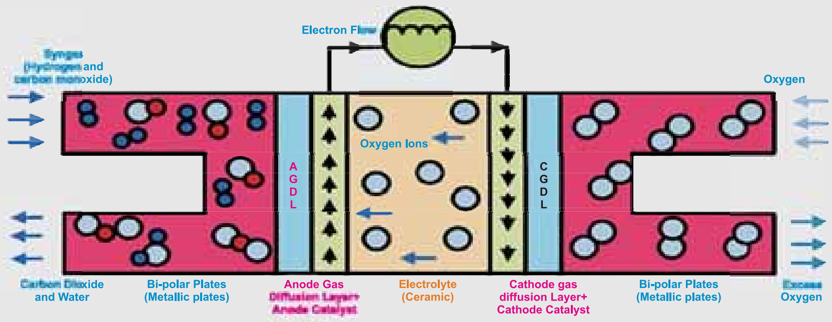

Figure 7 Portrayal of internal operation of solid oxide fuel cells

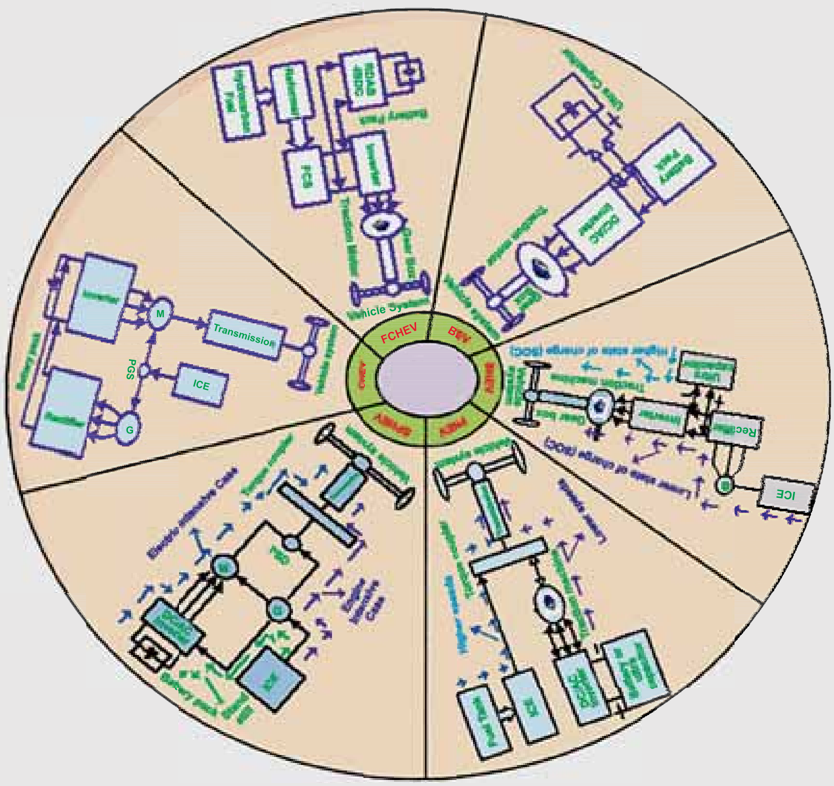

Figure 8 Description of topologies of drivetrains for electric vehicles available in India

of the system. However, some of the energy is lost because of the two-stage power-conversion process. Moreover, the engine/generator set maintains the battery charge around 65%–75%. A series hybrid vehicle is more useful for city driving.

Parallel Hybrid Electric Vehicles

In parallel hybrid electric vehicles (PHEVs), the traction motor and generator of the system are mechanically connected through the torque coupler. A PHEV has various modes of operation based on the usage of generator and traction motor. In PHEVs, the torque coupler is designed using digital concepts, such as continuous variable transmission rather than the conventional fixed variable transmission system for efficient usage of fuel and optimal operation. The transmission losses are lesser when compared to SHEVs, but PHEVs have a much bigger size and more complex operation and control.

Series–Parallel Hybrid Electric Vehicles

The advantages of both the series and parallel configurations of hybrid electric vehicles (HEVs) can be combined. When acceleration is required, the electric traction motor is used in combination with the ICE to give extra power in both the configurations. During braking or deceleration, the traction motor is used as a generator to charge the battery. In standstill, the ICE can continue to run and drive the generator to charge the battery, if needed. However, it must be highlighted here that the series–parallel HEVs are also relatively more complicated and expensive. Table 1 gives the performance index of a series–parallel HEV.

Complex Hybrid Electric Vehicles

Another form of series hybrid configuration is the complex hybrid electric vehicle (CHEV), which is a split-power HEV topology. In CHEVs, the energy flows in a fashion similar to that of either a parallel HEV or a series HEV. In the parallel HEV mode, energy flows from the ICE via the gearbox to the wheels, whereas in the series HEV mode of operation, energy flows from the generator and motor to the wheels. Table 1 gives the performance index of a CHEV.

Fuel Cell Hybrid Electric Vehicles

The potential for superior efficiency and zero (or near-zero) emissions has long attracted interest in fuel cells as the potential automotive power source of the future. The overall goal of the ongoing fuel cell research and development programmes is to develop a fuel cell engine that will give vehicles the range of conventional cars, while attaining environmental benefits comparable to those of battery-powered electric vehicles. The power conditioner must have minimal losses leading to a higher efficiency. Power conditioning efficiencies can typically be higher than 90%.

Statistical Analysis and Trends of Fuel Cell Electric Vehicles in India

The technology of fuel cells is extremely advanced in the European and American markets, spurring a growth in their sales. In comparison, the sales of fuel cells have been very sluggish in the Indian market. The early 2010s saw the development of prototype fuel cell systems for transportation applications, and in the later part of 2015, the country started producing fuel cells for portable and transportation applications. The production and sales of fuel-cell-based electric vehicles are expected to reach a peak of around 3 lakh vehicles by 2020. Figure 9 shows the predicted world market, especially for buses and cars. India does not have sufficient knowledge in the technology of fuel cell electric vehicles compared to the Western countries. It will take some time to reduce the cost per kW for these vehicles. In early 2004, the cost was `9000 per kW for fuel cell systems, which later has come down because of advances and availability of materials to make fuel cell systems and availability of skilled labour for production. India has a target of reducing the cost to `1800 per kW of fuel cell system (PEMFC) by 2020 and `1000 per kW by 2030 (shown in Figure 10).

The fuel cell system is manufactured in separate parts and assembled like a transformer. It has several components such as membrane electrode assembly, gas diffusion layer, bipolar plates, and field plates. Figure 11 gives the breakdown cost of PEMFC system components in 2008. By 2016, the cost of a PEMFC system was expected to decrease by 15% compared to 2008. This price reduction has been feasible because of reduction in the manufacturing cost of catalysts and better fuel management. Reduction in the PEMFC system cost achieved is 15%, as shown in Figure 11 as the hatched portion.

The worldwide electrification of vehicles started from 1997 as a result of the Kyoto Protocol for improving environmental conditions. It is a big challenge for the automobile industry to develop vehicles with zero emission and emit less harmful particulates in the environment. Due to this protocol, a lot of advancements in vehicle technology and drivetrains of vehicles have started appearing in the market, such as mild hybrid, full hybrid, PHEVs, and so on to name a few (Figure 12).

