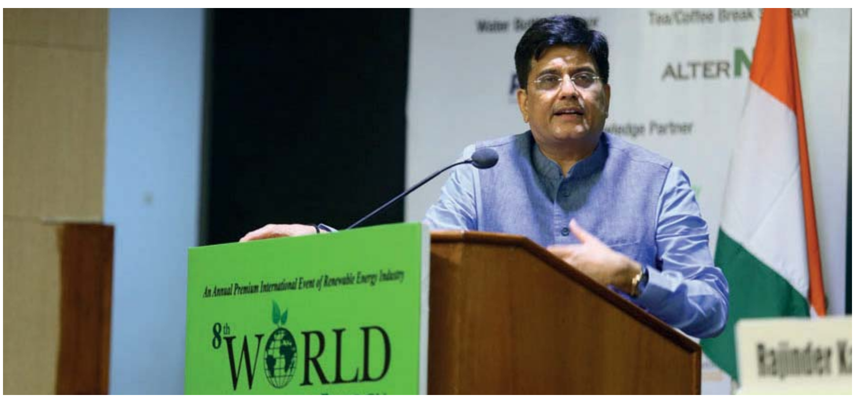
8TH WORLD RENEWABLE ENERGY TECHNOLOGY CONGRESS & EXPO 2017

The 8th World Renewable Energy Technology Congress & Expo-2017 was held on August 21–23, 2017, at the Convention Centre-New Delhi City Centre in New Delhi. The Conference and Expo was organized by the Energy and Environment Foundation and supported by Ministry of New and Renewable Energy; Ministry of Environment, Forest and Climate Change; and Ministry of Micro, Small and Medium Enterprises. It served as an excellent energy platform for the global renewable energy industry to address various industry issues including innovations, new technologies, investment opportunities, and project financing. The theme for this year's conference was 'Renewable Energy: Global Cooperation for Sustainability'.

Hon'ble Shri Piyush Goyal, the Union Minister of State (IC) for Power, Coal, Renewable Energy and Mines, addressed the delegates attending the three-day 8th World Renewable Energy Technology Congress. The Minister gave away Energy and Environment Foundation Global Excellence awards 2017 during the Inaugural Session. In his Inaugural address, Shri Goyal emphasized about the 3Ds—Decarbonization, Decentralization, Digitalization—in today's global engagements on energy. He said that these are common shared goals of decarbonization of the energy space; to look at more decentralization of energy space; and more and more digitalization of the energy space. With each passing day we are running out of time and we need to accelerate our efforts in coordination to promote clean energy and to reduce greenhouse gas emissions. He said, "I am sure this event of Technology will make renewable energy more attractive particularly for emerging and growing economies, such as India, especially when renewable energy costs



are down as compared to other forms of conventional energy sources."

Dr Upendra Tripathy, DG, International Solar Alliance, delivered the special address wherein he emphasized on use of solar energy through technology so that poor get benefitted. Delivering the theme address Mr Anil Razdan, Chairman Energy and Environment Foundation, said to ensure access to energy mix through global cooperation, evolution of an integrated strategy for meeting the energy needs of the global citizen and a sustainable planet is needed. Dr Ajay Mathur, Director General, The Energy and Resources Institute and Chairman Steering Committee, WRETC, delivered the welcome address and said we have to find supporting technologies that can help us to move low-cost renewable energy as and when we needed through grid and off-grid solutions. Mr K S Popli, CMD IREDA & Co-Chairman Steering Committee, WRETC, highlighted that stepping up of private investments and introduction of new investment vehicles have created a positive movement in the renewable energy market across the world. Dr Anil K Garg, President, World Renewable Energy Technology Congress, emphasized the importance of global cooperation for sustainability in renewable energy sector.

The conference and expo was attended by national and international delegates. The conference brought together leading international and domestic players, policy makers, government officials, and technocrats on a common platform. The concurrent conference sessions comprised interesting workshops as well as interactive panel discussions. The conference served as an important gateway for worldwide new energy companies to access the Indian market to foster partnerships and collaborations with local players.

The main features of the resolutions adopted in the conference were as follows:

» The Congress reiterated the resolve to ensure Energy for All by 2030, cleaner cooking fuels, cleaner air and attainment of the universal Sustainable Development Goals, 2015.
» The Congress appreciated the sincere commitment of developing countries such as India towards meeting the commitments made at CoP 21.
» The Congress noted with satisfaction that renewable energy has attained grid parity with conventional sources of energy in many countries. It appreciated this breakthrough.
» Systems should integrate new renewables with conventional energy systems to synergize the energy system to ensure harmonious development in industry and electricity.
» Improvement in international cooperation and exchange of new development in renewable energy technology is desirable.
» Renewable energy should be harnessed across the energy chain for providing electricity, mobility, and heat as a comprehensive energy source.
» Manufacturing facilities for new renewables should be located equitably across the consuming countries so that job creation and maintenance go hand in hand with installation of generation facilities. The maintenance of renewable energy systems is as important as installation.
» The steep fall in prices of solar PV is posing a threat to existing solar PV systems, and the danger of purchasers abandoning the power purchase agreements (PPAs). There is need to protect the validly executed PPAs, through the life of the assets. Otherwise, there will be acute financial distress in the sector.
» A much closer interface between industry and academia, preferably in a symbiotic relationship, will result in faster and more focussed development of products and trained manpower, and the most economic development of resources.
» Dramatic reduction in cost of offshore wind energy is very encouraging.
» There is need for supporting research and development for cheaper storage options and new battery materials.
» For commercial viability of renewables in the electricity sector, there is need to ensure open access, and stability in transmission and distribution charges, besides development of smart grids for load management, integration, and grid stability.
» The renewable energy landscape necessitates concurrent investment in forecasting, monitoring, and storage of renewable energy in view of its intermittent characteristic.
» Despite the steep fall in solar PV tariffs, there is need to work aggressively towards maximization of the utilization of the solar spectrum to increase efficiency of solar cells, in view of land and location constraints.
» Hydrogen as a fuel needs to be developed. The extraction of carbon from biomass and hydrogen through solar energy could be utilized to produce methane and methanol, an easily storable energy source with wide applications.
» There is need to accelerate deployment of sustainable biofuels in order to decarbonize transport. EF

