transportation. Since the conversion for biogas use is the same as for natural gas use, upgraded biogas can be easily substituted in the existing natural gas vehicles and infrastructure available in the country. Upgraded biogas takes the advantage of the pre-existing natural gas network infrastructure. For other conventional fuel driven vehicles, licensed natural gas conversion companies can provide conversion services with certified conversion kits. The original equipment manufacturers (OEMs) are also responding to the growing market for CNG in the country by adapting and indigenizing the technology into varied vehicle segments, such as buses, three-wheelers, taxis, light commercial vehicles, and passenger cars. As on 31st March 2017, there was over 17,753 km of natural gas pipeline with approximately 1500 CNG pumping stations serving about 32 lakh gas-based vehicles, and it is increasing rapidly in tandem with burgeoning demand and growing supplies. Growing awareness among consumers has created opportunities to connect this existing infrastructure and customer base to CBG supply.

Adaptability of CBG in Natural Gas Infrastructure and Network in India

By 2022, India aims to increase the share of natural gas to 15% of its primary energy consumption, which is at present 6–7%. The availability of domestic natural gas, import of natural gas at competitive prices, development of adequate LNG infrastructure, and expansion of the natural gas pipeline network will be critical to achieve this goal. India currently has around 18,000 km of natural gas pipeline.

There are six major regional natural gas markets in India. These are northern, western, central, southern, eastern, and northeastern. The western and northern gas markets have the highest consumption owing to better pipeline connectivity. The northern and western regions have most of the gas pipelines and much development is needed in southern, eastern and central regions. The implementation of the natural gas vehicle programme in a large number of Indian cities has led to the rapid increase in the consumption of natural gas in the past two decades. As per the Ministry of Petroleum, Government of India, India has an estimated current demand for natural gas of around 58.2 billion m^3/year, which could reach 113 billion m^3/year by 2030 depending on how the gas market evolves. NGV (natural gas vehicle) programmes have been in place for over 20 years to control pollution resulting from automobiles run on diesel

Utilization of upgraded and bottled biogas as a vehicular fuel

Utilization of upgraded and bottled biogas as a cooking fuel and petrol in India's major cities. 2.8 million CNG vehicles are on the road, and they constitute the bulk of NGV in use. As of December 2017, there were 1273 CNG stations in the country, with many of these concentrated in Delhi (36%), Gujarat (32%), and Maharashtra (20%). CNG stations can be set up outside urban areas, for example, along freight corridors for heavy commercial vehicles. However, they are more difficult to maintain compared to the traditional filling stations and therefore not currently considered as a viable option. CBG can be supplied to areas without pipelines in bottles. Bottled biogas can be easily dispensed through the existing natural gas infrastructure in the country. Hence, biogas bottling systems would stimulate the natural gas demand for the local and remote transport in India.

Success Stories of Biogas Upgradation and Bottling in India

Under the technology demonstration of the new RDD&D policy of MNRE during 2008-09, the Ministry took up a new initiative for bottling of biogas to demonstrate an integrated technology package in entrepreneurial mode on medium size mixed feed biogas fertilizer plants (BGFP) for generation, purification, bottling, and piped distribution of biogas. Under the demonstration phase, the Ministry has sanctioned a central financial assistance (CFA) up to 50% of the cost (excluding the cost of land) for a limited number of such projects for implementation following an entrepreneurial mode on reimbursement basis. Until 2016, under the demonstration phase, around 14 biogas production and upgrading plants with the cumulative capacity of 23,116 m^3/day were installed in eight states, namely, Haryana, Punjab, Gujarat, Chhattisgarh, Karnataka, Bihar, Rajasthan, and Maharashtra. MNRE has also sanctioned projects on energy from urban, industrial, and agriculture wastes/residues for 2017-18, 2018-19, and 2019-20. Approval is accorded for the biogas, CBG/enriched biogas, power, and biomass gasifier components under the waste to energy programme at a total central financial assistance of ₹78.0 crore with physical target of 57.0 MW$_{eq}$. The details of the biogas bottling projects under BGFP and waste to energy scheme are given in Table 1.

Table 1 Technology demonstration projects on biogas generation, purification, and bottling (BGFP) under RDD&D policy and waste to energy scheme of MNRE

BGFP plants		
S. No.	**Name of the project/organization**	**Capacity of the plant (m^3/day)**
1	Ashoka Biogreen Pvt. Ltd., Vill. Talwade, Tehsil Trimbak, Dist. Nasik (Maharashtra)	500
2	Anand Energy, Vill. Kalatibba, Tehsil Abohar, Dist. Ferozepur (Punjab)	600
3	SASK Energy, Vill. Najabt Kukrian, P.O. Lubaniawali, Tehsil and Dist. Muktsar (Punjab)	1000
4	Shashi Energies, Near Green Valley Public School, Ratiya Road Tohana, Tehsil. Tohana, Dist. Fatehabad (Haryana)	600
5	Option Energy Pvt. Ltd, Shree Haryana Gaushala, Village and Block Hansi, Dist. Hissar (Haryana)	1000
6	Singla Bio-Energy, Vill Siaghawali, Tehsil Sadulsehar, Dist. Sri Ganganagar (Rajasthan)	1000
7	21st Century Enviro Engineers (P) Ltd., Vill. Begu, Block Sirsa, Dist. Sirsa (Haryana)	4216
8	Brahma Enterprises, Vill. Marripallyguda, Gram Panchayat Edulabad, Taluka Ghatkesar, Dist. Rangareddy (Andhra Pradesh)	1000
9	Enhanced Energy Inc. Survey No. 647, Vill. Dhantej, Tehsil Savli, Dist. Vadodara (Gujarat)	1000
10	Maltose Agri Products Pvt. Ltd., Vill. Huskur, Post Aralumallige, Taluka Doddaballapur, Dist. Bangalore rural (Karnataka)	1000
11	R.G. Organics, Plot No. 25-27, Industrial Area Birkoni, Mahasamund (Chhattisgarh)	1000
12	Ashoka Biogreen Pvt. Ltd. Vill. Memdi, Tal. Mhow, Dist. Indore (M.P.)	4500
13	Amit & Sumit Dairy Farm, Vill. Jahajgarh, Tehsil Beri, Dist. Jhajjar-124201 (Haryana)	700
14	Sanjh Deep Gas Energy, Vill./P.O. Mehma Sarja, Tehsil Bhatinda, Dist. Bhatinda (Punjab)	5000
Waste to Energy Scheme		
S. No.	**Name of state/union territories**	**CBG (kg/day) and the number of plants**
1	Gujarat	12,538 (2)
2	Haryana	2,050 (2)
3	Madhya Pradesh	1,200 (1)
4	Maharashtra	19,533 (3)
5	Punjab	1,847 (1)
6	Rajasthan	4,000 (2)
7	Uttarakhand	5,460 (1)

Government Initiatives

The Ministry of Drinking Water and Sanitation launched GOBAR (Galvanizing Organic Bio-Agro Resources)-DHAN scheme at National Dairy Research Institute (NDRI) Karnal. It was launched under Swachh Bharat Mission (Gramin) by Union Minister for Drinking Water and Sanitation Uma Bharti. The Scheme aims to positively impact village cleanliness and generate wealth and energy from cattle and organic waste. It also aims at creating new rural livelihood opportunities and enhancing income for farmers and other rural people. The scheme focuses on managing and converting cattle dung and solid waste in farms to useful compost, biogas and bio-CNG, thus keeping villages clean, increasing income of rural households, and generating energy from cattle waste. The scheme envisages implementation of 700 biogas units in different states of the country in 2018-19.

The government launched the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme in October 2018, which will benefit vehicle users as well as farmers and entrepreneurs. CBG plants are proposed to be set up mainly through independent entrepreneurs. The CBG produced at these plants will be transported in cylinders to the fuel station networks of oil marketing companies (OMCs) to be marketed as the green transport fuel. Entrepreneurs will be able to separately market other by-products from these plants, including bio-manure and carbon dioxide, to enhance returns on investment. The government plans to roll out 5000 CBG plants across India in a phased manner. At the state level, Haryana and Punjab are expected to see investor interest in bio-CNG plants that run on paddy and wheat straw, thanks to the announcement of incentives by the Central Government on 1 October 2018 for utilizing these agricultural residues instead of burning them. Of late, the burning of paddy straw has become a major environmental concern.

Future Scope

Biomethane is a promising renewable energy option for substitute of natural gas for grid and vehicular applications. It can be easily compressed to increase its utility as compressed natural gas and can directly be fed to transportation vehicles. Despite the feedstock potential, easy adoption feasibility, and the various benefits of using bottled biogas as a transport fuel in India, the development of this industry is quite slow. For increased and widespread promotion of this technology, cost-economics of upgradation plants needs to be improved with substantial subsides, policies, and governmental support. With increased awareness, technical knowledge and support, this technology can be applied worldwide for waste management, energy security, and climate change mitigation. EF

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Horizons of Energy Storage

Chemistry Nobel Prize 2019

The ability of lithium-ion batteries (LIBs) to store electricity generated by solar and wind technologies and their sufficiently high charge density allow them to power entire vehicles, thus providing pathways to reduce our carbon footprint. By storing energy when the sun does not shine and the wind does not blow and by providing emission-free options for personal mobility, the batteries are powering technologies that can help in the fight against climate change. In this article, **Vinita Ahuja** takes a deeper dive into this revolutionary technology and talks about current research advances.

The technology that revolutionized consumer electronics and has been a cornerstone in the push to move towards renewable energy and fossil fuel free technologies made its Kodak moment when three legendary scientists were honoured with the prestigious Nobel Prize. Their work led to the development of the powerful, lightweight, and rechargeable lithium-ion batteries that have totally revolutionized the whole world we live in. The work by John Goodenough (97), Stanley Whittingham (77), and Akira Yoshino (71) led to the foundation of the rechargeable, lightweight, dry, and safe batteries that power our appliances, mobiles, and consumer electronics.

Electric Energy Storage Before LIBs

The concept of batteries has existed for a long time and may date as far back as to the period in which the Baghdad battery was used. However, its application became marked when voltaic pile and Leclanche cells came into existence in 1800 and 1864, respectively. This marked the birth of battery technology with great impetus and led to the explosion of lead batteries, Ni-Cd, and Ni-MH till the last decade of the 20th century when lithium took over the world owing to its lighter weight and smaller size that further contributed to its high energy density. The widest diversity of electric energy storage (EES) technologies is to be found in electrochemical systems, which include lead-acid, lithium-ion, nickel-cadmium, nickel metal hydride, sodium-sulphur, vanadium redox, zinc-bromine, nickel hydrogen, nickel-zinc, molten salt, and metal-air batteries. Another categorization involves solid state batteries and flow batteries, such as vanadium redox and zinc-bromine. Flow batteries are akin to fuel cells. At a commercial level, currently the most relevant rechargeable batteries are lead-acid, Li-ion, nickel metal hydride (NiMH), and nickel-cadmium (NiCd) (Figure 1). Although lead acid batteries had major share in EES technologies, the drawbacks such as safety concerns, use of lead metal, and their limited temperature range of operation were apparent. High reliability, satisfactory specific energy and power, and moderate initial cost of NiCd and NiMH batteries were really attractive and overcome the drawbacks of lead acid batteries. However, relatively short cycle life and high discharge rate were still a matter of concern for NiMH and NiCd batteries in EES technologies. Growing need of portable devices and increasing rate of consumer electronics moved the EES towards the LIB era. LIBs were known for their outstanding specific energy and power, long calendar and cycle lives, high round trip efficiency, high reliability, and technological diversity; several chemistries, intensive global R&D efforts, and chemistries with eco-friendly materials were available. Figures 1 and 2 show the timeline and brief summary of other EES technologies till now.