The costs of different types of fuel cell systems are shown in Figure 13, wherein it can be seen that the cost of SOFCs is the highest compared to the other fuel cell systems. The cost of reference fuel cell system is `37,000 per kW, and a huge difference exists between the PEMFC system and the reference system. The cost of the fuel cell system would become equal to that of the reference system by 2020s, according to the data from the Centre

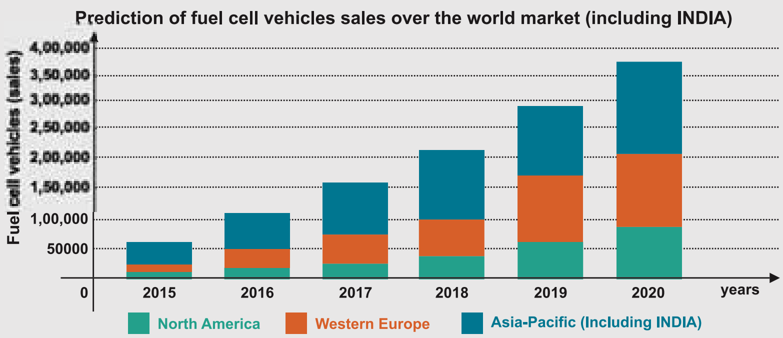

Figure 9 Prediction of fuel cell vehicle sales over the world market

Source Pike Research

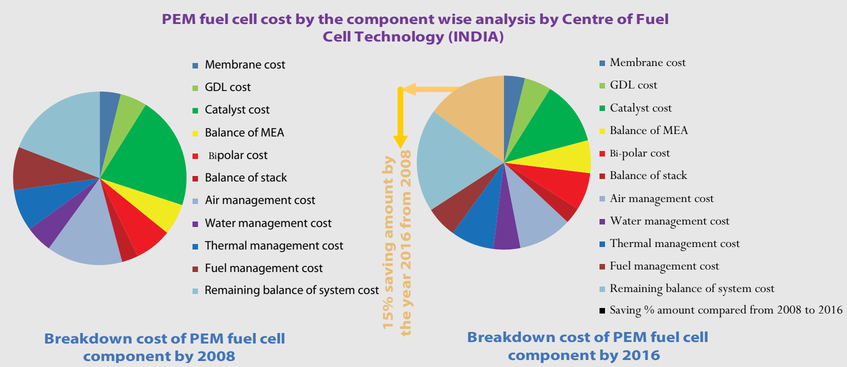

Figure 11 Breakdown cost of proton exchange membrane (PEM) fuel cell component in financial years 2008 and 2016

Source www.arci.res.in/centres-about-fuel-cell-technology

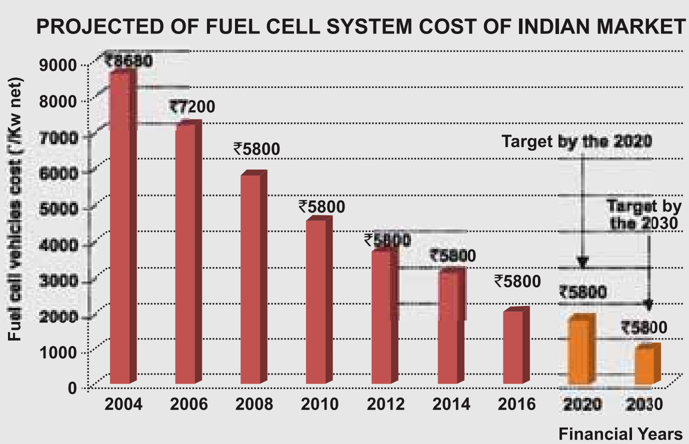

Figure 10 Projected proton exchange membrane (PEM) fuel cell system cost in the Indian market

Source Centre of Fuel Cell Technology

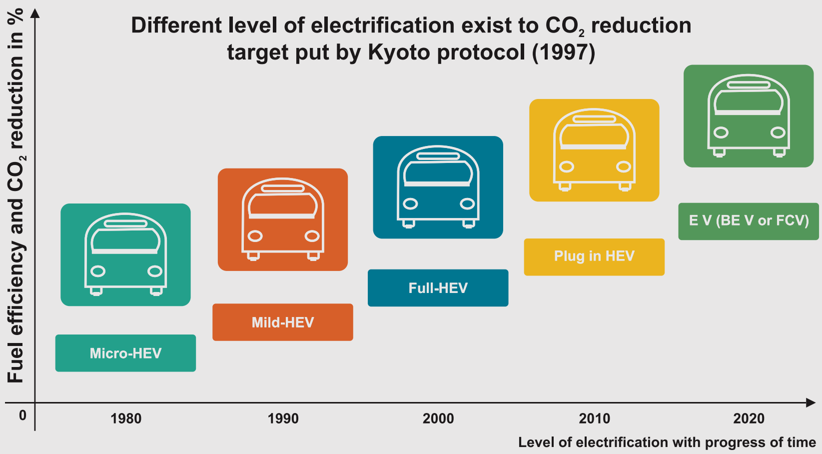

Figure 12 Different levels of electrification to reach the target set by the Kyoto Protocol over the world market to reduce greenhouse gases

Source http://indianpowersector.com/2016/06/hydrogen-energy-fuel-cell-in-india-a-way-forward

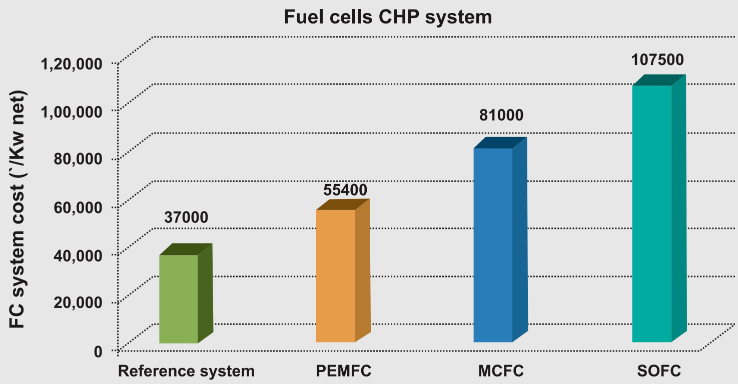

Figure 13 Comparison among the different fuel cell systems over the reference system

Source www.cecri.res.in/ResearchAreas/ElectrochemicalPowerSources

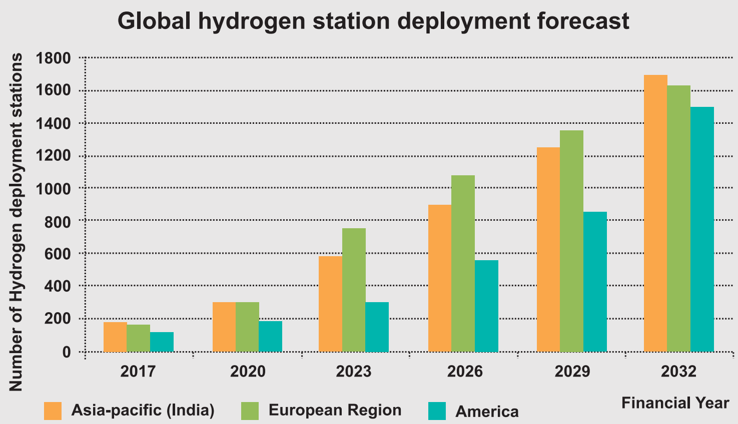

Figure 14 Deployment of hydrogen fuel stations in the world market, including the Faridabad hydrogen fuelling station