Biofuel Economy Significant to India in the Coming Decade

On *World Biofuel Day in 2017*, Cabinet Minister for Petroleum and Natural Gas, Shri Dharmendra Pradhan announced that the government plans to bring a new policy to promote the use of biofuels in transport fuel. Apart from catalysing ₹1 lakh crore of investment in the entire value chain, the move is also likely to boost the sector and give it the much-needed impetus. ***Dr Anjan Ray***, Director-CSIR-Indian Institute of Petroleum, speaks to **Sapna Gopal** for *Energy Future* on what this entails for the industry and for the country at large.

India is all set to unveil a new biofuel policy. In what way will it help the sector?
The previous biofuel policy has run its course. It got the nation thinking about biofuels, but set ambitious future targets of 20% ethanol blending in gasoline (petrol) and 20% biodiesel in diesel that were, in hindsight, not easy to achieve with the operating ecosystem that existed at the time when it came into force in 2009. A new policy is expected to be more holistic, less prescriptive of technology—leaving that as far as practicable to market forces and leaving room for rapid assimilation of new breakthroughs in applied science, and more focused on measurable outcomes year-on-year. The key needs are reduction in imported carbon-based fuels (which will help India's balance of payment and drive energy self-reliance), reduced greenhouse gas emissions (which are essential for a secure future of our planet) as well as for the fulfilment of our national commitments to the CoP21 under the UNFCCC, amelioration of urban air pollution issues, and creation of income and job opportunities in the energy sector.

The government plans to bring a new policy to promote use of biofuels in transport fuel that will catalyse Rs1 lakh crore of investment in the entire value chain. Since India imports 80% of its crude oil needs, it is believed that the use of biofuel will help meet the target of reducing imports by 10% by 2022. What are your thoughts on this?
Biofuels alone cannot reduce petroleum imports by 10% by 2022. It is essential that the biofuels incentivized are produced with domestically available carbon feedstock—whether that be non-edible oils; biomass; or wastes, such as municipal solid waste, kitchen wastes, waste plastics, used cooking oil, or sewage. If we replace imported crude oil with imported biofuel feed stocks, such as palm stearin, this would help our greenhouse gas reduction initiatives but not necessarily our balance of payments or energy self-reliance issues.

It is heartening that the government is taking concrete steps to promote biofuels. An important part of this is to raise awareness across the country and to encourage entrepreneurs and investors to see the future value of participation in this growing sector. Recently, at a World Biofuel Day event, I was delighted to see many young people from across the country ask pertinent questions about both demand side (job opportunities, end-use options, etc.) and the supply side (collection of wastes and cultivation of biofuel crops). I think there is a real chance that the biofuel economy could mean as much to India in the coming decade as the mobile technology did in the previous one.

The Union Petroleum and Road Transport Ministries announced that they will ask for a reduction in GST on biodiesel from the current 18% to 5%. Is this necessary? If yes, why so?
I am not a tax expert but I believe this move makes sense for driving adoption from an end-user point of view.

Biofuels are not produced to scales of economy that petroleum fuels enjoy with over a century of investment into a mature sector, and therefore, can be disadvantaged without suitable incentivization. The end-user of fuels—be it the general public or the farmer who needs diesel to run their water pumps or tractors—does not avail GST credit. Hence, a lower GST should, to my mind, help drive adoption. On the other hand, a zero GST would mean no tax credit for the biofuel producer and seller on their tax-paid inputs, so the proposed reduction is probably a sensible via media.

With state-run oil-marketing companies (OMCs) ready to invest up to $2 million in biofuel research and development, are things finally looking up for the biofuel sector?

I would say yes, but the devil is in the details. We are still far behind international economies in areas such as drop-in fuels such as renewable hydrocarbon diesel ('green diesel'), which—unlike biodiesel—contains no oxygen and can be used at 100% replacement of conventional petro-diesel. Green diesel would also be as good as or better than Euro-6 diesel and can be run on unmodified engines with superior vehicle performance. The United States, Europe, and even Thailand have incorporated renewable diesel (alternately referred to as BTL, HVO, or BHD depending on the feedstock and technology used) into their policies. Green diesel plants with technologies from Neste of Finland and Honeywell UOP of USA are already delivering over 4 million metric tonnes of this next-generation biofuel annually worldwide.

Some technologies, such as iH2 from Shell, can convert even agricultural waste into green diesel. Another breakthrough concept—of using waste carbon-containing gases, such as carbon monoxide and carbon dioxide from steel mills and petroleum refineries, is currently under implementation at IOCL's Panipat refinery in partnership with Lanzatech, a NRI-promoted US-based company that pioneered the concept of gas fermentation by microbes to produce fuels from waste gases.