Working Principle of LIB

A battery is an energy storage device made of several electrochemical cells connected in series or parallel to increase the output voltage and current. The electrochemical cell consists of two electrodes, anode and cathode, that are separated by the electrolyte. In case of the primary battery, electrochemical reactions take place at the anode and the cathode (oxidation and reduction, respectively), where the electrolyte allows the passage of ions. If the corresponding electrochemical reactions could be reversed by the application of external power, battery can be classified as the secondary or rechargeable battery. The total charge stored or the capacity Q (Ah/g or Ah/L), energy density (Wh/kg or Wh/L), and coulombic efficiency (CE in %) of the battery are given in Eqs (1), (2), and (3), respectively, where I, V and t are discharge/charge current, voltage, and time, respectively.

$$Q = \int_0^{\Delta t} I dt \quad (1)$$

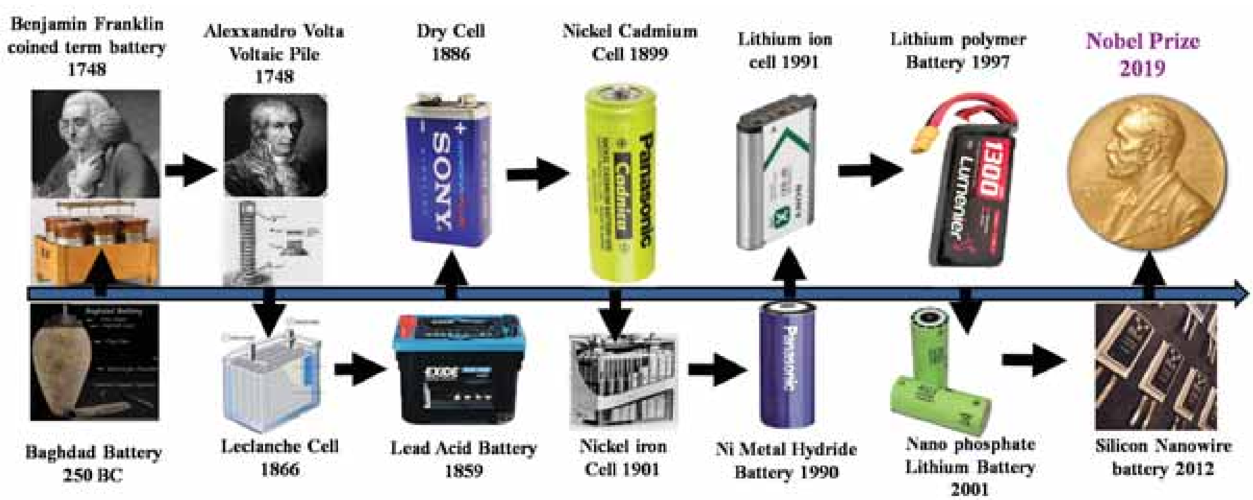


Figure 1 Brief timeline of battery technologies

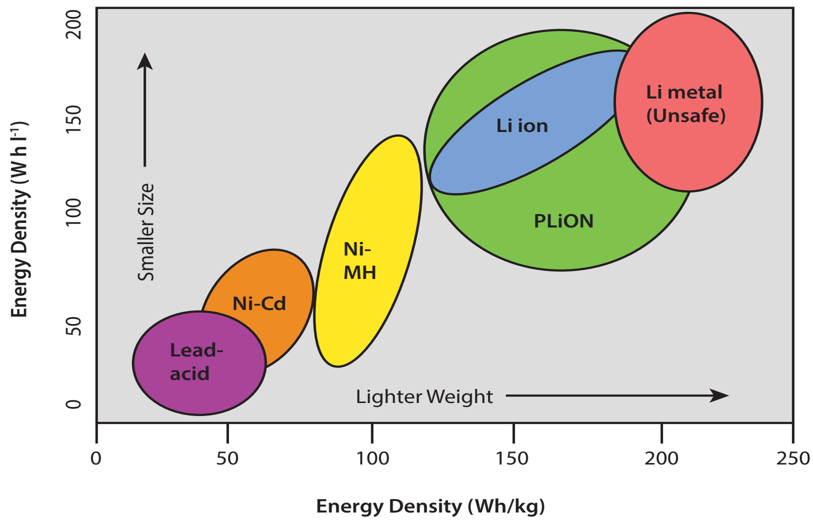


Figure 2 Comparison between different battery technologies in terms of volumetric and gravimetric energy densities

$$\text{Energy density} = \int_0^{\Delta t} IV(t)dt \qquad (2)$$

$$\text{CE} = 100 \times (Q_{disch}/Q_{ch}) \qquad (3)$$

Hence, the energy density of the battery could be varied by carefully tuning the voltage and the capacity of individual cells. These two parameters are strongly related to the thermodynamics of electrode and electrolyte materials. Figure 3 shows the open circuit energy diagram of the electrode and electrolyte in terms of relative electron energies. The anode is the electron source (reductant), the cathode is the electron sink (oxidant), and the energy gap, E_g, between the lowest unoccupied molecular orbital (LUMO) and the highest occupied molecular orbital (HOMO) is the electrolyte window. The open circuit voltage (V_{oc}) of the cell is determined by

$$V_{oc} = \mu_A - \mu_C/e \qquad (4)$$

In Eq. (4), μ_A and μ_C are the electrochemical potentials of anode and cathode, respectively, and e is the magnitude of the electron charge. If μ_A and μ_C lie above and below LUMO and HOMO, reduction and oxidation of electrolyte occur at anode and cathode, respectively. When a passivation barrier is created at the electrode–electrolyte interphase, the exchange of electrons between anode/cathode and electrolyte is prevented, thus suppressing the parasitic reactions and increasing the cell voltage. The total charges stored or the capacity of electrode materials is governed by the number of electrons exchanged in the corresponding electrochemical reaction (Δe) and the molar mass of the electrode materials (M).

$$\text{Capacity} = (26.8 \times \Delta x)/M \qquad (5)$$

Lithium-Ion Batteries

Coming back to the story of the lithium-ion battery, lithium is believed to have been produced in significant quantities in the immediate aftermath of the Bing Bang. It was introduced to mankind by Johan Arfwedson in 1817 during his analysis of petalite in the laboratory of the chemist Jöns Jakob Berzelius. Berzelius named the new element after *lithos*, the Greek word for stone. This light element which fires up our mobile phones and laptops acted as the negative electrode in Stanley Whittingham's battery during the early 1970s after the series of evolution.

The first commercial Li-ion battery (Figure 4), released by Sony Corporation in 1991, was based on a $LiCoO_2$ cathode and a carbon anode. Lithium ions move out of the cathode ($Li_{1-x}CoO_2$) and become trapped inside the anode storage medium, which is usually graphitized carbon (Li_xC_6), when an electrical current is applied to charge the cell. Upon battery discharge, lithium ions travel back to the cathode and produce an external electrical current. During the cell operation at 3.0–4.2 V, the surface reactivity and instability of the delithiated $Li_{1-x}CoO_2$ structure limit the practical capacity of $LiCoO_2$ electrodes to approximately 140 mAh/g, which corresponds to $x \approx 0.5$ (i.e., ~50% of its theoretical value (273 mAh/g)). These limitations, as well as the high possibility of thermal runaway caused by cell overcharge and short circuit

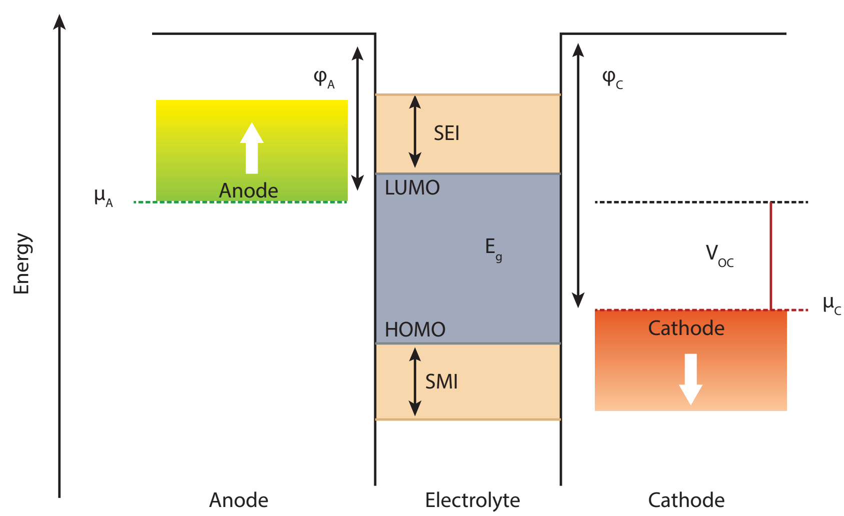


Figure 3 Open circuit energy diagram

Source: Goodenough, J. B. and Y. Kim. 2010. Challenges for rechargeable Li batteries. Chem. Mater. 22: 587–603

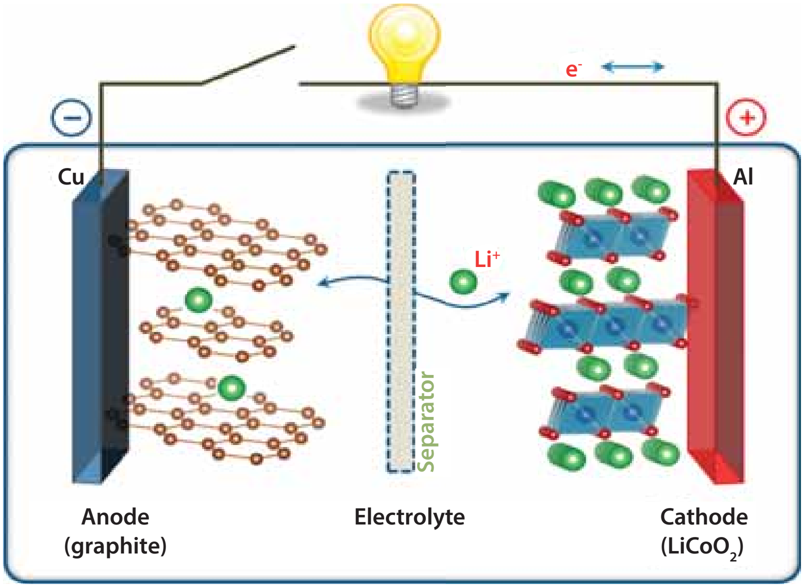


Figure 4 Schematic illustration of first LIB battery ($LiCoO_2$ and C battery)

Source: Goodenough, J. B. and K.S. Park. 2013. The Li-ion rechargable battery: a perspective. J.Am. Chem. Soc. 135: 1167–1176

in inadequately controlled batteries and the relatively high cost of cobalt, have led to enormous efforts to find alternative cathode materials to $LiCoO_2$ that provide Li-ion cells with superior energy density, rate capability, safety, and cycle life.

Electrode materials

To obtain high-performance batteries, it is important to understand the ion/electron transport as well as reaction mechanisms in electrode materials. Depending on the in-depth understanding of the structure–property relationship and thermodynamic as well as kinetic analysis, these electrodes are classified according to their reaction mechanisms into three types: insertion, conversion, and alloying-type materials.

Insertion-type materials involve the insertion of lithium ions into interstitial sites of the electrode materials following the progression to capture electrons. Most insertion-type materials have robust crystalline skeletons that provide an energetically favourable pathway for Li transport, conferring these materials with long-term cycling stability and high rate capability. Figure 6 shows the wide range of crystal structures exhibiting fast alkali conduction. In general, the diffusion topology of Li-ion conductors can be distinguished in terms of the dimensionality, for example, 1D in olivine $LiMPO_4$ and tavorites, 2D in layered AMO_2 and graphite, and 3D in spinel, NASICON, garnet, regular and antiperovskites. In the past decades, intensive efforts have been made to develop various insertion-type materials. Insertion-type materials can be categorized into the following two groups based on the crystalline structure:

» Layered oxides (e.g., $LiCoO_2$, LiV_3O_8, V_2O_5, $LiNi_xCo_{1-x-y}Al_yO_2$ (NCA), $LiNi_xCo_{1-x-y}Mn_yO_2$, Li_2MnO_3, and $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$): The layered materials with the formula AMO_2 (where A is an alkali ion and M is a transition metal or a mixture of transition metals) are the current dominant form of cathodes for rechargeable alkali-ion batteries.

» Polyanionic compounds (e.g., PO_4^{3-}, SO_4^{2-}, SiO_4^{4-}, BO_3^{3-}, and fluoride-containing PO_4^{3-}): Since the discovery of $LiFePO_4$ olivine in 1997, polyanionic oxides have attracted much attention as potential cathodes due to their higher voltages via the inductive effect.

However, most of insertion-type materials suffer from low specific capacity owing to their insufficient interstitial sites. In addition, some high-capacity cathode materials (e.g., Li_2FeSiO_4, Li_2MnSiO_4, Li_2MnO_3, and $Li_{1.2}Ni_{0.13}Mn_{0.54}Co_{0.13}O_2$) also suffer from serious structural transformations during cycling, leading to large initial irreversible capacity and poor cycling stability. NCA offers a slightly higher practical capacity (160–180 mAh/g) compared to $LiCoO_2$. However, its thermal instability on delithiation owing to the presence of the high valence Ni compromises the safety of Li-ion cells. Spinel $LiMn_2O_4$ and olivine $LiFePO_4$ electrodes are more stable to lithium extraction compared to layered Co- and Ni-based electrodes (both structurally and thermally), but they have relatively low practical capacities in a lithium cell above 3 V, typically 100–150 mAh/g at moderate current rates.

Alloying-type materials refer to some metals or metalloid materials that can form alloy with lithium. These materials (e.g., Si, Sn, In, Bi, Zn, Te, and intermetallic compounds) can offer much larger specific capacity during the alloying process. However, the major drawback in host structures is the large volume expansion upon the ion insertion and extraction. The large volume variation of the alloying materials can easily lead to the thickening and destabilization of the

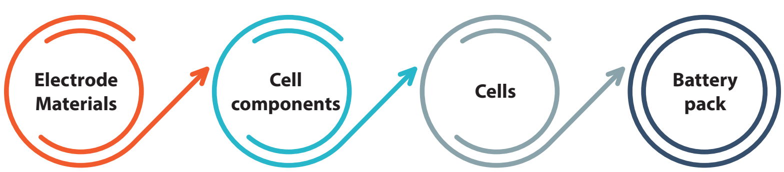


Figure 5 Production structure of LIBs

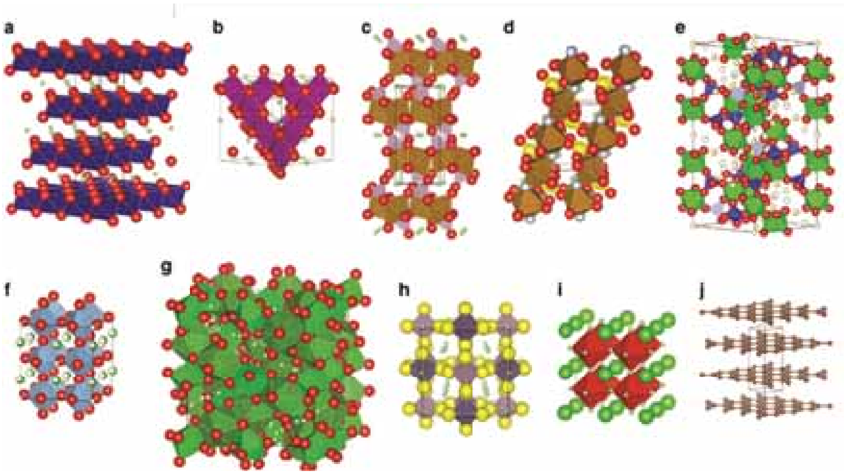


Figure 6 Electrode materials in LIBs. Crystal structure of (a) layered $LiCoO_2$, (b) spinel $LiMn_2O_4$, (c) olivine $LiFePO_4$, (d) tavorite $LiFeSO_4F$, (e) natrium superionic conductor (NASICON) $Na_3Zr_2Si_2PO_{12}$, (f) perovskite $Li_{3x}La_{2/3-x}TiO_3$, (g) garnet $Li_7La_3Zr_2O_{12}$, (h) thiophosphate $Li_{10}GeP_2S_{12}$, (i) antiperovskite Li_3OCl, and (j) graphite

Source: Deng, Z., Y. Mo, and S. P. Ong. 2016. Computational studies of solid-state alkali conduction in rechargeable alkali-ion batteries. NPG Asia Mater. 8: e254

SEI film, thus resulting in low columbic efficiency and rapid capacity decay.