Source www.cecri.res.in/ResearchAreas/ElectrochemicalPowerSources

of Fuel Cell Technology (CFCT) of India. By 2032, the estimated deployment of hydrogen fuel cell stations worldwide is 4500. India will have to deploy at least 50 stations by then, while the present number is two (Faridabad and Dwarka, Delhi NCR), as shown in Figure 14. In the early 2030s, the Asia–Pacific region would have more hydrogen stations compared to the rest of the European zone as well as America, as shown in Figure 14.

Development of FCVs in India

- A group of BHU scientists and the MNRE have achieved a breakthrough in cutting-edge FCV technology. The fuel box for a motorcycle weighs about 17 kg, or twice that of a tank with 10 litres of petrol. This lasts for 70–80 km before a recharge. During tests, the three-wheeler clocked a range of 50–60 km.
- A fuel cell (PEMFC) battery hybrid van has been developed in the country.
- A reformer for a 10 kW PEMFC system was developed and tested in the CFCT.
- TATA Corporation Ltd and ISRO have taken the lead role in introducing the latest FCV technology with the new fuel-cell-based passenger vehicle “Starbus” in India during the financial year 2012/13.

Challenges of FCVs in India

Fuel Infrastructure

- In the case of electric vehicle applications, the fuel cell reaction has slower dynamics, and it may not be able to respond to sudden acceleration demands. Moreover, the fuel cell electric vehicles may have to be supplemented with a storage battery or ultracapacitor to deliver the required power instantaneously.
- If vehicles are hydrogen fuel based, then the equipment for producing, distributing, storing, delivering, and maintaining hydrogen fuel is important and needs to be in place.

Cost

- A competitive cost of `4000–`6700 per kW in the automobile sector would be acceptable for the fuel cell power pack.
- Currently, FCVs are more expensive than conventional vehicles and hybrids, but costs have decreased significantly and are approaching more affordable rates in the coming years.

Durability and Reliability

- The fuel cells would have longer life if and only if the hydrogen-storing tank is properly maintained and the system is properly cooled.
- The long-term performance, safety, and reliability of FCVs have not been significantly demonstrated in the market.

System Size

- The size and weight of the current FCVs must be further reduced to meet the packaging requirements for the automobile industry.
- Greater policy support and investment are essential to achieve market readiness. The Indian government must support FCV development through favourable policies and implementation of some pilot projects in reputed national scientific research labs and reputed organizations such as IITs and NITs.

Lesser Familiarity of the Public

- Fuel cell technology must be embraced by consumers before its benefits can be realized. The technology would come into the market if and only if it is marginally higher or comparable in cost per kW when compared with the hybrid vehicles and plug-in hybrid vehicles.

Comparison

The drivetrains of electric vehicles are distinguished based on key parameters, such as propulsion, efficiency, refuelling time, speed (average maximum speed), acceleration (average), and cost and technology.

Conclusion

This article explores the Indian PEMFC vehicle market with respect to the need for fuel cells in the transportation field and the necessity for zero-emission vehicles in logistic hubs. It also identifies specific fuel supply strategies to meet the growth of fuel cell technology.

Table 1 Comprehensive comparison among electric vehicles

	Electric vehicles			
	Internal combustion engines	**Battery electric vehicles**	**Hybrid electric vehicles**	**Fuel cell vehicles**
Parameters				
Propulsion	Internal combustion engines	Electric motor drives	Electric motor drives, internal combustion engines	Electric motor drives
Energy storage subsystems (ESS)	Fossil or alternative fuel	Battery/ supercapacitor	Fossil or alternative fuel, battery/super capacitor	Hydrogen tank, battery/ super capacitor
Energy source and infrastructure	Gasoline stations	Electrical grid charging facilities	Gasoline stations, electrical grid charging facilities	Hydrogen, hydrogen production, transportation infrastructure and facilities (for plug-in hybrid)
Efficiency	Converts 20% of the energy stored in gasoline to power the vehicle	Converts 75% of the energy stored in supercapacitor to power the vehicle	Converts 40% of the energy stored in gasoline and supercapacitors to power the vehicle	Converts 50% of the energy stored in hydrogen to power the vehicle
Refuelling time	Typically 5 min	Normally 5–7 hours	Depending on the usage	5 min
Speed (average maximum speed)	124 miles per hour	80 miles per hour	110 miles per hour	40–95 miles per hour
Acceleration (an average)	0–55 miles per hour in 8.5 sec	0–50 miles per hour in 6–7 hours	0–60 miles per hour in 6–7 sec	0–60 miles per hour in 4–6 sec
Major issues	Sound and air pollution	Battery size and management, battery life, charge facilities, and cost	Battery size and management, control, optimization and management of multiple energy sources	Fuel cell cost, life cycle and reliability, hydrogen production, infrastructure cost
Cost (`)	950,450–1,157,550	1,362,500–1,770,750	1,294,000–1,702,450	408,600–6,012,000
Technology	Obsolete technology	Fully available	Huge demand and good technology available	Under development, require huge technology to reach the customers

Several environmental and economic drivers are inspiring the fuel cell technology players in developing countries such as India. As mentioned earlier, PEMFC vehicles have many merits compared to ICEs and hybrid vehicles. These are efficient and emit less or no greenhouse gases. In the beginning of the eighteenth century, Humphrey Davy invented and demonstrated the concept of fuel cells. Later, William Grove, a chemist, developed a fuel cell in 1839.

Grove led a series of experiments with, what he termed, a gas voltaic battery. The term 'fuel cell' was used for the first time in 1889 by Charles Langer and Ludwig Mond, who researched fuel cells using coal gas as a fuel. In the early 1960s, NASA and its industrial partners did experimental work on manned space vehicles based on alkaline fuel cells (AFCs). Later, the International Fuel Cells (IFC) made advances in AFCs for the Apollo space mission, which enabled supporting the requirements of drinking water and electricity to the astronauts.

In the light of this historical evolution, according to experts, the future belongs to modern FCVs. Therefore, it is prudent to say that there is a huge potential for FCVs in the future in our country. EF

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ENERGY STORAGE

A Key Enabler and Black Start Support System

Energy storage is a crucial tool for enabling the effective integration of renewable energy and unlocking the benefits of local generation and a clean, resilient energy supply. Through this article, **Radhey Shyam Meena**, **Dilip Nigam**, **Dr A K Tripathi**, **Dr P C Pant**, **Prof. D K Palwaliya**, **Dr Rohit Bhakar**, and **Poonam** provide an overview of energy storage deployments in emerging markets in India through which emerging economies must bring reliable electricity service to the those people in India who currently lack access to electricity.