Is the recent transfer of the biofuel vertical from the New and Renewable Energy Ministry to the Road Transport Ministry a sensible move and a viable one?

Absolutely! The biofuel economy—especially with first-generation oxygenate biofuels, such as biodiesel and sugarcane ethanol—is joined at the hip with the petroleum products economy that will remain the big brother for several years to come given India's massive and growing fuel requirements. Without a common administering ministry, it is difficult to bring efficiency and alignment between the hydrocarbon fuels sector and the biofuels sector.

What according to you, should be done on the policy level and in terms of incentives/subsidies to further improve the sector?

A lot of thought and discussion has gone into policy formulation over the past few years on renewable energy areas. The results are already tangible and impressive in areas, such as solar photovoltaic and co-generation in the sugar sector. Wind and biomass energy have made reasonable progress.

I believe the one important thing that should be done at the policy level is technology neutrality. The government should not specify the biofuel products to be incentivized, whether cellulosic ethanol, methanol, bio-CNG, or otherwise. Policy should simply support any alternate fuel on the basis of a clearly agreed computation of (a) imported carbon replacement potential (energy equivalence) and (b) greenhouse gas reduction potential (life cycle analysis). This will also allow for sound comparisons between different technology pathways in the context of national priorities and allow us to determine, for example, whether biomass in the Northeast is better deployed for cellulosic ethanol or for firing brick kilns or making hydrocarbon fuel. EF

Sapna Gopal is an independent journalist based in Hyderabad; she writes and blogs on renewable energy.

CURRENT R&D RENEWABLE

Musa balbisiana Colla peel as highly effective renewable heterogeneous base catalyst for biodiesel production

Industrial Crops and Products, Volume 109, 2017, Pages: 8–18

Minakshi Gohain, Anuchaya Devi, Dhanapati Deka

Biodiesel production process encourages use of heterogeneous catalyst over homogeneous catalysts. The major problems associated with the use of homogeneous catalysts are its non-renewable nature, separation, and washing, which can be overcome by the use of heterogeneous catalysts. Therefore, in this work, *Musa balbisiana* Colla peel, a waste biomass material, has been used for preparing eco-friendly and highly effective heterogeneous base catalyst for sustainable biodiesel production. The peels of *Musa balbisiana* Colla have been characterized by Fourier transform infrared spectroscopy (FTIR), powder X-ray diffractograms (XRD), energy dispersive analysis of X-ray (EDAX), Brunauer–Emmett–Teller (BET), scanning electron microscopy (SEM), and transmission electron microscopy (TEM) analysis. The conversion of the waste cooking oil into biodiesel was confirmed by proton nuclear magnetic resonance (1H NMR), Carbon-13 nuclear magnetic resonance (13C NMR), and gas chromatography-mass spectroscopy (GC–MS) techniques. The peels of *Musa balbisiana* Colla furnished 100% conversion of waste cooking oil into biodiesel. Low-cost, renewable heterogeneous catalyst from banana (*Musa balbisiana* Colla) peels can be developed for fatty acid methyl esters (FAME) production providing a new route for sustainability of fuels.

Modelling Baseline Conditions of Ecological Indicators: Marine Renewable Energy Environmental Monitoring

Ecological Indicators, Volume 83, December 2017, Pages: 178–191

Hannah L Lindera, John K Hornea, Eric J Ward

Ecological indicators are often collected to detect and monitor environmental change. Statistical models are used to estimate natural variability, pre-existing trends, and environmental predictors of baseline indicator conditions. Establishing standard models for baseline characterization is critical for effective design and implementation of environmental monitoring programmes. An anthropogenic activity that requires monitoring is development of marine renewable energy sites. Currently, there are no standards for the analysis of environmental monitoring data for these development sites. Marine renewable energy monitoring data are used as a case study to develop and apply a model evaluation to establish best practices for characterizing baseline ecological indicator data. We examined a range of models, including six generalized regression models, four-time series models, and three nonparametric models. Because monitoring data are not always normally distributed, we evaluated model ability to characterize normal and non-normal data using hydro-acoustic metrics that serve as proxies for ecological indicator data. The nonparametric support vector regression and random forest models, and parametric state–space–time series models generally were the most accurate in interpolating the normal metric data. Support vector regression and state–space models best interpolated the non-normally distributed data. If parametric results are preferred, then state–space models are the most robust for baseline characterization. Evaluation of a wide range of models provides a comprehensive characterization of the case study data and highlights advantages of models rarely used in marine renewable energy environmental monitoring. Our model findings are relevant for any ecological indicator data with similar properties, and the evaluation approach is applicable to any monitoring programme.

Designing Auctions for Renewable Electricity Support. Best Practices from Around the World

Energy for Sustainable Development, Volume 41, December 2017, Pages: 1–13

Pablodel Río

Auctions have recently been regarded as a useful alternative to other support schemes for the setting up of the remuneration of renewable electricity (RES-E) worldwide. However, whether auctions will fulfil the expectations depends on the choice of design elements. The aim of this article is to analyse the advantages and drawbacks of different design elements according to different criteria. We support our analysis with economic theory and identify best and worst practices in the design of RES-E auctions from around the world. Our findings show that a few design elements score better than the alternatives in some criteria, without scoring worse in others. These 'best' practices include a schedule of auctions, volume disclosure, price ceilings, penalties, streamline of administrative procedures, and provision of information to potential participants. Design elements usually involve trade-offs between criteria. Overall, these results suggest that the choice of a specific design element is not a win–win decision and depends on the priorities of the respective government. EF