Conversion-type materials use transition metal oxides as LIB anode materials and have been widely studied. A typical chemical equation of conversion-type materials for LI is

$M_aX_b + (b{\cdot}n)Li \leftrightarrow aM + bLi_nX$

Here, M denotes the transition metal elements (e.g., Fe, Co, Ni, and Cu), X denotes O, S, N, P, F, and H elements, and n is the valence number of X. An important characteristic of the conversion-type materials is the formation of at least two products. The reduction of M_aX_b into the metallic state is often a multi-electron reaction. It endows the conversion-type materials with a high capacity. However, the applications of conversion-type materials have been hindered owing to large volume change, low conductivity, and severe voltage hysteresis.

Electrolyte

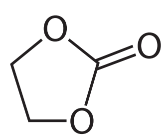
Systematic understanding of the electrode surface chemistry in LIBs is necessary. SEI (solid electrolyte interphase) is a lithium-ion conductor but an electronic insulator that mainly consists of polycrystalline materials. Stable SEI on electrodes has significant influence on the safety, power capability, shelf life, and cycle life of the battery. A key issue related to the operation of Li-ion batteries is the choice of electrolyte solutions. The electrolyte is a mixture of lithium salt and organic solvents.

Lithium hexafluorophosphate ($LiPF_6$), lithium perchlorate ($LiClO_4$), and lithium hexafluoroarsenate ($LiAsF_6$) are the common lithium salts. Organic solvent is vital for enhancing the mobility of lithium ions and so a key factor in the battery performance. Common organic solvents include ethyl methyl carbonate, dimethyl carbonate, diethyl carbonate, propylene carbonate, and ethylene carbonate (Figure 7).

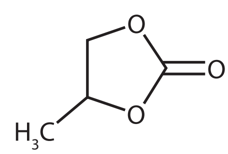
The separator is a safety component between cathode and anode. It prevents direct contact (i.e., short-circuiting), while being permeable to lithium ions. The most common separator materials are polyethylene and polypropylene. Li-ion battery cells are manufactured as cylindrical or stack cells. In the stack configuration, the cathode, anode, and separator are enclosed in laminate film. In the cylindrical configuration, layers are rolled and sealed in a metal can. Both configurations are used to produce different standard cell sizes. Some sizes are most common. For example, for the cylindrical cell, 18 mm diameter and 65 mm height size is common. Some specific applications, such as wearable electronics or smart uniforms, require mechanically flexible batteries, and in this case polymer Li-ion batteries are useful. These are stack cells with a polymer casing. When flexibility is required, several small cells are preferred over a single big cell.

Current Research in Lithium-Ion Battery

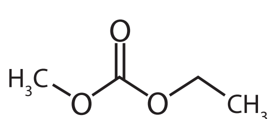
LIBs are the most suitable technology for the next-generation electric vehicles owing to their flexibility, higher energy and power densities, lower costs, relatively less pollution, and smaller



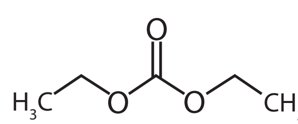
Ethylene carbonate



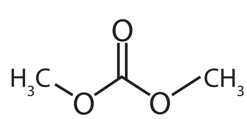
Propylene carbonate



Ethyl methyl carbonate



Diethyl carbonate



Dimethyl carbonate

Figure 7 Common organic solvents used in LIBs and lighter cell designs (Figure 8). The current state-of-the-art automotive Li-ion chemistries include $LiMn_2O_4$ (LMO), $LiFePO_4$ (LFP), $LiNi_{0.8}Co_{0.15}Al_{0.05}O_2$ (NCA), and layered $LiNi_{1-x-y}Mn_yCo_zO_2$ (NMC) as electrode materials in the successful realization of technology.

However, there are theoretical energy limitations of current Li-ion chemistries (lithium transition oxide cathodes and graphite anodes: 350 Wh/kg at the cell level) for automotive industries. The world is moving towards new high energy and high-capacity battery materials, such as Ni-rich NMC cathode materials, silicon-based anode materials, and innovative battery chemistries, including all-solid-state batteries (SSBs), as a potential alternative for EV (electric vehicles) applications and grid storage. Tesla is building new battery factories marketed as 'Gigafactory' in Nevada, USA to increase production yield of battery packs. Upon the completion of the Gigafactory, the projected capacity would be 150 GWh/year of battery packs (the associated production volume of 1.5 million units of electric cars per year). Tesla expects that the production costs of battery packs for EVs will reduce by 30% (Table 1).

Table 1 Commercial electric vehicles and their key characteristics

Manufacturer and model	Battery size (kWh)	Battery chemistry	Battery supplier	Vehicle range (km)
Tesla S	60–100	C/NCA	Panasonic/Tesla	334–508
Tesla X	60–100	C/NCA	Panasonic/Tesla	335–500
BMW i3	22,33	C/NMC	Samsung/Bosch	129,183
Nissan Leaf	24,30	C/LMO (C/NMC)	AESC and LG Chem	135,172
Volkswagen e-Golf	24,35.8	C/NMC	Panasonic	135,200
Chevrolet Spark	19	C/LFP	A123	132
Fiat 500e	24	C/NMC	Samsung/Bosch	140
Kia Soul EV	27	C/NMC	SK Innovation	145
Smart Fort EV	17.6	C/NMC	LG Chem	109
Ford Focus EV	35.5	C/NMC	LG Chem	160
Mercedes B-Class	28	C/NCA	Panasonic/ Tesla and SK Innovation	137
Mitsubishi	16	LTO/LMO	Toshiba	100

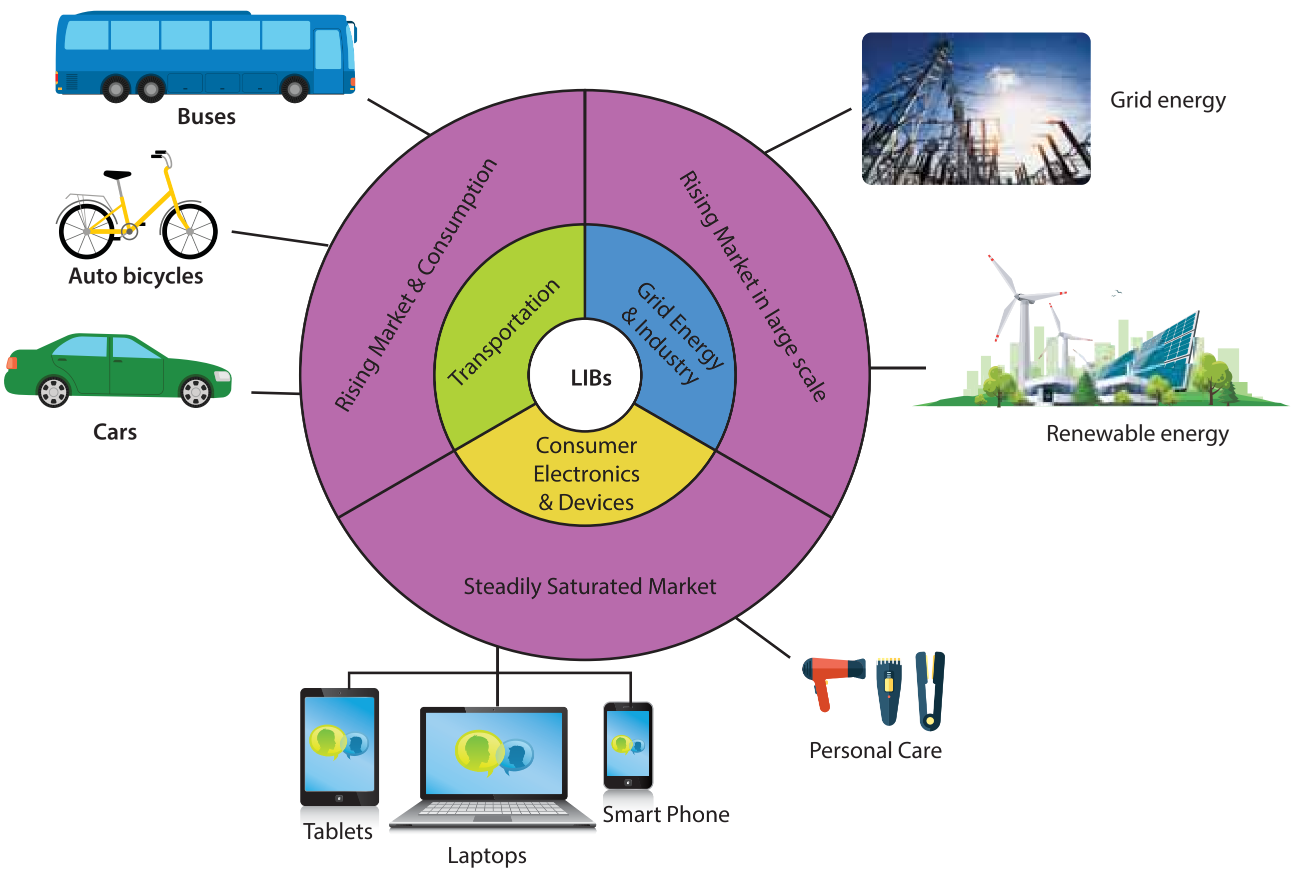


Figure 8 Modern applications of LIBs

Beyond Lithium-Ion Chemistry

Although lithium-ion battery technology is well developed, there are concerns regarding the lithium battery safety, lifetime, poor low-temperature performance, and cost. It is even predicted that supplies of lithium will run out in the foreseeable future. Supplies are likely to be further constrained if these batteries are adopted for large-scale energy storage. At present, options for stationary electrical storage are pumped-storage hydro, compressed air storage, thermal sinks, and batteries, including flow batteries and Li ion batteries.

To address this issue, battery chemistries, such as Li(Na)/S, Li(Na)/O_2, and Na-ion, are being explored. Sodium-ion batteries (SIBs) have the potential to replace Li-ion batteries. The progress in SIBs is compelling as the knowledge gained from LIBs has been useful to design new electrode and electrolyte materials. With respect to large-scale stationary energy storage systems for energy grids in sustainable energy networks of wind and solar energy, low-cost SIBs are expected to be produced at lower cost than that of Li-ion batteries in the future.

Many promising battery technologies are under development. Redox flow batteries using solutions of redox complexes or ions are good options for stationary applications, such as in energy grids based on sustainable sources. Mg-ion batteries have the advantages of increased safety due to the lack of formation of dendrites and high-energy density comparable to Li-ion batteries at significantly lower cost. Therefore, Mg-ion batteries are highly promising for electric vehicles. Toyota is leading the industrial efforts to commercialize Mg-ion batteries, which are expected to power electric vehicles by 2020. Al-ion batteries, with three-electron transfer, could achieve three times higher energy density than that of Li-ion batteries. However, the use of expensive ionic liquids will limit Al-ion batteries to special applications. Rechargeable Zn-air batteries may be more promising than Li-air batteries. Primary Zn-air batteries were invented more than 100 years ago. The recent efforts are mainly focusing on the development of rechargeable Zn-air batteries. Rechargeable Zn-air batteries can find applications in electric vehicles. The new battery technologies may not necessarily directly compete with Li-ion batteries in market share due to their unique characteristics in terms of performance, cost, and size. EF

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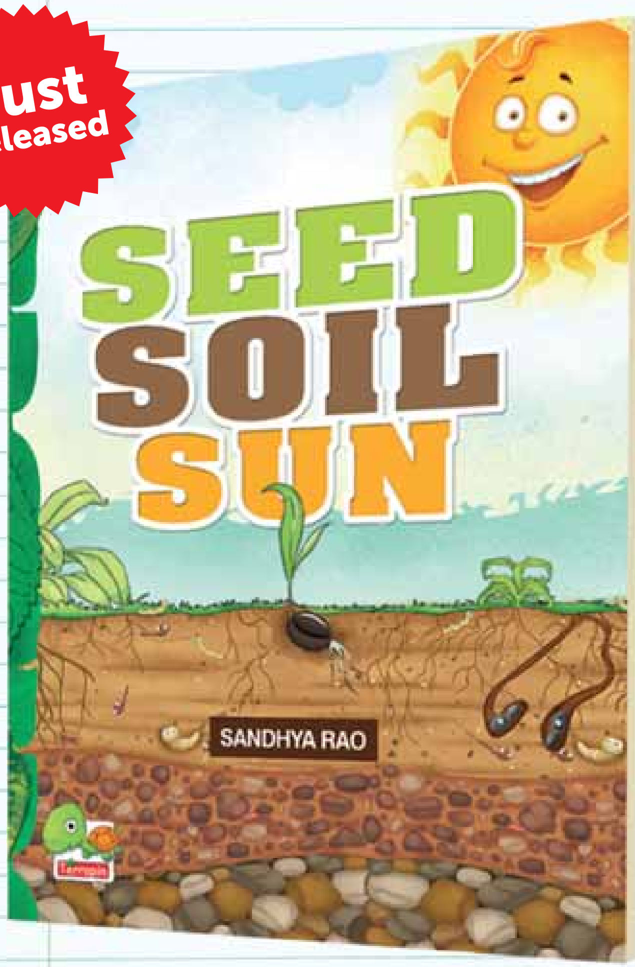

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Endeavour of Rajasthan Towards Ultra-Mega Solar Parks

Sun's Glow and Future Opportunities

Driven by perpetually rising demand for energy, more than 170 countries set renewable energy development goals and more than 145 countries adopted a variety of supportive policies for harnessing solar energy. Solar energy intensity fluctuates geographically across the nation; however, the Thar Desert in the western Rajasthan gets more than 325 days of sunshine every year with annual mean daily global solar radiation in the range of 5–7 kWh/m^2/day. The state of Rajasthan with the solar potential of around 142 GW is the only state in India that has established a strong power hub in the desert area. In this article, **Radhey Shyam Meena**, **Kunji Lal Meena**, **P V Tarun Saketh**, **Dilip Nigam**, **Sunil Kr Gupta**, and **Anindya S Parira** analyse the growth made so far in the solar energy expansion in Rajasthan, specifically the setting up of ultra-mega solar parks in the Thar Desert of Rajasthan.