Energy storage in the form of electrochemical cells and batteries has been an integral part of the off-grid solar programme. In reference of the large-size grid connected solar and wind plants, introduction of storage is being viewed to address a number of issues, such as grid stability, frequency regulation, load shifting, transmission congestion, balancing, etc.

Introduction

The Government of India is committed to achieve a total cumulative capacity of renewables of 175 GW by 2022. While the costs for renewable generation continue to fall, integrating and effectively using these renewable resources, especially in regions with weak grid infrastructure, will require energy storage. Experience over the past several decades has shown that the traditional, centralized grid cannot or will not cost-effectively provide even basic electrical service to the underserved population within a reasonable amount of time. Distributed and remote power systems have enormous potential to provide service around the world, but are subject to a number of barriers. Despite a major effort by the government and regulators, deployment of both renewable resources and energy storage lag behind expectations in India.

The current global energy consumption is rapidly increasing together with the demand for primary energy sources, thereby causing rapid depletion of these limited sources. Environmental pollution is also increasing with the consumption of fossil fuels, which is affecting the health of living beings on earth. The influence of greenhouse gas emissions on global warming is also well documented. Thus, energy security and environmental degradation are a growing global concern. The conventional/commercial energy sources are not likely to meet the energy demand which necessitates alternate energy sources. This has compelled to take initiatives to shift from carbon-based to carbon-neutral technologies, such as solar, hydro, wind, biomass, and biofuel-based technologies, etc.

In India, several key factors are driving the market for energy storage, perhaps most notably the ambitious National Solar Mission, a national target to install 100 GW of solar PV capacity by 2022 which would make the country one of the largest solar power markets in the world. As of end January 2018, the cumulative installed solar capacity was around 18.5 GW. India's rapid population growth, particularly in urban areas, is driving the need for increased investment in both electricity generation capacity and the transmission and distribution (T&D) infrastructure across the country. Furthermore, the country experiences frequent power outages due to severe weather, insufficient generation capacity, and fragile infrastructure, which contribute heavily to the need for new investments to improve the grid's resilience and reliability. The projected annual stationary energy storage deployments, power capacity, and revenue by market segment for the year 2016–2025 is shown in Figure 1. Despite a major effort by government and regulators, deployment of both renewable and energy storage have lagged behind expectations in India. A number of planned storage projects have been delayed or cancelled due to lack of affordable financing and the cost overruns resulting from poorly planned development and limited local technical expertise. Furthermore, the weak condition of the grid and poorly organized energy markets are proving to be significant barriers towards the deployment of storage. However, there have been a few positive developments in recent months. The Ministry of New & Renewable Energy (MNRE), Government of India, approved India's first solar-wind hybrid project with storage of capacity 160 MW proposed to be developed at Muthavakunta and Kanaganapalli villages, Kanaganapalli Mandal in Ananthapuram district of Andhra Pradesh by the New & Renewable Energy Development Corporation of Andhra Pradesh Ltd (NREDCAP), Government of Andhra Pradesh, under the Solar Park Scheme of MNRE. The capacity of 160 MW includes 120 MW from solar and 40 MW wind with 40 MWh storage facilities. The Solar Energy Corporation of India (SECI) has called the tenders for both solar and wind along with storage. The World Bank loan is proposed to be utilized by SECI for this project. A power purchase agreement (PPA) would be signed by DISCOMS with SECI without mentioning the tariff. APTRANSCO would identify the site for construction of pooling substation of 33/220 KV along with inter-connecting lines. It was decided that the said substation would be connected to 400 KV substations at Hindupuram for permanent evacuation of power. Earlier, in Himachal Pradesh, a 2.5 MW hybrid plant has already proposed with capacities of 2.0 MW of photovoltaic (PV) and 0.5 MW of wind. Besides, capacity of 1 MWh battery storage will be set up at Kaza, Lahaul Spiti district, Himachal Pradesh. The proposed plant is expected to generate approximately 6 million units of electricity.

Further, under the Prime Minister

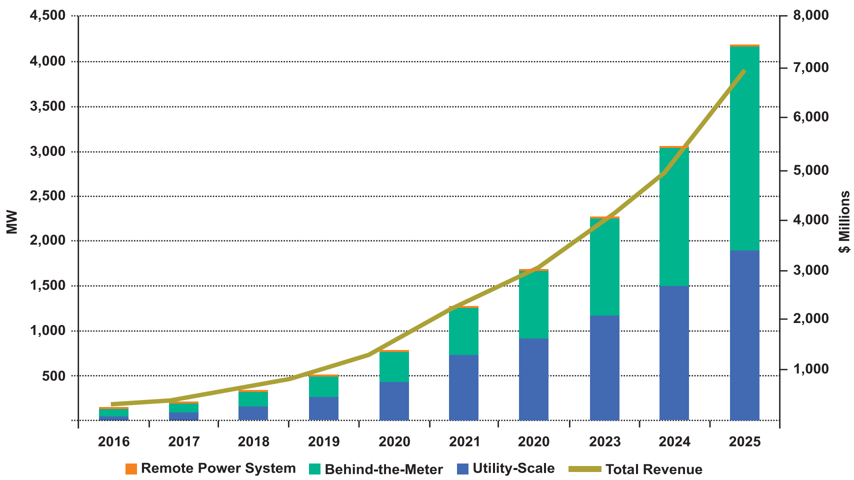


Figure 1 The projected annual stationary energy storage deployments, power capacity, and revenue by market segment for the years 2016–2025

Development Package (PMDP) at Leh and Kargil in Jammu & Kashmir a targets for 14 MW solar projects with 42 MWh battery storage facility is under the consideration of Standing Finance Committee. In the first phase it is proposed to set up at least 7 MW solar projects capacity with 3 hours battery storage facility each in Leh and Kargil.

This type of requirement, typically only used for island grids, is necessary to ensure grid stability because the storage will be used to smooth solar PV output and control ramp rates. To overcome barriers to storage development in India and throughout the region, this type of requirement for combined solar PV plus storage may be crucial for establishing local technical expertise and developing investor trust in the technology and project development process.

Other than India, there have been few energy storage market developments in South Asia till date and the deployments are expected to be limited over the coming decade. Numerous factors are limiting the growth of the stationary energy storage market worldwide. Several of these barriers include: lack of familiarity with storage technology among utilities, regulators, and financiers; high upfront costs; the need for highly skilled and experienced technicians to maintain and operate systems correctly; regulations preventing third-party or customer ownership of certain DERs; regulations preventing storage from competing in energy, ancillary service, or capacity markets.