Will Technology Advances Alleviate Climate Change? Dual Effects of Technology Change on Aggregate Carbon Dioxide Emissions

Energy for Sustainable Development, Volume 41, December 2017, Pages: 61–68

Mingquan Li, Qi Wang

The relationship between technology change and carbon dioxide emissions is complex. Existing research has emphasized technology progress in reducing carbon emission intensity but has ignored the impact of technology progress on economic growth, which leads to changes in carbon dioxide emissions. The researchers argue that technology has relatively independent economic and environmental attributes. To provide evidence for this, they developed a method to distinguish the scale effect of technology change and its influence on economic scale from the intensity effect of technology change and its influence on carbon emission intensity. They applied this method to study the impact of technology change on carbon dioxide emissions in 95 countries between 1996 and 2007. The researchers found that technology change indeed reduced aggregate carbon dioxide emissions, but the scale and intensity effects of technology change separately expressed positive and negative values. As a consequence, previous studies that only consider the intensity effect overestimate the impact of technology change on carbon dioxide emissions. Their findings yield important considerations for carbon dioxide emissions control in policy making. EF

Achievable or Unbelievable? Expert Perceptions of the European Union Targets for Emissions, Renewables, and Efficiency

Energy Research & Social Science, Volume 34, December 2017, Pages: 144–153

Tahamina Khanam, Abul Rahman, Blas Mola-Yudego, Paavo Pelkonen, Yannick Perez, Jouni Pykäläinen

In 2007, the European Union (EU) set goals to reduce greenhouse gas (GHG) emissions, called H2020 targets, by 2020. Following the adoption and implementation of policies related to these targets, this study surveyed 187 experts from 25 EU countries to analyse their perceptions regarding the achievement of the H2020 targets. The experts' countries are grouped in five geographical regions: Central European countries (CEC), Western European countries (WEC), South-Eastern European countries (SEEC), Nordic countries (NC), and East European countries (EEC). The survey results demonstrate a broad scepticism among those interviewed: 49% perceive that the renewable energy (RE) target will not be accomplished, 60% perceive that the EU's GHG emission policies are not sufficient to fulfil the GHG reduction target, and 85% state that the EU's energy efficiency will not succeed. The regional comparison reveals that an overwhelming majority (82%–93%) from SEEC, NC, and EEC feel that consistent and sufficient incentives are necessary to meet the RE targets for biomass. Contrary to the majority opinion among WEC experts, the majority from all other regions perceive that the EU GHG policies are insufficient and that the H2020 targets will not be achieved. EF

The Carbon Footprint of Integrated Milk Production and Renewable Energy Systems—A Case Study

Science of the Total Environment, Volume 609, December 2017, Pages: 1286–1294

Elisabetta Vida, Doriana Eurosia Angela Tedesco

Dairy farms have been widely acknowledged as a source of greenhouse gas (GHG) emissions. The need for a more environmentally friendly milk production system will likely be important going forward. Whereas methane (CH_4) enteric emissions can only be reduced to a limited extent, CH_4 manure emissions can be reduced by implementing mitigation strategies, such as the use of an anaerobic digestion (AD). Furthermore, implementing a photovoltaic (PV) electricity

generation system could mitigate the fossil fuels used to cover the electrical needs of farms. In the present study, to detect the main environmental hotspots of milk production, a life cycle assessment was adopted to build the life cycle inventory according to ISO 14040 and 14044 in a conventional dairy farm (1,368 animals) provided by AD and PV systems. The Intergovernmental Panel on Climate Change tiered approach was adopted to associate the level of emission with each item in the life cycle inventory. The functional unit refers to 1 kg of fat-and-protein-corrected-milk (FPCM). In addition to milk products, other important co-products need to be considered: meat and renewable energy production from AD and PV systems. A physical allocation was applied to attribute GHG emissions among milk and meat products. Renewable energy production from AD and PV systems was considered, discounting carbon credits due to lower CH_4 manure emissions and to the minor exploitation of fossil energy. The CF of this farm scenario was 1.11 kg CO_2eq/kg FPCM. The inclusion of AD allowed for the reduction of GHG emissions from milk production by 0.26 kg CO_2eq/kg FPCM. The PV system contribution was negligible due to the small dimensions of the technology. The results obtained in this study confirm that integrating milk production with other co-products, originated from more efficient manure management, is a successful strategy to mitigate the environmental impact of dairy production. EF

Performance of Distributed Energy Systems in Buildings in Cooling Dominated Regions and the Impacts of Energy Policies

Applied Thermal Engineering, Volume 127, December 2017, Pages: 281–291

Jing Kanga, Shengwei Wang, Wenjie Gang

The distributed energy system (DES) is an energy-efficient and economical alternative to the centralized energy system (CES). However, quantitative performance assessment, the influential factors, and the impacts of energy policies in cooling dominated regions are still not well studied. This paper, therefore, presents an investigation on the building integrated DES in Hong Kong, a typical city with cooling demand year-around. Considering the characteristics of the energy demands, DESs, which integrate distributed generations, chillers, and the utility grid, are designed. The performance of DESs in buildings is tested on a simulation platform using dynamic models. The primary energy saving and the payback period are estimated. The impacts of major design parameters and energy policies on the DES performance are studied. Results show that DESs achieve energy saving only when integrated in large-scale buildings of certain functions. Moreover, the performance can be improved by optimizing the equipment capacities. The comparison between two different energy policies with respect to the grid interaction illustrates that DESs can achieve better performance when selling electricity is permitted. The gas price has very significant impacts on economic benefits of DESs and the current market gas price could allow cost-effective application in some circumstances. EF