Introduction

Keeping in view the commitment to a healthy planet and nationally determined contributions as per the Paris Accord on Climate Change, India made a pledge that 40% of the installed power generation capacity shall be based on clean sources by 2030. It was determined that 175 GW of renewable energy capacity will be installed by 2022. This includes 100 GW from solar, 60 GW from wind, 10 GW from bio-power, and 5 GW from small hydropower. Furthermore, the demand forecast suggests that solar and wind power capacity of 500 GW will be required by the year 2030.

India has an immense solar potential of around 750 GW, provided land is also available for setting up of ultra-mega solar projects. The largest accessible but least tapped form of energy on the earth is solar radiation in deserts. India has large deserts, both hot and cold, for example, the Thar Desert of Rajasthan, the Rann of Kutch of Gujarat, Leh–Kargil–Ladak, and Spiti Valley in Himachal Pradesh. As deserts have a good wind potential as well, a hybrid model of wind and solar energy is envisaged to be harnessed utilizing identified wasteland in an optimal manner, which also reaps benefits of the diversity of resources.

India is building up its installed solar power capacity through comprehensive and ambitious National Solar Mission (NSM), state solar policies, and relatively increased enforcement of the Renewable Purchase Obligation (RPO). To create more opportunities and promote ecologically sustainable growth to address the challenges of energy security, the Indian government launched in 2010 a major initiative in the form of National Solar Mission (NSM). The Mission targets include 20 GW grid-connected solar power by the year 2022 and 2000 MW of off-grid solar applications. However, in June 2015, the Government enhanced the target of solar from 20 to 100 GW by 2022. The enhanced target of 100 GW will bring India on the global solar power map. Of the solar target of 100 GW, solar projects of around 30 GW capacity was already commissioned at the end of June 2019, the capacity of around 14 GW is under the commissioning stage, and around 33 GW capacity is in the different phases of the tendering stage.

As shown in Figure 2, Karnataka with 6497.41 MW capacity tops in the grid-connected solar installation, followed by Rajasthan with a capacity of around 4737.63 MW.

The cost of solar and wind power generation has also declined significantly. For new projects, depending upon the location, the cost ranges between ₹2.44 and ₹2.85 per unit of power produced. On a life cycle basis, the delivered cost of solar and wind power (even after including the normative transmission charges of ₹1 per unit of power) has become cheaper than the marginal cost of power from thermal power plants. Now, renewable energy not only is a matter of commitment and faith but also has emerged as a cost-competitive option for meeting the electricity requirement.

Solar Parks in India

Development of Solar Parks and Ultra Mega Solar Projects is an important aspect of the solar mission. Solar parks can be instrumental in overcoming all the bottlenecks faced by independent power producers of solar PV projects. These can include land availability, developing the evacuation infrastructure, its funding, and other financial challenges.

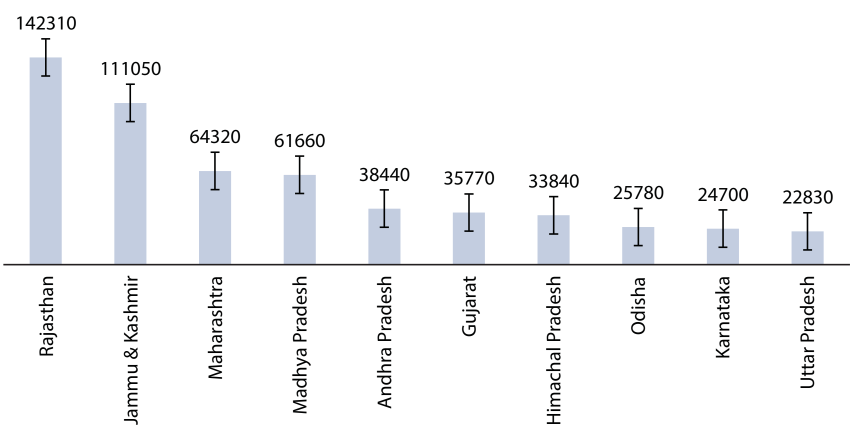


Figure 1 Solar potential (in MW) of major states in India

Source: MNRE website

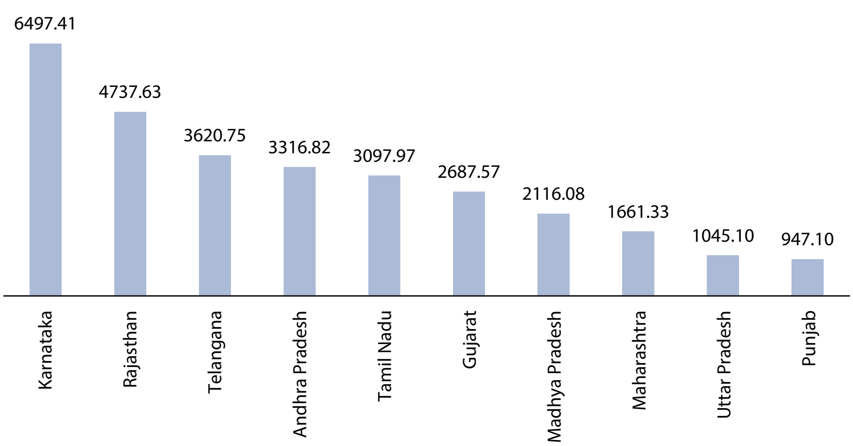


Figure 2 Major states in solar installation (in MW) as on 31 October 2019

Source: MNRE website

To overcome these challenges, the Ministry of New and Renewable Energy (MNRE) undertook a scheme in December 2014 for the development of Solar Parks and Ultra Mega Solar Projects in order to set up several solar parks in various states of the country. The Scheme proposed to provide financial support by the Government of India to establish solar parks to facilitate the creation of infrastructure necessary for setting up new solar power projects, targeting around 20,000 MW in 5 years commencing from 2014-15. Thereafter, the capacity of the solar park scheme was enhanced from 20,000 to 40,000 MW in March 2017, which is to be commissioned by 2021-22. By the end of October 2019, 39 solar parks with a cumulative capacity of 22,879 MW have been approved in 17 states. Out of 39 solar parks, 12 solar parks are fully/partially developed and solar projects of around 7030 MW capacity have already been commissioned. The remaining capacity is at different stages of development. A few solar parks have been cancelled owing to slow progress and the request from states.

Sun's Glow and Expansion of Solar Energy in Rajasthan

Rajasthan is endowed with the solar energy potential of around 142 GW. The state has received overwhelming response from project developers/ investors for setting up solar projects, especially the ultra-mega solar power projects in the form of solar parks. The state is poised to establish itself as a leader in renewable power generation and a pioneer in providing energy security and sustainable growth to India with its perennial and abundant solar radiation and low land cost and has the potential to become the power hub for solar and wind power technologies. Rajasthan is also favourably placed to become the largest provider of solar power among all sources of energy in India at a competitive cost and achieve the scale on solar power generation on the record low price of ₹2.44 per unit, which can transform the complete economic situation for the betterment of masses. The substantially higher capacity target and achievements will ensure greater energy security, improved energy access, and enhanced employment opportunities in the state.

For promoting and developing non-conventional energy sources in the state with a vision to lay the foundation for generation of clean electrical power, Rajasthan Renewable Energy Corporation Limited (RRECL) is designated as a state nodal agency (SNA). Despite having huge potential, the large-scale deployment of solar power will be feasible only if solar generation costs achieve the grid parity. The solar tariff has been brought down from the initial high of approximately ₹17 per unit to ₹2.44 per unit in 2018.

The favourable conditions, coupled with a conducive policy and regulatory environment, have attracted a lot of solar investment in the country. As of October 2019, Rajasthan stands at the second position with the solar installed capacity of 4737 MW after Karnataka (Figure 2). Nearly 80% of the projects allotted in the first phase of the Jawaharlal Nehru National Solar Mission (JNNSM) were received by Rajasthan and all these have already been commissioned.

Under the next phase of the National Solar Mission, a total of 750 MW of solar PV projects was allotted to interested developers through a competitive bidding process and Rajasthan bagged 50% of the total capacity (i.e., 375 MW). These projects were commissioned in 2015.

The Government of Rajasthan launched Solar Energy Policy, 2014. Initially, solar developers proposed to install solar power plants in Rajasthan on a project-specific tariff basis. However, before such tariff was determined by RERC (Rajasthan Electricity Regulatory Commission), they migrated at CERC approved tariff to Jawaharlal Nehru National Solar Mission Projects handled by NVVN for supply of solar power bundled with unallocated power from thermal power stations of NTPC.
In the next phase of JNNSM that kicked off in 2015-16 and with the competitive

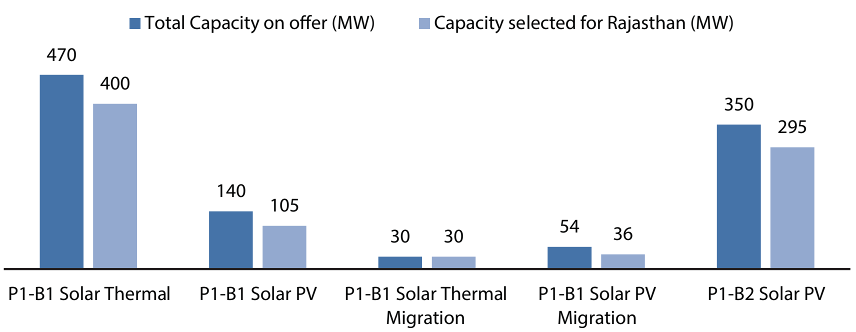


Figure 3 Projects under NSM Phase II

Source: MNRE website

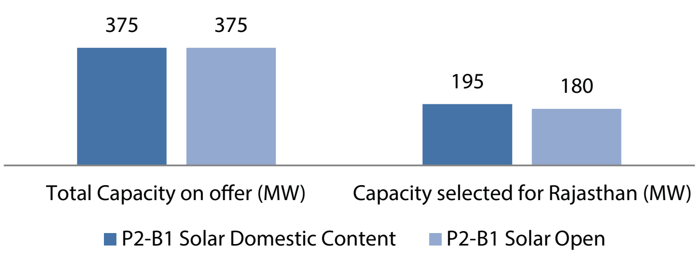


Figure 4 Projects under NSM Phase II

Source: MNRE website

bidding, the levellised solar tariff for 75 MW bidding for Bhadla Phase I was received at ₹6.45 per kWh and bid of 420 MW conducted in Rajasthan witnessed a record low tariff of ₹4.34 per kWh through transparent selection and award process. After that a 100 MW domestic content based bid was conducted in March 2016 with a discovered tariff of ₹5.06 per kWh. Another bid of 130 MW in July 2016 was concluded with the lowest tariff of ₹4.35 per kWh.