In view of these, there is an urgent need of energy storage technology in India to black start* the system. For isolated power systems such as micro/mini grids, a reliable and efficient black start procedure is more important than interconnected power systems. Since the problem is a non-differentiable mixed integer nonlinear programming (MINLP) problem that is difficult to be solved by traditional mathematical optimization techniques, a hybrid approach combining the graph algorithm and swarm intelligence may be adopted to achieve the optimal solutions. With the modular structure and multi-thread programming, the system can efficiently evaluate the optimal black start strategies according to the prevailing system condition and the planning objectives. The energy storage system is used mainly for stabilization of energy for a short span, issue of ride through capability, and to fulfill the dispatchability of any system. Energy storage used in conjunction with distributed generation (DG) / Grid can be divided into two groups. The first one stores energy as electrical energy and the second one is that which stores it in some other form (e.g. electro-chemical storage, thermal storage, hydraulic storage, pressure storage, mechanical storage, electro-magnetic storage, electro-static storage, etc.), which can be converted into electrical energy when

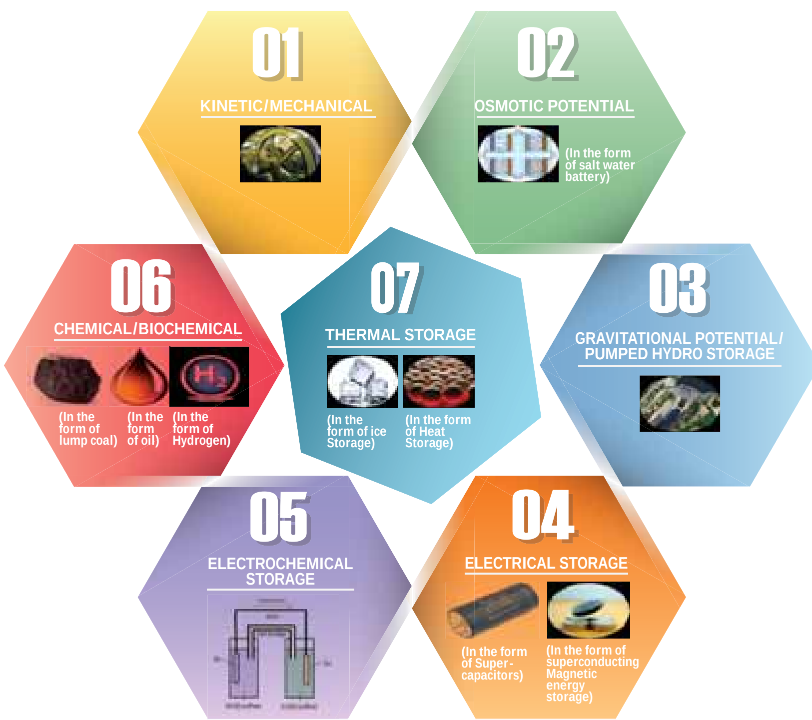


Figure 2 Seven major forms of energy storage

* A black start is the process of restoring an electric power station or a part of an electric grid to operation without relying on the external electric power transmission network.

needed. Seven major forms of storage, enumerated in Figure 2, are currently in practice.

In case of energy stabilization, it permits the distributed system to run at a constant stable output level with the help of the energy storage devices, even if the load fluctuates rapidly. The ride through capability is the capability of energy storage device which provides the proper amount of energy to loads, when the DG unit is unavailable and the dispatchability permits the DG owner to commit in advance, for certain time, regardless of how much power the DG unit is producing at that time. The dispatchable energy is always more worthy than non-dispatchable energy due to its inherent characteristic of availability and commit-ability.

Storage systems can be designed with a broad portfolio of technologies, such as pumped hydro, Compressed Air Energy Storage (CAES), a large family of batteries, flywheels, and superconducting magnetic energy storage (SMES). Each technology has its own performance characteristics that makes it optimally suitable for certain grid services and less so for other grid applications. There are several applications of storage as shown in Table 1.

Key Drivers of Storage

Energy storage is set to play a key role in enabling better utilization of both new and existing resources, more local generation and use of micro-grids as well as strengthening the grid against diverse threats, including natural disasters and physical attacks. This dynamic will play a major role in emerging economies where grid infrastructure may already be unreliable and can benefit from the resilience provided by energy storage.

Perhaps the most important driver of utility-scale storage is the substantial growth in the amount of renewable energy being deployed around the world. The waste or curtailment of renewable energy production presents a key opportunity for long-duration, utility-scale storage to enable greater utilization of these resources by shifting energy supply in ways to be better aligned with demand. The next major driver is the effort by governments around the world to reduce carbon emissions. Another key driver is the need for new infrastructure to modernize and expand the grid. Another major driver is the need to improve the resilience of the electrical grid.

As a result of these trends, grid operators and regulators are beginning to recognize the value of storage for multiple services. As deployed systems continue to meet expectations, standardized contracts are likely to become the norm, which can result in

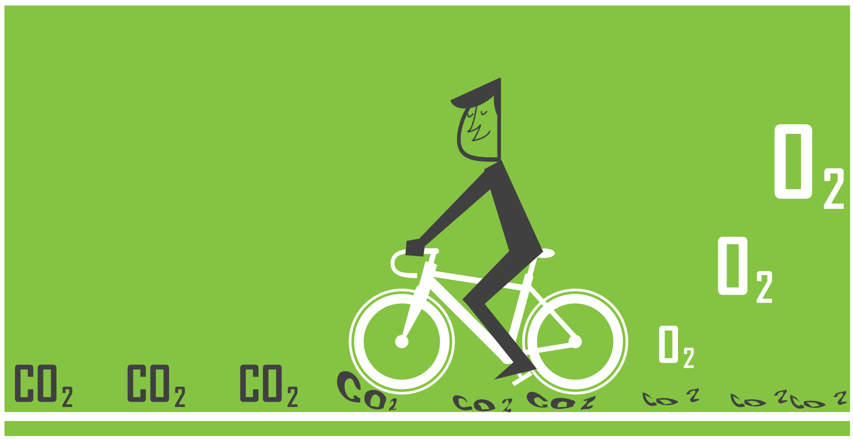


Table 1 Applications of Storage Technology

Application	Capacity Requirement	Classification	Discharge Cycles per Year	Applicable Technologies
Peak Pricing Arbitrage	4-6 hours	Bulk Storage	200–400	Advanced Batteries, Compressed Air Energy Storage (CAES), Pumped Storage
Generation Capacity	2-6 hours	Bulk Storage	200–600	Advanced Batteries, CAES, Pumped Storage
Transmission and Distribution (T&D) Asset Capacity	2-4 hours	Bulk Storage	201–600	Advanced Batteries, CAES
Frequency Regulation	1-15 mins	Ancillary/ Power Services	1,000–20,000	Advanced Batteries, Flywheels, Ultracapacitors
Volt/VAR Support	1-15 mins	Ancillary/ Power Services	1,000–20,000	Li-ion, Advanced Lead-Acid, Flywheels, Ultracapacitors
Renewables Ramping/ Smoothing	1-15 mins	Ancillary/ Power Services	500–10,000	Advanced Batteries, Flywheels, Ultracapacitors

more predictable revenue streams. Due to this maturation of the industry, the financial community is growing more comfortable with investments in energy storage, which are further lowering the cost to deploy systems and accelerating growth of the industry.