Time-Based Category of Combined Cooling, Heating and Power (CCHP) Users and Energy Matching Regimes

Applied Thermal Engineering, Volume 127, December 2017, Pages: 266–274

Lejun Fenga, Xi Zhuo Jiang, Jing Chen, Yuezheng Ma, Lin Shi

Appropriate classification of combined cooling, heating, and power (CCHP) users will facilitate the design and analysis of CCHP systems. In this research, a time-based categorizing method was proposed to classify CCHP users. Six representative commercial CCHP users (hospitals, restaurants, hotels, gymnasiums, schools, office buildings) in Beijing were selected and categorized into three categories. Parameters regarding time and load characters were extracted for simplifying load variations of the three categories of CCHP users. To investigate the energy matching between CCHP systems and users, capacity design modes were proposed, and energy matching regimes were constructed based on capacity design mode diagrams. Energy matching regimes for CCHP users of three categories were also discussed. Results show that the three categories of CCHP users have distinguished energy matching performance in the energy matching regime diagrams. Boundaries of the ESR (energy saving rate) in energy matching regimes were also summarized. EF

SOLAR POWER
to Light Up Diwali

India is geared to celebrate Diwali on October 19, 2017. Every year, Diwali brings in its wake concerns about safety and pollution. Bursting of crackers and use of non-biodegradable and plastic decorations cause immense pollution while use of lights result in increased electricity bills and surge in power demand.

Use of energy-efficient LED lights has brought this down considerably. However, a better way to decorate homes is with the use of solar powered decorative lights. Solar-powered string lights work as well as conventional decorative lights while giving users savings on electricity bill and have the added benefit of reducing carbon-based energy consumption.

Like conventional decorative lights, solar lights too create a warm and inviting atmosphere; however, these can be used year-round to create the festive atmosphere without any worry about heavy electricity bills.

These lights can be charged during the day by attaching the solar panel to the convenient pole or stake outside. In the evening, one can simply turn on the lights with the press of a button. Similar to the rice lights available in markets, some of these lights can be set to mode to stay on steadily or to flash.

Here are some of the solar decorative lights available online and their features:

SolarOcta Solar LED String Light

- Charge by attaching the solar panel to the convenient garden stake and setting outside

- Great battery backup
- 100 LEDs Twinkle type, 8 function mode
- String light length: 10 m
- Waterproof to IP65
- 18 Months warranty

Quace Solar Light

- Made with 120 individual LEDs and Waterproof Copper Wire
- Safe to Use—The Quace Solar Outdoor Lights is guaranteed with CE and RoHS certification
- Low power (150 mA, 2 V) and heat insulated copper wire

- 6–8 hours of solar power charging can last for 10 hours
- Wire Length: 12 m

Samyo 200 LED Solar Fairy

- 200 multicolour LEDs
- Mode: flashing or steady
- Solar panel has built-in NI-MH battery.

- Provide up to about 8 hours of continuous lighting at night
- Safe and waterproof

MaiTian Garden Solar Multicolor Butterfly LED String

- Changing colour fibre optic 12 butterfly shaped LEDs
- Mode: flashing or steady
- Solar Panel: 2 V 100 mA
- Charging time: 8 hours
- Working time: 6–8 hours
- Length of String: 3.75 m
- Totally waterproof, suitable for outdoor and indoor use

INST Solar Powered Led String Light

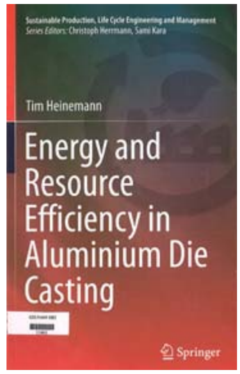
- Switches on automatically at dark.
- Light Indicator on solar panel turns shows when it needs to be charged
- 65 Ft or 20 m long; 200 LED lights
- Suitable for indoor and outdoor decoration
- Waterproof.
- Steady and flash mode.

Happy and Green Diwali!

Source: www.amazon.in

Energy and Resource Efficiency in Aluminium Die Casting (Sustainable Production, Life Cycle Engineering and Management)

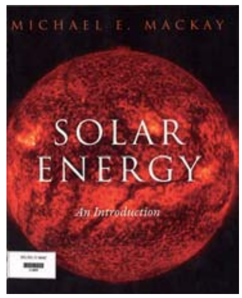
This monograph provides a field-proven approach to analyse industrial production with a cross-company scope as well as regarding all hierarchical system levels of manufacturing enterprises. The book exemplifies this approach in the context of aluminium die casting and presents a set of measures that allow a 30% energy reduction along the value chain. The target audience primarily comprises researchers and experts in the field but the book may also be beneficial for graduate students. EF