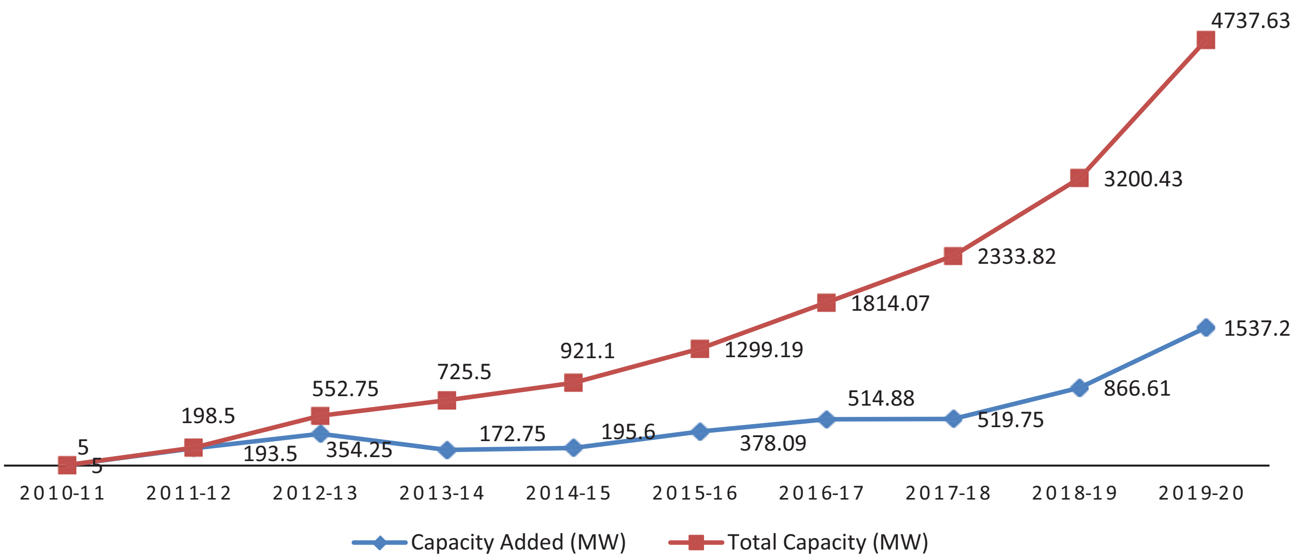
In the next phase of development, the tariff based competitive bidding was held for 500 MW at Bhadla Phase III Solar Park. It ushered in a new era of the tariff in the solar sector, with the lowest tariff of ₹2.44 per kWh in May 2017, and created a history of the lowest tariff in the country. Again, at the end of December 2018, an average tariff in the range of ₹2.47 per kWh to ₹2.48 per kWh arrived in Bhadla Phase III and IV of Rajasthan.

Out of the total installed capacity of 31,696 MW, Rajasthan has a share of around 4737 MW, which is almost around 15% of the total capacity, and tenders of another 1500 MW have been floated and are in the process of implementation. The solar capacity added in the previous years and the total installed capacity of Rajasthan are shown in Figure 5.

As shown in Figure 6, Jodhpur district, which lies in the Thar area of Rajasthan, accounts for around 73% of the total solar installed capacity of Rajasthan, followed by Bikaner with around 12% and Jaisalmer with around 11%. This signifies that the desert part is a hotspot not only for Rajasthan but across the nation.

Developing a solar energy project is a complex process. Several issues, such as land availability, financing, project development, approval, and clearances, are involved in the development of solar projects.

» *Land availability:* Availability of clear land is a major issue faced in the development of solar power projects.
» *Power evacuation*: The availability and capacity of power evacuation infrastructure in remote areas are critical issues.



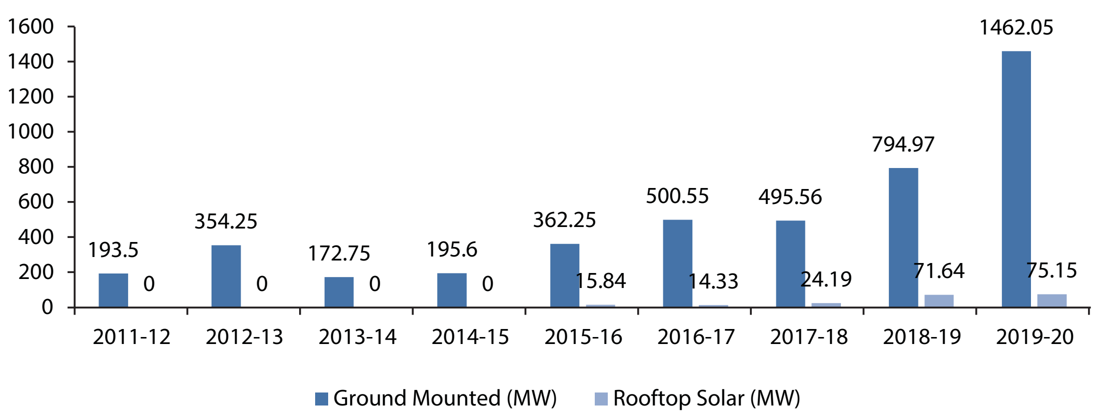


Figure 5 Year-wise growth of solar in Rajasthan (in MW and up to October 2019)

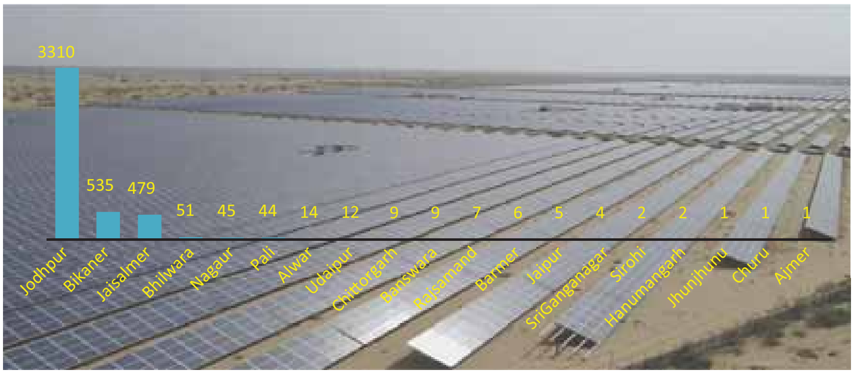


Figure 6: District-wise solar capacity installed (in MW) in Rajasthan

Note: The balance capacity is from rooftop solar

» *Financing:* Purchase power agreements, transmission agreement and land acquisition, and so on are prerequisites for financing, and developers are supposed to utilize equity (for payment of charges/fees, etc.) till debt disbursements are available.

» *Project development:* Solar project development requires multiple approvals and process steps that involve various departments.

Solar parks provide an integrated approach for addressing some of the key issues related to the development of solar projects. They reduce costs related to power evacuation. Solar parks will allow states to attract significant investment from project developers, meet solar renewable purchase obligation (RPO) mandate, and provide employment opportunities to the local population. The state will also reduce its carbon footprint by preventing emissions equivalent to the installed capacity and generation of solar parks. Furthermore, the expense made by the state on fossil fuels for the conventional power plants is reduced. The tariff arrived at different solar parks is shown in Figure 7.

Solar Parks in Rajasthan

Rajasthan Solar Energy Policy, 2014 facilitates the development of Solar Park in the state. On the recommendation of RREC, a developer can get an allocation of government land and/or acquisition of other private/agricultural land over the ceiling as per Agricultural Holdings Act. Rajasthan, being the most promising solar hotspot of the country, moves towards large-scale ultra-mega solar projects and solar parks to utilize the huge potential of solar energy. MNRE has approved six solar parks in Rajasthan with the aggregate capacity of 5410 MW under the Solar Park scheme. Out of 5410 MW, the capacity of around 1730 MW is already in operation

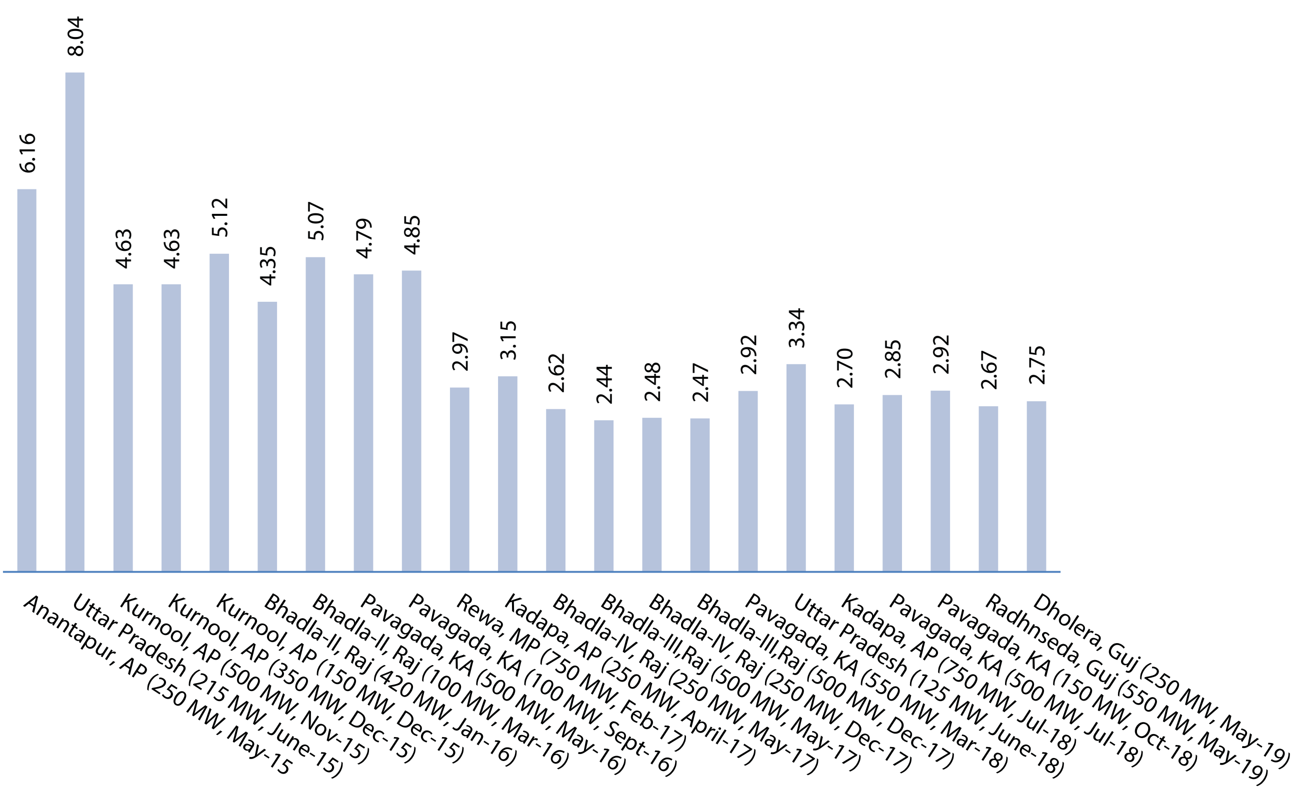


Figure 7 Tariff arrived at different solar parks in India

and the remaining capacity is under different stages of development. The park-wise brief analysis and status are as follows:

- *Bhadla Phase II Solar Park (680 MW)*: The Bhadla Phase II Solar Park was developed by Rajasthan Solarpark Development Company Limited (RSDCL), a wholly owned subsidiary of Rajasthan Renewable Energy Corporation Ltd (RRECL), and the capacity of 680 MW has already been commissioned and fully operational since March 2017.
- *Bhadla Phase III Solar Park (1000 MW)*: It is being developed at Bhadla village of Jodhpur district by M/s Saurya Urja Company of Rajasthan Ltd, a joint venture of IL&FS Energy Development Company Limited (IEDCL) and Govt. of Rajasthan. The park is being developed in two phases of 500 MW each. In the first phase, SECI (Solar Energy Corporation of India) invited bids and the lowest tariff discovered for 200 MW was ₹2.44 per unit, followed by ₹2.46 per unit for 300 MW. Further, for balance capacity of Phase II, a tariff of ₹2.47 per kWh arrived for 200 MW and ₹2.48 per kWh for 300 MW. The development work of the solar park and solar projects is already in process and the capacity of 700 MW has been commissioned and operational. Once the park is fully commissioned, it will be the largest solar park of Rajasthan and the second largest solar park of the country commissioned at a single location, equivalent to the Kurnool Solar Park of capacity 1000 MW in Andhra Pradesh.
- *Bhadla Phase IV Solar Park (500 MW)*: This is also at Bhadla in Jodhpur and developed by JVC of Government of Rajasthan and M/s Adani Renewable in around 3285 acres of the land bank. It is also developed in two phases of capacity 250 MW each. The lowest tariff discovered is ₹2.62 per unit for 250 MW by SECI under the VGF (viability gap funding) scheme. Furthermore, the balance capacity of 200 MW at a tariff of ₹2.48 per kWh and 50 MW at the rate of 2.49 per kWh discovered in the transparent bidding process. In this park, 500 MW has already been commissioned and operational.
- *Phalodi-Pokaran Solar Park (750 MW):* Essel Saurya Urja Company of Rajasthan Limited (ESUCRL), a JVC of M/s Essel Infraprojects and Government of Rajasthan, plans to develop this 750 MW solar park in an estimated area of 3577.18 acres with footprint that spreads across Ugraas, Nagnechi Nagar, and Dadhu villages of Phalodi tehsil of Jodhpur district and Purohitsar and Lawan villages of Pokaran tehsil of Jaisalmer district. SPPD has started the development of the park infrastructure.
- *Fatehgarh Phase IB Solar Park (421 MW):* Adani Renewable Energy Park Ltd (AREPL) has entered into a 50:50 joint venture agreement with the Government of Rajasthan to form a JV company called Adani Renewable Energy Park Rajasthan Ltd (AREPRL). The primary objective of M/s AREPRL is to develop and facilitate the development of large-scale solar projects in Rajasthan. In line with the government's ambition to boost solar power in state, M/s AREPRL is planning to develop a 1500 MW Fatehgarh-Pokaran Solar Park in an estimated area of 7958.28 acres (3219.37 hectares) with the footprint that spreads across Nedan in Pokaran tehsil and Duwada and Rasla villages in Fatehgarh tehsil of Jaisalmer district.
- *Nokh Solar Park (980 MW)*: Nokh Solar Park with 980 MW capacity is conceived in the western Rajasthan in about 2140 hectares of wasteland/non-agricultural land surrounding the Nokh village in Pokaran tehsil, Jaisalmer district and Jodhpur division of Rajasthan. It is being developed by RSDCL, a wholly owned subsidiary of Rajasthan Renewable Energy Corporation Limited. The park is approved under Phase II of Solar Park Scheme and the development activities have started.