Till date, backup power has been one of the major selling points for energy storage. Both distributed customers and utilities are interested in utilizing battery systems in homes to improve the resilience of their power supplies and help mitigate the effects of power outages caused by natural disasters or grid equipment failures. To enable an adequate supply of backup power, the sizing of storage is crucial. If there is too little power or energy capacity (measured in kW and kWh respectively), the system will not be able to support critical loads during an outage. However, an oversized system will be prohibitively expensive compared to alternatives. The ability to provide backup power is particular to the value proposition of battery storage systems.

In large customer-led storage or behind the meter markets, the main driver for these systems has been the ability to reduce electricity expenses. This is primarily done by reducing peak demand and time-of-use (TOU) rates. Demand charges are charges levied by electric utilities based on the maximum electricity demand of a customer over a period ranging from 15–60 minutes, typically over an interval of 30, 60 or 90 days. These charges may then stay in place for 30, 60 or 90 months and such charges can account for a significant portion of commercial and industrial (C&I) customer's bill. Since energy cost management is the primary function of energy storage for C&I customers, utility rate structures are expected to determine the economics in a given market. The higher and more volatile electricity prices and demand charges are for C&I customers, the better is the business case for energy storage.

A key component of the energy storage value proposition in developed and emerging markets is consuming the majority of energy generated by onsite solar photovoltaic (PV) and other DG systems. In most developed countries, the compensation structure for solar PV discourages the use of storage because PV system owners are guaranteed payment for any excess energy generated by their system at a rate that is equal to or higher than the retail cost of electricity. However, due to the successful growth of the solar PV industry in many countries, compensation programmes, including net metering and feed-in tariffs are being phased out or replaced with alternative rate structures in many areas. When these types of programmes are eliminated or when compensation for exported energy falls below the retail price of electricity, storage can allow end users to save money. By storing excess solar PV energy produced throughout the day, customers can avoid purchasing energy from the grid during evening peak demand periods when electricity rates may be highest in markets with dynamic pricing.

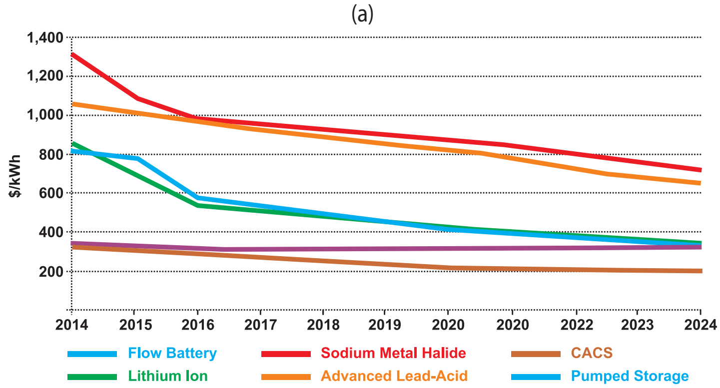
Customer-led storage allows customers to keep the excess energy generated onsite, thus, preventing many of these issues. These systems can also automatically respond to grid signals to correct frequency, voltage, and reactive power, thereby greatly improving grid stability and reducing barriers and objections to increasing deployments of distributed renewables. The trends of cost in utility scale and customer-led system are as shown in Figures 3 (a) and 3 (b).

Need of Energy Storage

Energy storage restores flexibility to low carbon systems and it actually works as a part of a system.

Energy Storage Benefits

It facilitates clean technology by restoring flexibility, provides multiple services; capable of rapid response; time shifting and decoupling supply from demand; enhances security of supply and mobility; reduces dependence on fossil fuels; improves efficiency; and empowers consumers. Energy storage has captured the public imagination



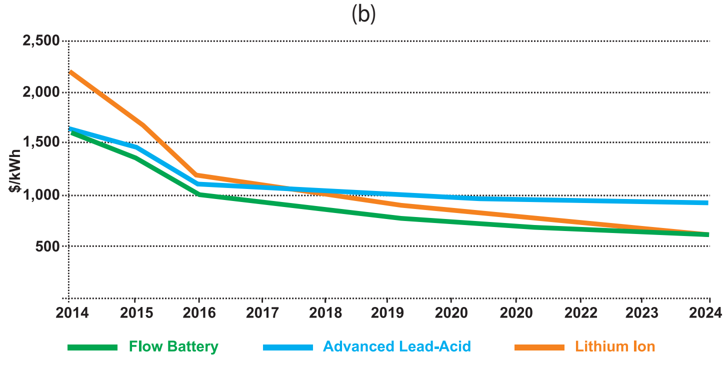
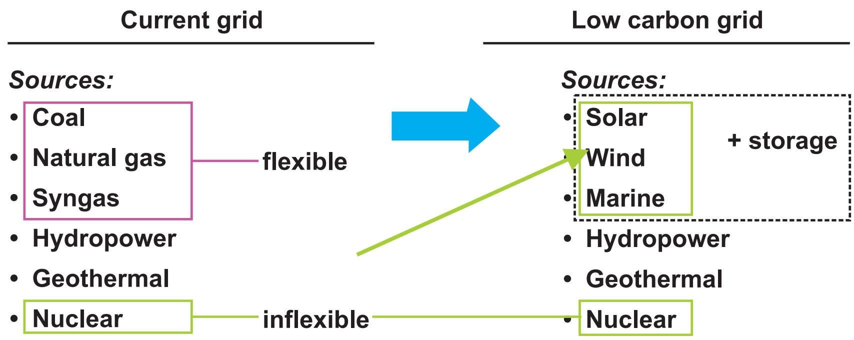


Figure 3 (a) Utility-Scale Energy Storage System Cost Trends (b) Behind-the-Meter Energy Storage System Cost Trends



and provides a unique opportunity for engagement while facilitating a cleaner world along with decarburization. It reduces dependence on fossil fuels (oil spills) and replaces diesel generators (improves air quality, reduces noise pollution). It also helps in clean transportation.

Figure 4 Sources of Pollution

In addition to these, storage helps in operation of multiple grid services and make renewable smooth and dispatchable through which a rapid response (milliseconds) system may be developed for any event. In case of shifting of load; peak shaving-energy store supplies power during peak demand, load leveling-charges up when supply is too high and decouples demand from supply. It helps to improve the quality of power using voltage control and enhances frequency regulation of grid resilience when changes occur in the system. Modern life and its safety benefits would be impossible without energy as it enhances the security of supply and enhance the grid resilience and offers multiple and rapid services. In the case of energy storage, the offsets network upgrades its costs and disruptions by making use of existing assets which also help in autonomy/islanding for a critical system. Developing nations and off-grid regions are balancing the micro-grids-bottom-up grid developmental activities and made deployable in the modular energy applications since it helps to support critical infrastructure/services during natural disasters, allows time to respond, recovery efforts can start sooner and mostly provide support to black start power which is also known as restart power as shown in Figure 5.

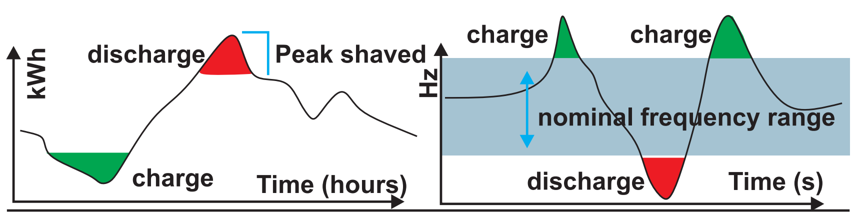


Figure 5 Black-start support via storage system

In case of non-renewable energy, factors such as oil wealth, are concentrated in few countries. However, the renewable is available to everyone at a minimum cost which reduces the expensive, scarce, risk of fuel theft and more reliable source of energy.