Author: Tim Heinemann
Publisher: Springer Nature; 1st Edition.
Year: 2016

Solar Energy: An Introduction

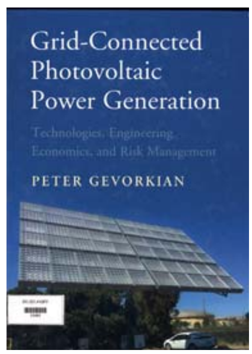
Solar Energy presents an introduction to all aspects of solar energy, from photovoltaic devices to active and passive solar thermal energy conversion, giving both a detailed and broad perspective of the field. It is aimed at the beginner involved in solar energy or a related field or for someone wanting to gain a broader perspective of solar energy technologies. A chapter considering solar radiation, basic principles applied to solar energy, semiconductor physics, and light absorption brings the reader on equal footing with the technology of either solar-generated electrical current or useful heat. Details of how a solar cell works and then production of current from a photovoltaic device is discussed. Characterization of a solar cell is examined, allowing one the ability to interpret the current–voltage relation, followed by discussion of parameter extraction from this relation. This information can be used to understand what limits the performance of a given solar cell with the potential to optimize its performance. Applications of solar thermal energy are reviewed in detail from passive applications, for example, the solar chimney, to active, such as the solar (power) tower, flat plate water heater, and solar thermal electricity generation. Consistency of analysis between the solar thermal applications is used enabling the reader to fully appreciate similarities and dissimilarities between these technologies. Ultimately, the scientist or engineer can understand existing systems, either photovoltaic or solar thermal devices, and design their own technology given the information in this book. EF



Author: Michael E. Mackay
Publisher: OUP Oxford

Grid-Connected Photovoltaic Power Generation: Technologies, Engineering Economics, and Risk Management

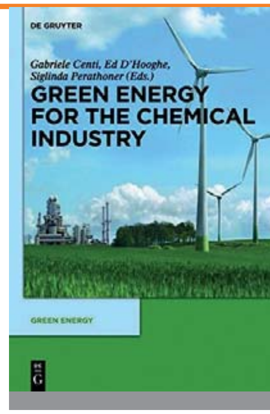
Covering technical design and construction aspects as well as financial analysis and risk assessment, this professional reference work provides a comprehensive overview of solar power technology. Whether or not you have a technology background, this essential guide will help you to understand the design, construction, financial analysis, and risk assessment of solar power technology. The first two chapters present an uncomplicated overview of solar power technology physics, solar cell technology, applications, and equipment. In subsequent chapters, readers are introduced to fundamental econometric analysis in such a way that will allow anyone, whether or not they have a background in finance, to become familiar with the fundamental costing and financing of large-scale solar power programmes. This book is essential reading for anyone involved with solar power project development and is suitable for both graduate students and professionals. EF



Author: Peter Gevorkian
Publisher: Cambridge University Press; 1st Edition. Year: 2017

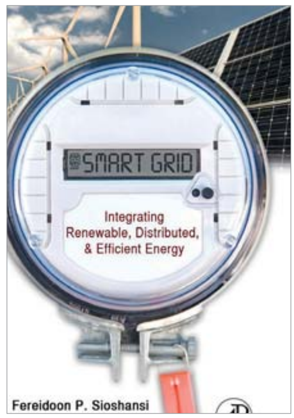
Green Energy for the Chemical Industry

The book is about the concept of how to introduce renewable energy into the chemical production chain and how to revise the chemical production from this perspective—a direction along which the chemical industry and Europe (resource efficiency, low carbon economy) is moving. This topic will be discussed with the direct participation (and contribution to the book) of top managers of the chemical companies. EF



Editors: Centi G, Perathoner S, Ed d'Hooghe E
Publisher: De Gruyter; Kindle Edition. Year: 2019

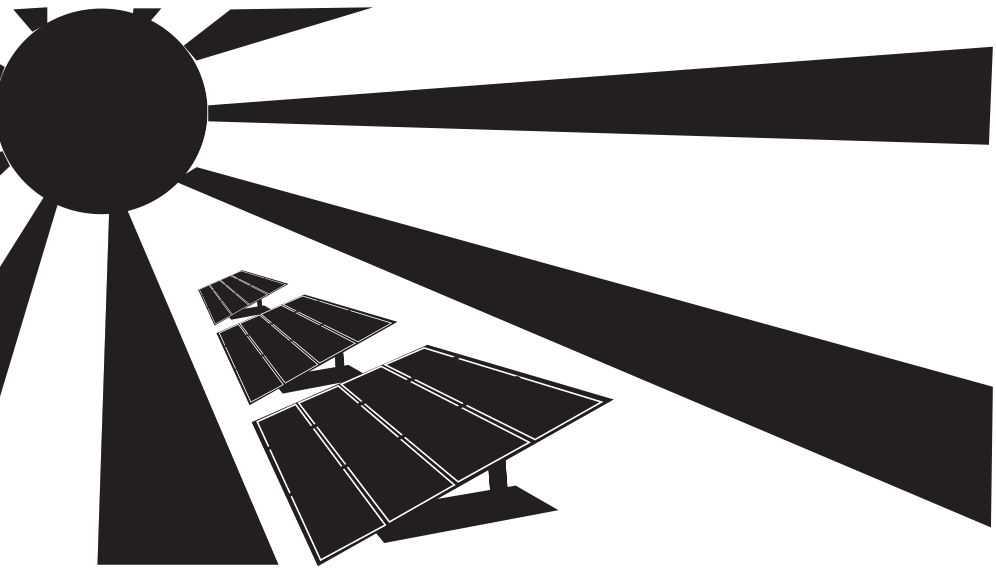
Smart Grid: Integrating Renewable, Distributed and Efficient Energy



Editor: Fereidoon P Sioshansi
Publisher: Academic Press. Year: 2018

The creation of a flexible, efficient, digitized, dependable, and resilient power grid may well be the best route to increasing energy efficiency and security, as well as boosting the potential of renewable and distributed power sources. This book covers smart grids from A–Z, providing a complete treatment of the topic, covering both policy and technology, explaining the most recent innovations supporting its development, and clarifying how the smart grid can support the integration of renewable energy resources. Among the most important topics included are smart metering, renewable energy storage, plug-in hybrids, flexible demand response, strategies for offsetting intermittency issues, micro-grids for off-grid communities, and specific in-depth coverage of wind and solar power integration. The content draws lessons from an international panel of contributors, whose diverse experiences implementing smart grids will help to provide templates for success.