Figure 8 Solar projects inside solar park of Bhadla site

Transmission Challenges

To plan a transmission scheme for envisaged renewable energy zones (REZs) comprising wind, solar, or both,

pockets/complexes are identified by the government with the help of central transmission utility (CTU) and state transmission utilities (STUs). Based on inputs, initially solar (50,000 MW) and wind (16,500 MW) generation is envisaged in seven RE rich states, namely, Tamil Nadu, Andhra Pradesh, Karnataka, Gujarat, Maharashtra, Rajasthan, and Madhya Pradesh. This includes 20,000 MW to be developed in Rajasthan. Considering envisaged RE (wind and solar) capacity addition and to achieve load generation balance, thermal generation dispatch is reduced up to 50% of the total installed capacity. At some locations, thermal generation is even needed to be backed down. Most wind and solar pockets are located in different complexes. However, some complexes/pockets are common for both wind and solar (hybrid) resources and for which common transmission schemes need to be identified.

The challenge faced in the transmission is the mismatch between the gestation period of renewable energy projects and transmission systems. While wind and solar plants get completed in 6–18 months, 220 kV and 400 kV transmission system takes around 4 years. Thus, an integrated planning approach needs to be adopted at intra-state and interstate levels. Another challenge is the voltage problem as renewable energy projects are located far away from load centres. This requires considerable investments in installing suitable compensation elements, such as reactor, STATCOMs, and capacitors. The utility also faces operational and grid stability issues because of huge variations in renewable energy generation. Renewable energy management centres integrated with the existing load despatch centres are being established in the state to address this problem.

Rajasthan Rajya Vidyut Prasaran Nigam Limited (RVPN), the State Transmission Utility (STU), has also significant expansion plans, with the Transco planning to set up 84 grid substation, 5,993 ckt.-km of lines, and 9770 MVA of transformer capacity in the Thirteenth Five Year Plan (2017–22). Overall, concerted efforts of RVPN to augment its transmission system technologically and improve efficiency are likely to help prepare the grid for a renewable-rich future.

Future Opportunities

Clear land and power evacuation are the two most critical elements for the success of RE projects. If these two inputs are facilitated by the government, developers would be enthused to participate in the establishment of RE projects. Recognizing their importance, MNRE has constituted five teams for detailed planning of identified solar and wind zones in the renewable rich states, that is, Andhra Pradesh, Gujarat, Madhya Pradesh, Karnataka, Rajasthan, Tamil Nadu, and Telangana. The teams have identified potential sites for the development of renewable energy projects in these states and also assessed the transmission requirement for the same. In Rajasthan, around 300,000 acres of barren land is available for setting up projects of around 60,000 MW capacity.

Based on the available land, the planning for the evacuation of 8900 MW in Rajasthan has already been approved by the Standing Committee under Phase I, out of which Stage-II connectivity applications have been received for around 6700 MW and LTA applications have been received for 3700 MW. Further, the balance 2200 GW under Phase I would be exhausted through various bidding conducted by SECI in the state. In addition, system studies have been carried out for 11,100 MW (Phase II) and the transmission plans are under different stages of approval. The capacity of 11,100 MW in Phase II would be developed under Mode-7 of the Solar Park Scheme by SECI in Jaisalmer, Jodhpur, and Bikaner districts. Furthermore, SECI, NTPC, and PFC are also planning to develop ultra mega renewable energy power parks (UMREPPs) of around 5000, 5000, 3000 MW, respectively, in around 66,700 acres of land in different districts of Rajasthan.

Way Forward

Solar tariff has been declining in India on account of the bidding conducted through various schemes. However, GENCOs, TRANSCOs, and DISCOMs are still reluctant to generate, transmit, and distribute power from ultra-mega solar parks. To balance solar power, DISCOMs sometimes have to shut down or reduce generation from existing thermal power stations. In such situations, although they save variable charges, they have to pay fixed charges. Therefore, it is felt that there is a need to integrate the transmission corridors of ultra-mega projects.

As the gestation period of the RE project is short compared to the development of its transmission facilities, transmission work needs to be taken up in advance so that it can match with renewable generation. Envisaged solar generation capacity shall significantly impact the net load curve with a deeper belly in noon hours. This will also impact the requirement for quick ramp-up generation (thermal/hydro) in the later afternoon when solar generation tends to decline. Therefore, energy storage can be very useful.

To facilitate drawal of power by states, there would be additional requirements of the intra-state system. This shall be evolved based on the identification of beneficiaries at the subsequent stage. Further, infrastructure in the form of dynamic compensation, storage, and so on shall also be required at strategic locations. There is an urgent need to explore the requirement of including state-of-the-art controller/inverter features in specifications so that solar PV can be used as STATCOM for reactive support to the grid during night.

The article has highlighted critical success factors and aspects of the enabling environment in the implementation of solar energy. The issues of clear land and transmission infrastructure are also critical. It is hoped that Rajasthan will exploit the opportunity and address quickly and appropriately the highlighted challenges. EF

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BEE NUDGES INDUSTRY TO ADOPT ISO 50001

ENERGY MANAGEMENT SYSTEM TO SUSTAIN ENERGY EFFICIENT CULTURE

Estimated savings of worth ₹900 lakhs are achieved by over 50 MSMEs by implementing best energy efficiency practices under BEE – World Bank Project on Design & Implementation of Energy Management System as per IS/ISO 50001 standard. "The project was implemented by BEE jointly with CII Centre of Excellence for Competitiveness and BSI Group India," said Shri Abhay Bakre, Director General, Bureau of Energy Efficiency, while applauding the efforts put in by CII at 4th edition of CII EEETech held in New Delhi on 23–24 October 2019.

Mr Bakre, in his inaugural address, further outlined the importance of adopting the ISO standards and asserted that energy is the driving force for all the economic activities, including the MSME sector. Making efforts towards energy conservation and taking appropriate measures to mitigate carbon emissions is the key priority of the government. He stated that the Bureau has established energy management centres across India especially for the MSME sector, developing more than 300 energy efficiency case studies and preparing investment grade DPRs. The Bureau has also implemented around 50 energy-efficient technologies as pilot projects and carried out nationwide awareness and capacity building workshops for stakeholders, including 50 MSME units, for adopting energy management systems as per ISO 50001 standards.

Mr Bakre added that such technical conferences and programmes provide the industry an opportunity to identify, deliberate, and analyse new technologies/technology providers and latest techniques of energy efficiency with higher return on investment. This will help in not only dealing with issues, such as higher costs, low profits, and negative impact on environment, but also imparting knowledge and learning energy-efficient solutions. As energy plays a key role in development, various innovative policies and strategies have been adopted to conserve energy and promote clean energy technologies to ensure a safe, reliable, affordable, and sustainable energy system for the future.

The conference was attended by about 150 delegates from across the industry and covered various technical topics on energy efficiency, such as key enabler for climate change mitigation, adaptation and business competitiveness, strategy to achieve energy efficiency through innovations and innovative business models, energy efficiency in HVAC system – action plan, practices and technology, Energy 4.0 – game changer to accelerate energy efficiency, electrical safety, reliability and power quality, latest development in energy efficient technology, water and environment management as an integration with energy efficiency, renewable energy opportunities and innovative business models in renewable energy, and so on. The CII–Deloitte theme paper on sustainable technologies titled Adopting Global Benchmark on Energy Efficiency and Environment was also released during the conference.

There is significant potential to broaden and deepen our efforts on energy efficiency, unlocking multiple benefits across all end-use sectors. The immense potential of financial savings generated by adopting energy efficiency measures offers opportunities for both innovative products and improved production processes. The conference focused on addressing various issues of energy efficiency, including collaborative approach and efforts, policy interventions, innovative business models on energy efficiency adoption, technology led solutions on energy efficiency, innovation in energy efficiency, environment concerns and best practices that could accelerate energy efficiency business. EF

SUSTAINABILITY AS A FRAMEWORK, APPROACH, AND COMMITMENT

Companies play a critical role in achieving sustainable development and addressing challenges, such as climate change, the exploitation of natural and non-renewable resources, and the impact of humanity on our environment and ecosystem. Sustainability divisions in corporates help enable companies to achieve sustainability targets and reduce their environmental impacts. **Hitesh Kataria**, Manager in the Group Sustainability division of the Mahindra Group, in conversation with **TCA Avni** for *Energy Future* talks about the efforts taken by the Group to utilize waste, tackle carbon emissions, and reduce energy consumption.

Mahindra aims to follow a zero-waste philosophy – eight of your plants have been certified 'Zero Waste to Landfill'. Could you tell us a little about what does this mean and how this waste is utilized? Is this something which can be extended to other facilities as well?
Actually 13 of our plants have been certified till date! As you know, Mahindra has very diversified businesses, and each company and each location will have a different style, sort, and quantity of waste to deal with. The certification entails a third party assessing the location to certify that the waste generated does not end up in a landfill; for the certification which these locations have received, the diversion of waste from the landfill needs to be at least 99%. So in the locations which are certified, almost 100% of the waste is not going to a landfill. The wastes are managed using 6R principles (reduce, reuse, recycle, refurbish, rethink, and repurpose/upcycle) either in-house or through authorized third parties.

Out of 13 certified locations, 12 belong to Mahindra and Mahindra Ltd, which manufactures automobiles and farm sector vehicles, and 1 is the Virajpet resort of Club Mahindra, which became the first resort in the world to become ZWL certified with >99% diversion rate. In the manufacture process, the kind of waste which comes out is typical of the kind of waste you will find in equipment manufacture or in the use of heavy machinery to make consumer goods. The input is almost similar. To give you an example: to make vehicles, you will consume steel, plastics, rubber, paints, and various other things. If you use paint, the paint shop will generate paint waste and contaminated water. In our plants that are zero waste to landfill, the paint sludge that comes out is converted to primer, a technology that was developed and maintained in-house. That primer is used within various plants of M&M. Another example is that of oily cotton waste/CTP sludge that is converted to carbon black and furnace oil through pyrolytic processes. Our efforts include finding such recyclers who will use our waste as a resource. It's not just about the certificate. It's about the entire process which goes behind the certificate. And as my colleague Dr Pradeep Panigrahi, a champion of Zero Waste to Landfill certification and the lead of Circular Economy in Mahindra Group, will assure us that the waste generated is being taken care of – it is going to a recycler or industry which has the ability to use the waste to create new resources.

Water, waste, and energy management are said to be inextricably linked. Could you tell us a little about your views on this?
Waste, water, and energy are both inputs and outputs of any kind of activity. During operations, a variety of different processes occur – we use energy to manage waste, use waste to make energy, use energy to supply water, use water to create energy, use waste to make fresh water, and sometimes use water to clear waste. This is how we use resources to carry out human activities on this planet.

Since an organization or factory uses these resources, it also has a role to play. We have to make sure that we meet the compliances, that we meet the environmental regulations, and that we do not contaminate the land where we are working. For example, to avoid contamination by certain types of wastewater, we may need to try and ensure that there is no water discharge at all. A responsible corporation tries and manages its resources in such a way that they do not leave any negative footprint outside. And that is what Mahindra has been trying to do for many years now.

In the World Economic Forum at Davos, Mr Mahindra pledged that the Mahindra group will be carbon neutral by 2040 through energy efficiency measures and use of renewable power, with the balance being addressed through carbon sinks. Could you talk about how the group aims to achieve this and the strategies which would be adopted?
The carbon neutral commitment was made by Mr Mahindra in September 2018 and has been a major step in Mahindra's efforts to tackle carbon emissions. Mahindra and Mahindra was the first company to commit to doubling energy productivity by signing on to The Climate Group's program EP100. What we did was to say that for the amount of energy which we are now using, we will use the same amount of energy and double our production and that is what the automotive business has done. Using efforts such as energy efficient lighting, efficient cooling and heating, ventilation, and heat recovery projects, we have reduced energy consumption in the automotive and farm sector business. The company also has increased its renewable energy intake over the years. After doing this much, there will be some carbon footprint from your operations; however, the Group's afforestation program, which was initiated almost 10 years ago, will create carbon sinks. This will eventually enable the company and the Group to become carbon neutral.

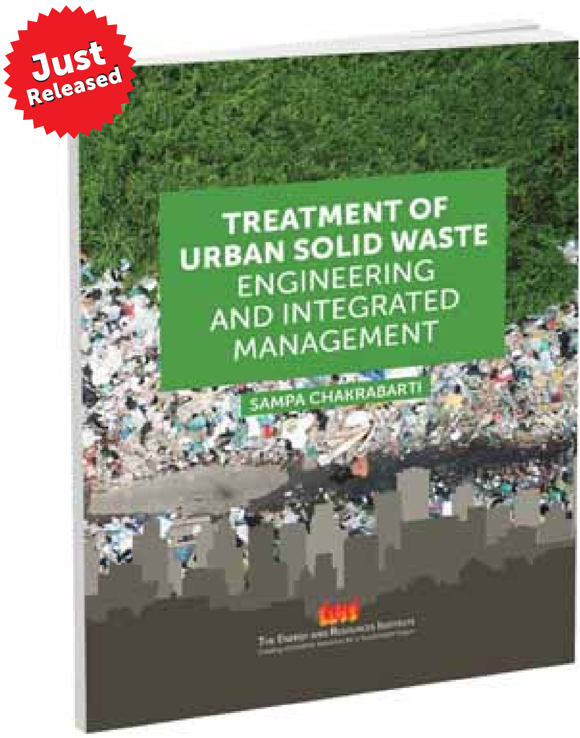
Of course, many of these efforts will demand financial commitments. In 2016, we had come out with an internal carbon price of $10. At that time, the aim was to use that $10 value to reduce 25% of carbon footprint in the next 3 years, which the company has successfully achieved. And now we are using that carbon price to see what sorts of efforts are required to meet our carbon neutrality targets. The Paris Agreement and the Science Based Targets urge the world to follow low carbon pathways and become carbon neutral by 2050 to control rising global temperatures. Our 2040 target is 10 years ahead of the world's aim for net zero and that is what is giving us the inspiration and guidance to move forward.