Mobility: In connection with mobility, energy storage technology is feasible for portable devices in the connectivity sense, in major transport systems, in heat and cold storage with efficient and required energy match, in the air conditioning system in a warming world, in winter for warmth, in food safety, and leads to less wastage of medicines. It also supports the empowerment the consumers in use of energy in another time and location.

In line with its aspiration to achieve 100% electric vehicle (EV) sales by 2030, India can rise among the top countries in the world in manufacturing batteries. This will, however, require a strategy designed to overcome India's relatively weak initial position in battery manufacturing while claiming an increasing share of total battery value over time. India's market for EV batteries alone could be worth as much as $300 billion from 2017 to 2030. India could represent more than one-third of global EV battery demand by 2030, if the country meets its goals for a rapid transition to shared, connected, and electric mobility (Figure 1). Since the battery today accounts for about one-third of the total purchase price of an EV, driving down battery costs through rapidly scaling production and standardizing battery components could be a key element of long-term success for India's automotive sector. India's EV mission could drive down global better prices by as much as 16% to $60 per KWh. Given the projected scale of its domestic market, India could support global-scale manufacturing facilities and eventually become an export hub for battery production.

Work on thermal storage has also been undertaken in the form of a research and development (R&D) project at the Brahmakumari Ashram, Mount Abu.

However, the development of advanced ESSs has been highly concentrated in select markets, primarily in regions with highly developed economies. Despite rapidly falling costs, ESSs remain expensive and the significant upfront investment

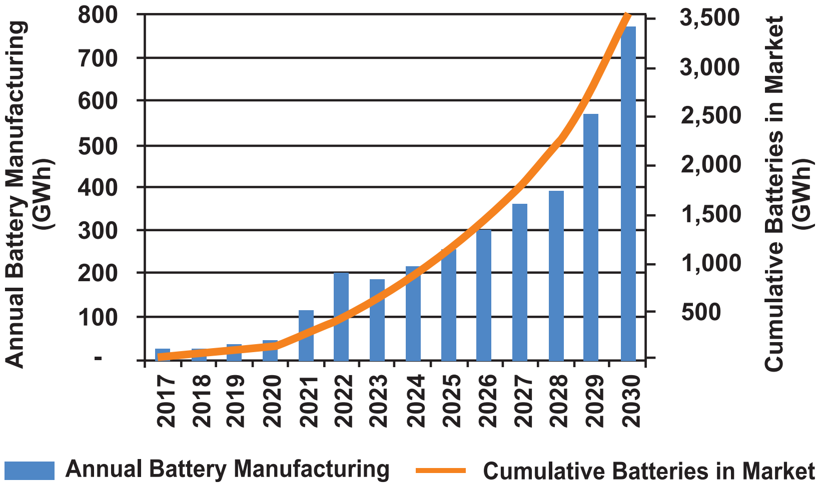


Figure 6 Annual and cumulative battery requirements to meet India's EV ambitions

Current Practices

In India, mainly lead acid batteries, both flooded and VRLA types, are being widely used as electricity storage device in SPV systems. Technological advancement in lead acid technology has continuously been taking place which includes indigenously developed and commercialized gel-AGM hybrid type VRLA batteries and introduction of carbon anode to improve the cycle life of the batteries. Introduction of modern electrochemical devices, such as li-ion, redox flow batteries, in such systems has already taken place. In the grid-connected context, modern energy storage systems (ESSs) are being studied to acquire adequate experience before being introduced in the main system. These include not only the chemical and physical aspects of various electrochemical cells and batteries but also the battery management systems.

required is difficult to overcome without government support and/or low-cost financing. This type of advanced technology requires significant knowledge and expertise to be developed and operated cost-effectively. Furthermore, the services provided by ESSs are often not properly valued or recognized within existing energy market regulations. Even with these barriers, installations of stationary ESSs are increasing dramatically around the world as system costs are rapidly decreasing and as energy markets are being reformed to allow for the use of more distributed resources.

Technology Hazards: Every technology has some hazards in some applications and the storage technology also has a few hazardous situations. In case of the large energy reservoirs for storage of electricity, temperature, water, etc., there is always a risk of the security conserved and use of the right design aspects. When discussing about storage in the form of chemicals, there are also flammable, corrosive, toxic, and explosive issues which affect the entire system.

In the other category, damage of environmental condition, extraction and processing of raw materials, use of several chemicals in manufacturing units, disposal at the end-of-life of storage system, and safety during transportation are the major areas where focus is essential.

In the case of charged batteries system, there are certain restrictions in some applications, such as in airlines, zero charge can also damage the battery system and is dangerous situation.

To resolve these issues, certain aspects in designing are exercised in terms of safer mode, better packaging technology, protection built-in system, use of safer, and less reactive chemistries during designing of these types of

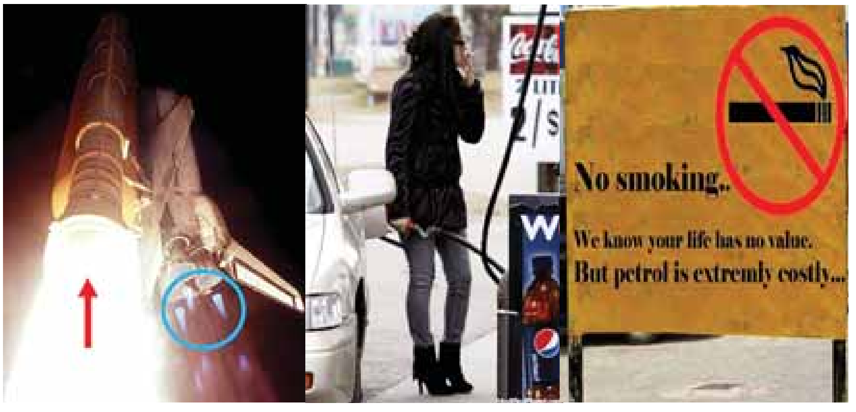


Figure 7 Hazards Point

storage items. Safer structure using the power electronics techniques are shown in Figure 7.