- Provides critical information on the technological, design, and policy issues that must be taken into account to ensure that the smart grid is implemented successfully
- Demonstrates how smart grids can help utilities adhere to increased renewable portfolio standards
- Provides examples of successful microgrid/smart metering projects from around the world that can act as templates for developers, operators, and investors embarking upon similar projects. EF



RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

A solar cell you can put in the wash

A team of scientists has developed a new type of ultra-thin photovoltaic device, coated on both sides with stretchable and waterproof films that can continue to provide electricity from sunlight even after being soaked in water or being stretched and compressed. This work could open the way to wearable solar cells, which will provide power to devices, such as health monitors incorporated into clothing. One of the requirements of the Internet of Things—referring to a world where devices of all sorts are connected to the Internet—is development of power sources for a host of devices, including devices that can be worn on the body. According to one of the researchers, these could include sensors that record heartbeats and body temperature, for example, providing early warning of medical problems. In the past, attempts have been made to create photovoltaics that could be incorporated into textiles, but typically they lacked at least one of the important properties—long-term stability in both air and water, energy efficiency, and robustness, including resistance to deformation—that are key to successful devices.

» For the present work, the members of the research group developed extremely thin and flexible organic photovoltaic cells, based on a material called PNTz4T, which they had developed during an earlier work.
» They deposited the device in an inverse architecture, which they had previously developed, onto a 1-um-thick parylene film. The ultra-thin device was then placed onto acrylic-based elastomer and the top side of the device was coated with an identical elastomer, giving it a coating on both sides to prevent water infiltration.
» The elastomer, while allowing light to enter, prevented water and air from leaking into the cells, making them more long-lasting than previous experiments.
» The researchers then subjected the device to a variety of tests, finding first that it had a strong energy efficiency of 7.9%, producing a current of 7.86 mW/sq. cm, and the current density was 13.8 mA/sq. cm at 0.57 V, based on a simulated sunlight of 100 mW/sq. cm.
» To test its resistance to water, they soaked it in water for two hours and found that the efficiency decreased by just 5.4%. And to test the durability, they subjected it to compression and found that after compressing by nearly half for 20 cycles while placing drops of water on it, it still had 80% of the original efficiency.

According to a researcher involved in the process, the device has great environmental stability while simultaneously having a good efficiency and mechanical robustness.

https://www.sciencedaily.com/releases/2017/09/170918111843.htm

Solar-to-fuel system recycles CO_2 to make ethanol and ethylene

Scientists at the Department of Energy's (DOE's) Lawrence Berkeley National Laboratory (Berkeley Lab) have harnessed the power of photosynthesis to convert carbon dioxide into fuels and alcohols at efficiencies far greater than plants. The achievement marks a significant milestone in the effort to move towards sustainable sources of fuel.

Many systems have successfully reduced carbon dioxide to chemical and fuel precursors, such as carbon monoxide or a mix of carbon monoxide and hydrogen known as syngas. This new work is the first to successfully demonstrate the approach of going from carbon dioxide directly to target products, namely ethanol and ethylene, at energy conversion efficiencies rivalling natural counterparts.

The researchers did this by optimizing each component of a photovoltaic–electrochemical system to reduce voltage loss and creating new materials when existing ones did not suffice.

The sun-to-fuel path is among the key goals of the Joint Center for Artificial Photosynthesis (JCAP), a DOE energy innovation hub established in 2010 to advance solar fuel research. The initial focus of JCAP research was tackling the efficient splitting of water in the photosynthesis process. Having largely achieved that task using several types of devices, JCAP scientists began solar-driven carbon dioxide reduction, setting their sights on achieving efficiencies similar to those demonstrated for water splitting, considered by many to be the next big challenge in artificial photosynthesis.

Another research group at Berkeley Lab is tackling this challenge by focussing on a specific component in a photovoltaic–electrochemical system. In a study published recently, they described a new catalyst that can achieve carbon dioxide to multi-carbon conversion using record-low inputs of energy.

» For this JCAP study, researchers engineered a complete system to work at different times of day, not just at a light energy level of 1-sun illumination, which is equivalent to the peak of brightness at high noon on a sunny day. They varied the brightness of the light source to show that the system remained efficient even in low light conditions.
» When the researchers coupled the electrodes to silicon photovoltaic cells, they achieved solar conversion efficiencies of 3% to 4% for 0.35 to 1-sun illumination. Changing the configuration to a high-performance, tandem solar cell connected in tandem yielded conversion efficiency to hydrocarbons and oxygenates exceeding 55 at 1-sun illumination.

Among the new components developed by the researchers are a copper–silver nano-coral cathode, which reduces the carbon dioxide to hydrocarbons and oxygenates, and an iridium oxide nanotube anode, which oxidizes the water and creates oxygen.