"Mahindra's businesses have institutionalized sustainability as a framework, approach, and commitment and all the credit goes to its team under the leadership of our Chief Sustainability Officer, Mr. Anirban Ghosh".

20 Mahindra companies have signed the Science Based Targets initiative (SBTi). Could you tell us about the targets they have pledged and how you foresee achieving them?
We are well led by our Chairman, Mr. Mahindra, who issued a SBT challenge for the corporate in Davos and today we have 20 companies committed to have science based targets set and 8 have already approved targets from the Science Based Targets initiative. These targets vary from company to company and sector to sector, but they commit companies to reducing greenhouse gas emissions through what are defined as scope 1 (direct emissions from sources owned or controlled by the company) and scope 2 (emissions from the generation of purchased electricity consumed). There are also scope 3 action areas, which can differ – for some it is employees commute and business travel emissions to be reduced, and for others it is purchased goods and emissions from logistics. It really depends on that particular sector, how those companies are using the method for the sector decarbonization, and what sort of target the SBTi has provided. More details about the initiative and methodologies are available on the website https://sciencebasedtargets.org/.

Thank you for taking the time to have this discussion with us. To end, could you tell us a little about future directions?
In the world today, we have two big commitments ahead of us. The first is the Paris Agreement and subsequent NDCs and articles coming out of it; the second is the Sustainable Development Goals (SDGs). These two frameworks are setting an excellent direction for everybody. We must look to them to correct our decision-making and remake business plans accordingly to adapt and mitigate to the best of our abilities. As they are for everyone's good, we all must work to achieve these commitments. EF

CHALLENGES AND SOLUTIONS OF URBAN SOLID WASTE MANAGEMENT



Major topics covered

- Engineering and management practices for treating urban solid waste including municipal, biomedical, construction and development, plastic, e-waste
- Problems and opportunities of municipal solid waste management, including separation, collection and transportation
- Environmental and public health issues of managing various types of solid wastes

ISBN: 9788179936580 • Price: ₹550.00

Treatment of Urban Solid Waste: engineering and integrated management describes the principles or steps of integrated solid waste management, especially in the Indian context. The Indian scenario of generating and treating urban solid waste is explained in the backdrop of international status. Latest technologies as well as current rules and regulations applicable in India are compiled for ready reference. It will be useful for the postgraduate students as well as for the practising environmental engineers engaged in the management of municipal solid waste.

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CURRENT R&D RENEWABLE

Renewable Energy Injustice: The Socio-Environmental Implications of Renewable Energy Consumption

Energy Research & Social Science, Volume 56, October 2019, 101214

Julius Alexander McGee and Patrick Trent Greiner

We explore how national income inequality moderates the relationship between renewable energy consumption and CO_2 emissions per capita for a sample of 175 nations from 1990 to 2014. We find that, independent of income inequality and other drivers of emissions, increases in renewable energy consumption reduce emissions. However, when national income inequality is considered, we find that renewable energy consumption is associated with a much larger decrease in emissions as inequality increases. We also find that when fossil fuel energy is controlled, inequality does not significantly moderate the association between renewable energy and emissions. These results suggest that fossil fuel consumption is the main vector through which inequality moderates the relationship between renewable energy and emissions. Drawing on the previous work from energy poverty scholars, we theorize that national inequality influences the way renewables are deployed. Specifically, our findings suggest that renewable energy displaces more fossil fuel energy sources when inequality is increasing, while– conversely– fewer existing fossil fuel energy sources are displaced when inequality is decreasing. In additional analyses, we find that as the top 20% of income earners' share of income grows, the association between renewable energy consumption and emissions decreases in magnitude. We conclude by arguing that efforts aimed at increasing renewable energy consumption should adopt policies that ensure the effective displacement of fossil fuels and reduce inequality. EF

Co-simulation and Optimization of Building Geometry and Multi-energy Systems: Interdependencies in Energy Supply, Energy Demand and Solar Potentials

Applied Energy, Volume 242, 15 May 2019, Pages 1661–1682

Christoph Waibel, Ralph Evins, and Jan Carmeliet

This paper presents a co-simulation framework for the simultaneous optimization of building geometries and multi-energy systems using the energy hub approach. The rationale for such coupling is that building geometry has an impact on energy demands and solar potentials on roofs and façades, thus also altering the corresponding optimal energy system. As a demonstration of this approach, we formulate bi-objective optimization problems for minimizing operational cost and carbon emissions, with decision variables for building geometry and for selection and sizing of energy system technologies. The methodology is applied to a case study in the city of Zurich, Switzerland, involving four office buildings. Different carbon emissions targets are studied to show the impact on cost, densities, sizing of the multi-energy system, and architectural design implications. Results for this case study show a clear relation between emissions targets and densities due to available solar potentials for renewable energy generation, with an optimal density in the strictest emissions target reaching only 10% of the optimal density without emissions target. This indicates that differentiated environmental targets should be defined depending on the location of a building, where rural sites could have stricter targets than dense urban sites to reflect the respective marginal costs for achieving the targets. Our study shows that coupling multiple simulators into a common optimization and design workflow brings together architectural aspects, such as geometry, with engineering aspects, such as the energy system design, and microclimate conditions, such as local solar potentials. Thus, essential interdependencies between the energy supply and demand side can be captured in the design of energy efficient cities. EF

Women's Leadership in Renewable Transformation, Energy Justice and Energy Democracy: Redistributing Power

Energy Research & Social Science, Volume 57, November 2019, 101233

Elizabeth Allen, Hannah Lyons, and Jennie C. Stephens

As women take on more leadership roles in the United States advancing social and political change, analysis of women's contributions to the transformation occurring within the energy sector is critically important. Grassroots movements focused on energy justice and energy democracy focus on: (i) resisting the power of large multinational fossil fuel energy companies that exacerbate inequities and disparities in energy, (ii) reclaiming the energy sector with more community and public control to redistribute benefits and risks, and (iii) restructuring the energy sector to prioritize equity and justice with community ownership and distributed governance. This research analyses women's leadership by focusing on how two women-led, non-profit organizations are advancing the renewable energy transition, operationalizing the concept of energy democracy, and contributing to the energy justice movement. The two organizations are Grid Alternatives, a solar installation and workforce training organization, and Mothers Out Front, an advocacy organization focused on addressing climate change by promoting a transition to renewable energy. These organizations differ in their mission and approaches, yet both intentionally link climate and energy action with other forms of social justice activism by expanding community engagement, strengthening participation, and fundamentally redistributing power to promote a transition to more equitable, resilient, and sustainable energy systems. This paper contributes to the theoretical understanding of gender in energy justice and energy democracy movements and to the practical consideration of the role that women's leadership is playing in accelerating energy system change and advancing the principles of energy justice and energy democracy. EF

Ecosystem Maintenance Energy and the Need for a Green EROI

Energy Policy, Volume 131, August 2019, Pages 229–234

Patrick Moriarty and Damon Honnery

A number of official energy forecasts—including those compatible with the aspirational 1.5 °C Paris Accord global temperature rise limit—see both global primary and net energy use continuing to rise, even out to 2100. Various technologies, including greatly increased use of renewable and nuclear energy, negative emission technologies such as direct air capture, and geoengineering are proposed as approaches for meeting the 1.5 °C target. In contrast, we argue that meeting this target and avoiding significant increases in extreme weather events will require marked reductions in future energy demand. We argue that the combined fossil fuel and renewable net green energy production will fall in the coming decades, after subtraction of various energy costs essential for ecosystems maintenance, including those needed to stabilize climate. At best, nuclear energy will only fractionally increase its global energy share, because of its high capital costs and political opposition arising from accident risks, waste disposal and proliferation concerns. Geoengineering will not solve fossil fuel depletion and has serious known—and perhaps unknown—risks. We conclude that global net energy produced in an ecologically sustainable manner will start falling in a decade or so and suggest the need to account for this at a policy level by introduction of a green EROI—EROIg. EF

Unveiling the Heterogeneous Effect of Energy Taxes and Income on Residential Energy Consumption

Energy Policy, Volume 129, June 2019, Pages 13–22

Djula Borozan

The paper investigates the effect of energy taxes in the European Union (EU) across different levels of residential final energy consumption (RFEC) in the period 2005–2016. The analysis is based on quantile panel regression models that directly and indirectly consider energy taxes. More precisely, the developed models provide a multivariate framework for evaluating their effects and, at the same time, for validating the existence of the energy environmental Kuznets curve (EKC) across the selected quantiles.

The results unveil significant heterogeneity in the RFEC responses across quantiles. Specifically, in less energy-consuming EU countries, an increase in energy taxes and energy prices influences stronger RFEC, and the rebound effect of real income and tertiary education is greater than in their more energy-consuming peers. Moreover, in the former, the energy EKC hypothesis holds, while in the latter, its existence is not clear, as well as the rebound effect caused by highly educated people. Consequently, EU energy policy aiming at achieving energy and environmental targets has to consider the heterogeneity in RFEC since the outcomes might be different for different energy-consuming groups of countries. EF

TRANSITIONING TOWARDS MORE SUSTAINABLE PRACTICES IN TEXTILE INDUSTRY

Textile industry is one of the world's most polluting industries, the second, in fact, after the oil industry. It produces 1.2 billion tons of CO_2 equivalent (CO_{2e}) per year and is responsible for around 5% of the total global emissions. In addition, according to an editorial published in Nature Climate Change in 2018, the limited recycling of textiles means that 60% of all clothing produced is disposed of within a year of production and ends up in a landfill or incinerated. In order to achieve the goals of the Paris Agreement on climate change and limit global warming to 1.5°C above pre-industrial levels, shifting towards more sustainable practices is vitally important.

Recognizing the necessity for this shift, the industry has been taking various measures to reduce its negative impact on the environment. Jaideep Sajdeh's family has been turning old garments from the West into recycled yarn for decades – recycling old and used woolens, synthetic sweaters, pullovers, coats, and jackets imported from the developed nations and converting them into yarn to produce blankets, blazers, and felts. Texool spins close to 4 tons of recycled yarn daily now.

After joining his family's recycling business, Jaideep Sajdeh decided to venture into creating a new source of demand for used textile through his initiative Texool, a Mumbai-based company that turns discarded textiles from wealthy countries into usable bags and fashion accessories.

Through Authentic, the upcycling arm, Texool converts old and used denim, bed and table linens (principally from hotels and restaurants) into bags ranging from basic laundry and shopping bags to handbags, totes and laptop sleeves for customized use by corporates and NGOs and sale at leading retail outlets. Authentic has sold or distributed more than 3 million

upcycled products since its inception and conservatively replaced 400 million plastic and other non-ecofriendly bags, saving 3 billion liters of water, 2.1 million kg of CO_2, and not to mention the energy savings of recycling instead of using energy-intensive virgin cloth.

The start-up has won several accolades, including India's Top 100 SME Award.

Texool and Authentic are audited by Control Union, which certifies that the products are GRS (Global Recycled Standard) compliant.

Demand for textiles produced by reclaiming fibres from old textiles is gaining momentum globally. As India has large manpower and rich textile history, it could play a vital role in this regard.

Europe and United States, which are the leading retailers, have mandates to increase recycled and sustainable collections and top Indian retailers also have begun to look for sustainable options.

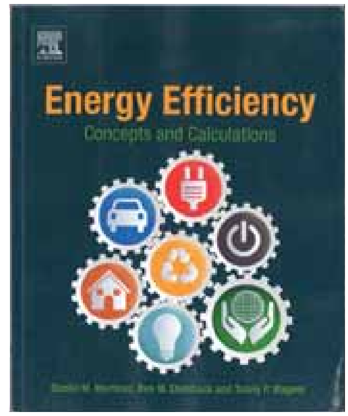
IMG Reliance dedicated an entire day to sustainability in fashion at the Lakme Fashion Week Winter/Festival 2019 and Arvind Limited used to have a 2-day sustainability exhibition each year for sourcing of sustainable yarns, accessories, and so on.

The Union Minister for Textiles Smriti Irani launched project SU.RE at the Lakme Fashion Winter/Festive 2019, which is a strong commitment of India towards sustainable fashion. Sixteen of India's top retailers are signatories to project SU.RE. EF

*70 grams is the weight of our lightest bag

*3 Million recycled products have been sold /distributed since start up.

Energy Efficiency: Concepts and Calculations

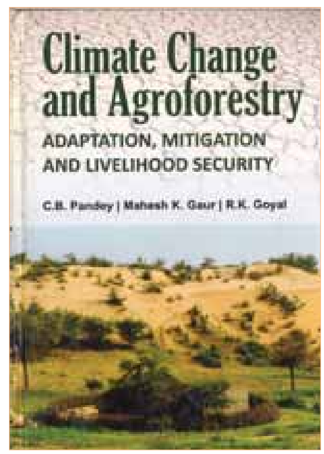


Energy Efficiency: Concepts and Calculations is the first book of its kind to provide an applied, systems oriented description of energy intensity and efficiency in modern economies across the entire energy chain. With an emphasis on analysis, specifically energy flow analysis, life cycle energy accounting, economic analysis, technology evaluation, and policies/strategies for adopting high energy efficiency standards, the book provides a comprehensive understanding of the concepts, tools, and methodologies for studying and modeling macro-level energy flows through, and within, key economic sectors (electric power, industrial, commercial, residential, and transportation).