The researchers characterized the materials at the National Center for Electron Microscopy at the Molecular Foundry. The results helped them understand how the metals functioned in the bimetallic cathode. Specifically, they learned that silver aids in reduction of carbon dioxide to carbon monoxide, while the copper picks up from there to reduce carbon monoxide further to hydrocarbons and alcohols.

https://www.sciencedaily.com/releases/2017/09/170918151713.htm

Non-toxic alternative for next-generation solar cells

Researchers have demonstrated how a non-toxic alternative to lead could form the basis of next-generation solar cells. The team of researchers has used theoretical and experimental methods to show how bismuth, also known as 'green element', which sits next to lead on the periodic table, could be used in low-cost solar cells. Their results suggest that solar cells incorporating bismuth can replicate the properties that enable the exceptional properties of lead-based solar cells but without the same toxicity concerns. Later tests by another research group showed that bismuth-based cells can convert light into energy at efficiencies up to 22%, which is comparable to the most advanced solar cells currently on the market.

Over the past several years, researchers have been looking for materials that can perform at similar or better levels to silicon, but that don't need such high purity levels, making them cheaper to produce. The most promising group of these new materials is called hybrid lead halide perovskites, which appear to promise a revolution in the field of solar energy. As well as being cheap and easy to produce, perovskite solar cells have, in the space of a few years, become almost as energy-efficient as silicon. However, despite their enormous potential, perovskite solar cells are also somewhat controversial within the scientific community, since lead is integral to their chemical structure. Whether the lead contained within perovskite solar cells represents a tangible risk to humans, animals, and the environment is being debated; however, some scientists are now searching for non-toxic materials that could replace the lead in perovskite solar cells without negatively affecting performance.

For this study, researchers looked at bismuth oxyiodide, a material that was previously investigated for use in solar cells and water splitting, but was not thought to be suitable because of low efficiencies and because it degraded in liquid electrolytes. The researchers used theoretical and experimental methods to revisit this material for possible use in solid-state solar cells.

» They found that bismuth oxyiodide is as tolerant to defects as lead halide perovskites. Bismuth oxyiodide is also stable in air for at least 197 days, which is a significant improvement over some lead halide perovskite compounds.
» By sandwiching the bismuth oxyiodide light absorber between two oxide electrodes, they were able to demonstrate a record performance, with the device converting 80% of light to electrical charge.

The bismuth-based devices can be made using common industrial techniques, suggesting that they can be produced at a large scale and at low cost. EF

https://www.sciencedaily.com/releases/2017/07/170718113713.htm

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NATIONAL AND INTERNATIONAL EVENTS

NATIONAL	INTERNATIONAL
EVREX **E-Vehicle Conference and Exhibition** **November 15 & 16, 2017** Hyderabad Website: http://www.evrexindia.com/	**Green Energy & Expo** **November 6–8, 2017** Las Vegas, Nevada, USA Website: https://greenenergy.conferenceseries.com/
3rd Envirotech Asia 2017 **November 22–24, 2017** Mumbai Website: http://www.envirotechasia.com/	**Wind Energy Conference** **November 7–9, 2017** Rostock, Germany Website: https://10times.com/windenergietage
InterSolar India **December 5–7, 2017** Mumbai Website: www.intersolar.in	**Energy Storage Summit Japan** **November 7–9, 2017** Tokyo, Japan Website: https://essj.messe-dus.co.jp/en/energy-storage-summit-japan-2017/energy-storage-summit-japan-2017/
India Energy Summit **December 6–8, 2017** New Delhi Website: https://10times.com/india-energy-summit	Australia Solar + Energy Storage Congress & Expo **December 5 & 6, 2017** Brisbane, Australia Website: http://www.australiaenergystorage.com/
International Seminar on Sustainable Development Goals **January 6 & 7, 2018** New Delhi Website: https://www.expohour.com/international-seminar-on-sustainable-development-goals	**Energy from Waste** **December 6 & 7, 2017** London, UK Website: https://www.smi-online.co.uk/energy/uk/conference/energy-from-waste
India Rooftop Solar Congress 2018 **January 17–18, 2017** New Delhi Website: http://www.solarquarter.com/indiarooftopsolarcongress/	**International Conference on Advanced Energy Materials (ICAEM) 2018** **January 20–22, 2018** Fukuoka, Japan Website: http://www.icaem.org/

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/ Scheme wise Physical Progress in 2017/18 & cumulative up to the month of August, 2017			
Sector	**FY-2017/18**		**Cumulative Achievements (as on 31.08.2017)**
	Target	**Achievement (April–August, 2017)**	
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	4000.00	354.13	32633.89
Solar Power—Ground Mounted	9000.00	1551.39	13184.22
Solar Power—Roof Top	1000.00	106.00	762.00
Small Hydro Power	200.00	9.70	4389.55
BioPower (Biomass & Gasification and Bagasse Cogeneration)#	340.00	0.00	8181.70
Waste to Power	10.00	0.00	114.08
Total	**14550.00**	**2021.22**	**59265.44**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWEQ)			
Waste to Energy	15.00	2.20	173.29
Biomass(non-bagasse) Cogeneration	60.00	9.50	661.41
Biomass Gasifiers	7.50	1.00	162.45
Aero-Genrators/Hybrid systems	.50	0.03	3.18
SPV Systems	100.00	58.43	520.97
Total	**183.00**	**71.16**	**1521.30**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (in Lakhs)	1.10	0.00	49.56*
Water Mills/Micro Hydel (Nos.)	150/25	0.00	2690/72

Progress of Biomass has been revised to installed capacity from exportable power

* Cumulative achievement as on February 2017

Source: www.mnre.gov.in

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