Providing a technical discussion of the application of common methodologies (e.g., cost–benefit analysis and life cycle assessment), each chapter contains figures intended to be diagnostic, charts, and examples from each sector, including the policies that have been put in place to promote and incentivize the adoption of energy efficient technologies. Models and tools are included to analyse each stage at the macro level by tracking energy consumption and how the resulting data might change energy use. EF

Editors: Daniel M Martinez, Ben W Ebenhack, Travis P Wagner
Publisher: Elsevier Science
Year: 2019

Climate Change and Agroforestry: Adaptation, Mitigation and Livelihood Security

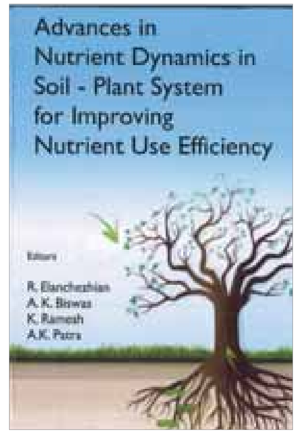


Climate change, resulting from the rise in global temperature, drives many stressors that make it difficult to predict the outcome in a general way. However, the impact of climate change is so far more visible in agriculture than other sectors. Rise in temperature causes oxidation of soil organic carbon and affects biogeochemical processes and mechanisms, making soil health and productive potential of soils weaker. It also affects weather at the local, regional and global scale and hydrological cycle, resulting in drought, flood, cyclones, and so on. Simultaneously, it impinges directly upon reproductive biology of crops by reducing pollen viability and leading to spikelet sterile, which result in crop yield reduction. In India, the impact of climate change on agriculture is predicted to occur more in northern parts, where wheat production may suffer losses of 4–5 million tons for each degree rise in temperature. Rice, pearl millet, and soybean are other crops in that line. Globally, it has been predicted to have a huge burden in future as the world needs to feed nine billion people by the turn of the 21st century. The book discusses several techniques, such as conservation agriculture, integrated farming, crop diversification, and carbon sequestration through agroforestry, that help in climate change mitigation and adaptation. Therefore, this book serves as a repository of information on climate change, mitigation, and adaptation in relation to agroforestry, which can be useful to planners, researchers, and undergraduate and postgraduate students pursuing studies in the field of agricultural and allied sciences. EF

Authors: C B Pandey, Mahesh Kumar Gaur, R K Goyal
Publisher: New India Publishing Agency
Year: 2017

Advances in Nutrient Dynamics in Soil-Plant System for Improving Nutrient Use Efficiency

This book consists of 31 chapters on advances in soil-plant systems for improving nutrient use efficiency with four major themes: (i) introduction and fundamentals of soil plant atmosphere continuum and nutrient use efficiency, (ii) soil physical, chemical, biological, and agronomic management for improving NUE (nitrogen use efficiency), (iii) plant physiological, genetic, and molecular biological basis for improving nutrient uptake and use efficiency, and (iv) climate change aspects related to soil and plant systems for improving NUE. Besides, the book also includes a few chapters on analytical techniques and instrumentation for the study of nutrient use efficiency with respect to physico-chemical and biological parameters. EF



Editors: R Elanchezhian, A K Biswas, K Ramesh, A K Patra
Publisher: New India Publishing Agency
Year: 2017

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

To rid electric grid of carbon, shore up green energy support

A team of researchers from Cornell and Northwestern University have created an energy model that helps to remove carbon-generated power from the U.S. electric grid, replacing it with a greener, financially feasible wind, solar, and hydro energy system. As per one of the researchers, they are trying to balance the priorities of maintaining a reliable, low-cost, efficient electricity system while shifting to a cleaner, greener system.

In the last three decades, electric utilities throughout the United States, which once controlled both power generation and transmission, have shifted towards restructured markets. These foster more competition than the once-traditional monopoly utility model, and electric energy now can be created by one company and transmitted by another. Choices made in the design of these restructured markets, however, make it easier for investors to fall back on carbon-based ways, such as natural gas, to generate electricity. Developing a new model keeps the creation of wind, solar, nuclear, and hydro power economically competitive and aligns markets towards a green future.

As per one of the researchers, about two-thirds of the country participates in restructured electricity markets. When these markets were established, solar and wind made very little contribution to the overall energy mix. The complexity of electricity makes it difficult to have completely free markets. Instead, competition happens within the context of administrative rules.

https://www.sciencedaily.com/releases/2019/10/191028175142.htm

Cost-effective fuel cell technology

Fuel cells are pollution-free power sources that convert chemical energy into electricity with high efficiency and zero emissions. Fuel cell cars, trucks, and buses would allow people to travel long distances with convenient refuelling and less of a carbon footprint. Researchers at the University of Delaware (UD) are working on technology to make fuel cells cheaper and more powerful so that fuel cell vehicles can be a viable option for all someday. Traditional fuel cell research involves hydrogen fuel cells, but the UD researchers are engineering fuel cells that utilize ammonia instead. In a new analysis, a team of engineers at the Center for Catalytic Science and Technology found that among fuels produced from renewable energy, ammonia has the lowest cost per equivalent gallon of gasoline. "As a nitrogen-based liquid fuel, ammonia is cheaper to store and distribute than hydrogen and avoids the carbon dioxide emissions of other liquid fuels, which are expensive to capture" said one of the lead authors and a postdoctoral associate at UD.

The challenges, however, are that ammonia does not work in a proton exchange membrane fuel cell and that ammonia is more difficult to oxidize than hydrogen, which causes ammonia fuel cells to produce less power than hydrogen fuel cells. The team solved the first problem by using hydroxide exchange membrane fuel cells that have been studied for over a decade in the lab of a distinguished engineering professor at UD. Assisted by a grant from the REFUEL program of the Advanced Research Projects Agency-Energy (ARPA-E) in the U.S. Department of Energy, the UD team

engineered a fuel cell membrane that can operate at higher temperatures to speed up ammonia oxidation. They also identified catalysts that were not poisoned by ammonia. With these improvements, they believe that they have demonstrated a new direct ammonia fuel cell prototype with a peak power density of 135 mW/cm^2, which closes much of the performance gap compared to hydrogen.

https://www.sciencedaily.com/releases/2019/08/190820130934.htm

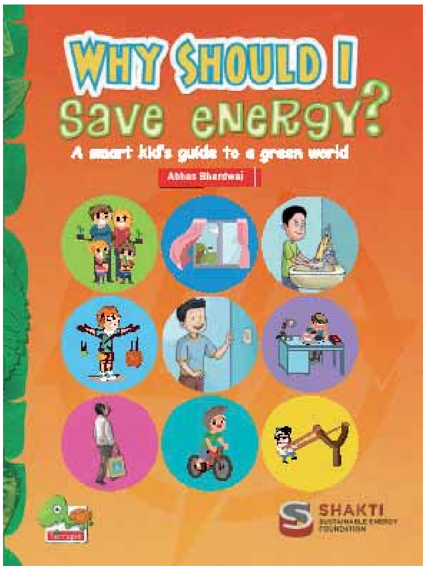
Using mountains for long-term energy storage

Batteries are rapidly becoming less expensive and might soon offer a cheap short-term solution to store energy for daily energy needs. However, the long-term storage capabilities of batteries, for example, in a yearly cycle, will not be economically viable. Although pumped hydro storage (PHS) technologies are an economically feasible choice for long-term energy storage with large capacities, higher than 50 MW, it becomes expensive for locations where the demand for energy storage is often smaller than 20 MW with monthly or seasonal requirements, such as small islands and remote locations.

In a study published in the journal Energy, IIASA researchers propose MGES to close the gap between existing short- and long-term storage technologies. MGES constitutes of building cranes on the edge of a steep mountain with enough reach to transport sand (or gravel) from a storage site located at the bottom to a storage site at the top. A motor/generator moves storage vessels filled with sand from the bottom to the top, similar to a ski lift. During this process, potential energy is stored. Electricity is generated by lowering sand from the upper storage site back to the bottom. If there are river streams on the mountain, the MGES system can be combined with hydropower, where the water would be used to fill the storage vessels in periods of high availability instead of the sand or gravel, thus generating energy. MGES systems have the benefit that the water could be added at any height of the system, thereby increasing the possibility of catching water from different heights in the mountain, which is not possible in conventional hydropower. One of the benefits of this system is that sand is cheap and, unlike water, it does not evaporate. So one can never lose potential energy and it can be reused innumerable times. This makes it particularly interesting for dry regions. Additionally, PHS plants are limited to a height difference of 1200 m due to very high hydraulic pressures. MGES plants could have height differences of more than 5000 m. Regions with high mountains, for example, the Himalayas, Alps, and Rockies, could, therefore, become important long-term energy storage hubs. Other interesting locations for MGES are islands, such as Hawaii, Cape Verde, Madeira, and the Pacific Islands, with steep mountainous terrain. In the explanation, researchers propose a future energy matrix for the Molokai Island of Hawaii using only wind, solar, batteries, and MGES to supply the island's energy demand. They also emphasized that the MGES technology should not be used for peak generation or storing energy in daily cycles. Instead it fills a gap in the market for locations with long-term storage. MGES systems can, for instance, store energy continuously for months and then generate power continuously for months or when there is water available for hydropower, while batteries deal with the daily storage cycles. EF

https://www.sciencedaily.com/releases/2019/11/191111124750.htm

An Imprint of TERI



WHY SHOULD I Save energy?

A smart kid's guide to a green world

Abhas Bhardwaj

• 2020 • 210 x 280 mm • 56 pages
• Hardback • ISBN: 9788179935798
• Genre: Pictorial-Reference • Price: ₹250.00

Ages: 12+ years

Did you know that energy consumption by humans has increased by at least 30,000 times in the last 5000 years? In Delhi alone, there are over 80,000 trucks that run on the city roads every night. They emit un-burnt fossil fuels from their exhausts. Isn't it terrifying that over 1 million seabirds and 100,000 sea mammals are killed by pollution every year?

Why Should I Save Energy? is a comprehensive book that will introduce children to different forms of energy, history of fossil fuels, great scientists and their inventions, and more importantly, to the problems our planet faces with depletion of natural resources. Filled with eye-opening facts, beautiful pictures, multiple activities, and a quiz that helps reinforce learning; this book is the perfect guide to help you become an energy saver.

Table of Contents

About the Author

Abhas Bhardwaj has studied botany and economics. Currently, he works as a market researcher. He has an avid interest in the environment and likes to share his enthusiasm with young minds. In his inimitable style, he likes to approach serious questions with humour.

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NATIONAL

Global Summit on Waste to Energy & Biofuels
January 30–31, 2020
Hotel Le Meridien, New Delhi
Website: http://www.gswe.in/event-info.php

Asia Pacific Solar Physics Meeting
February 03–07, 2020
Pune, Maharashtra
Website: http://www.iucaa.in/~apspm/

International Congress on Renewable Energy
February 07–08, 2020
Kolkata, West Bengal
Website: https://gnit.ac.in/pdf/Final-Brochure-of-iCORE-2020.pdf

Renewable Energy Expo
February 13–15, 2020
Chennai, Tamil Nadu
Website: https://www.renewableenergyexpo.biz/

International Conference on Renewable Energy Integration into Smart Grids (ICREISG-2020)
February 14–15, 2020
Bhubaneswar, Odisha
Website: https://chem.cvrce.edu.in/icreisg20/

INTERNATIONAL

2020 Energy Policy Outlook Conference & Innovation Summit
February 4–7, 2020
Washington, DC
Website: https://energyoutlook.naseo.org/

8th Winterwind International Wind Energy Conference
February 03–05, 2020
Åre, Sweden
Website: https://winterwind.se/

The Meeting Place for European Investors and Financiers to Find Projects
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Victoria Park Plaza, London
Website: https://financeeurope.solarenergyevents.com/

International Conference on Clean and Green Energy
February 10–12, 2020
Barcelona, Spain
Website: http://www.iccge.org/

Solar Energy to Biomass Conference
February 11–14, 2020
Porto, Portugal
Website: http://se2bconf.com/

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/Scheme wise Physical Progress in 2019-20 & Cumulative up to Dec 2019			
Sector	**FY- 2019-20**		**Cumulative Achievements (as on 31.12.2019)**
	Target	**Achievements (April-Dec 2019)**	
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	3000.00	1879.21	37505.18
Solar Power - Ground Mounted	7500.00	5013.00	31397.30
Solar Power - Rooftop	1000.00	536.88	2333.23
Small Hydro Power	50.00	78.40	4671.55
Biomass (Bagasse) Cogeneration	150.00	83.00	9186.50
Biomass (non-bagasse) Cogeneration)/ Captive Power	100.00	0.00	674.81
Waste to Power	2.00	1.50	139.80
Total	**11802.00**	**7591.99**	**85908.37**
II. OFF-GRID/CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	12.41	191.13
SPV Systems	400.00	29.61	945.22
Total	**411.00**	**42.02**	**1136.35**
III. OTHER RENEWABLE TECHNOLOGIES (Capacity in Nos.)			
Biogas Plants	0.76	0.12	50.39

Source: www.mnre.gov.in

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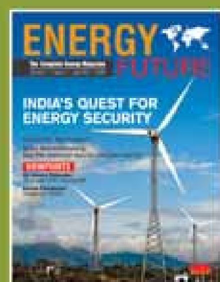

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DELENG/2012/49326 ISSN 2278 – 7186