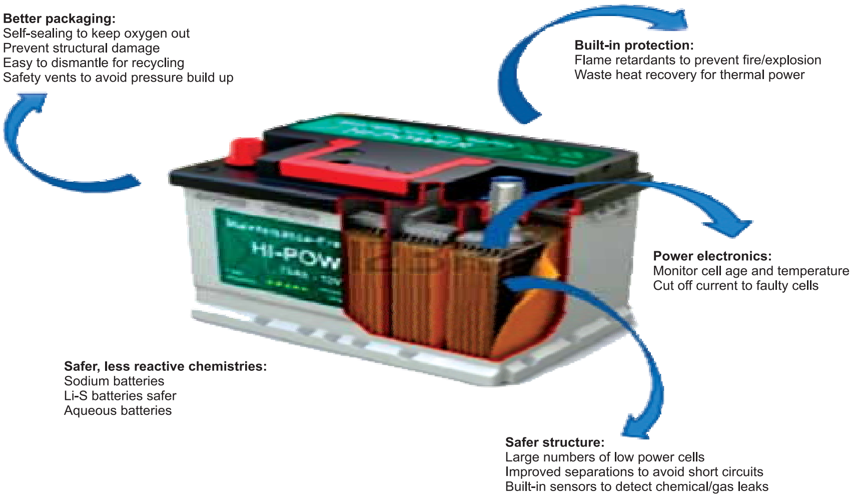


Figure 8 Safer design of storage battery

When discussing about hydrogen storage system, it is also important to go with safer mode as depicted in Figure 7. Although it is non-toxic and non-corrosive and lighter than air, it has some bad features such as being colourless, odourless, tasteless, and can emanate certain metals.

Table 2 Different Factors of Hydrogen

Property	Hydrogen	Natural Gas	Petrol Vapour
Auto-ignition temperature	585 °C	540 °C	232 °C
Flammability range in air	4%-75%	5%-15%	1.4%-7.6%
Explosion range in air	18%-59%	5.7%-14%	1.1%-3.3%
Minimum ignition energy	0.02 mJ (29%)	0.29 mJ	0.24 mJ
Radiant heat	Low	High	High

The Way Forward

A number of challenges remain for the growing utility-scale storage industry, especially in developing markets. As is the case with the entire energy storage industry, the high upfront cost for systems remains the most significant barrier to growth. However, there are additional issues that are significant because many industry stakeholders, including utilities, regulators, developers, and financiers, are often not familiar with energy storage, the benefits of the technology, and how it should be properly managed. Despite the major reductions in system costs that have been achieved over the past several years, utility-scale energy storage remains an expensive technology. The upfront cost for systems is one of the major barriers to the market's growth. Figure 3 provides a comparison of the cost trends and forecasts for various storage technologies. This assumes a duration of 4 hours for battery technologies (ex. 1 MW / 4 MWh) and a 10-hour duration for compressed air and pumped storage systems. The behind-the-meter energy storage industry continues to be a developing market for both C&I and residential customers. The critical factors enabling this market are the programmes supporting solar PV that compensate system owners for excess generation. However, many utilities are opposed to these programmes, including net metering and FITs, which can be disruptive to the power industry as a whole and may not appropriately value the cost of maintaining enabling grid infrastructure owned by the utility. Figure 3 (b) provides an illustration of the pricing trends and forecasts for BTM energy storage. This represents an average of costs across both residential and C&I markets and assumes systems with 2-hour duration (for example 50 kW / 100 kWh). As shown in Figure 3, the system costs have come down dramatically in the past two years.

Other major barriers to energy storage around the world have been the issuance of restrictive regulations and resistance from existing utilities. Despite the fact that these systems, when properly coordinated and incentivized, can improve the stability of the grid and allow for more renewables to be added effectively, they are viewed by some utilities as a direct threat to their business since it could allow some clients to deflect from the grid or greatly reduce the amount of energy they purchase from the grid. However, this is not always the case, and forward-looking utilities in some leading storage markets are supporting and using storage as a resource that can provide unique benefits to the grid.

Usage Cases: Mainly eight usage cases have been defined in the industry in three categories—Customer-led storage (behind the meter) in the domestic and I&C scale storage deployed alongside demand in the range of up 10 MW(<10 MW); Distribution-level storage for network reinforcement deferral or storage deployed by intermittent generators connected at the distribution level (<100 MW); and System level storage connected at the transmission level or primarily for system balancing (>100 MW). Energy storage will play a key role in building a smarter energy system. However, to understand where policy interventions could deliver the biggest benefit for consumers, Battery Energy Integrated System (BEIS) first needs to understand what value energy storage represents compared to conventional or flexible alternatives.

BEIS are taking a Use Case approach to understanding and supporting energy storage policy development. The Use Cases are split into two areas: electricity storage and heat storage. This document explores both categories of Use Cases; this section examines the electricity UC 1 to 5.

Each Use Case (UC) will set out for how the storage can meet the identified need, requirements of the technology neutral system with regards to attributes and performance and details of the investment case, including: Costs of the system (capital costs, operating costs and lifetime/discounted costs) and prospects for cost reduction; benefits of the system accrued to whoever is paying for the system; and drivers for installing the system (e.g. increasing energy security, sustainability, etc.). There are several applications of energy storage in energy arbitrage, peak reduction, ancillary service provision, and network reinforcement and optimal system balancing.

Energy Storage Enablers

New Business models: New and innovative business models are required to make storage projects attractive, behind the meter models may evolve where the developer or technology provider, retains ownership of the storage asset while sharing revenues from energy sales and services with the provider of the location. It potentially generates new IP and commercial incentives which may disrupt traditional models and approaches.

Commercial arrangements: The National Grid Ancillary Services are contracted for relatively short time periods (two to four years), extending the contract length would encourage more participants but may preclude new entrants, improvements to rules around the capacity market could encourage greater storage participation.

Clarification of policy: Clear policy relating to storage and its role in India energy strategy will promote storage as an investment opportunity and help financial institutes in developing financial models and contracts. Regulatory framework and market arrangements need to be updated to accommodate storage market needs and provide protection to consumers.

New classification of storage assets: Electricity storage installations are not classed as generation or demand assets, however, as they are able to inject on to the network their use by DNOs is constrained; a new class for electricity storage assets and an approach for their treatment should be considered a potential route forward.

Enable market signals and industry co-ordination: Clearly define the roles and objectives of storage participants and counterparties in energy markets, industry frameworks, and as service providers. Identify frameworks to establish clear price signals from central and decentralized energy markets, system services, and network usage.

Decision support and control: New intelligent control systems and decision support algorithms are needed to determine and issue instructions to operate storage assets in response to a wide range of technical and commercial requirements and to coordinate the responses. Uncoordinated responses may maximize revenue and cost reductions for a single asset from a range of potentially conflicting price signals but may also conflict with other system responses and requirements

Conclusion & Future Scope

Consider quantifying non-energy/cost benefits to deploying storage like the carbon impact of a Distribution Network Operators (DNO) deferring conventional reinforcement with distributed storage. The development of new business models potentially generates new IP and commercial incentives which may disrupt traditional models and approaches. Besides, considering various ways insofar as EVs can supply services to the grid; understanding the value storage can contribute to security of supply; and understanding technology gaps in the storage market based on findings and discussions.

While India is starting from a relatively weak position in battery manufacturing globally, the scale of its market opportunity is attracting strong interest from leading companies in India and across the world. Battery production in India could ramp quickly if manufacturers have confidence in the future of market growth. Clear and stable policies to guide India's transition to EVs are fundamental to support investment in vehicle and battery manufacturing capacity in India. Coordination among industry stakeholders and government can help define a pathway to growth and competitiveness by establishing a shared technology roadmap, creating common standards, and aligning policies. The government will play a key role in catalysing, convening, and driving this consortium. The government's active engagement will not just infuse urgency and purpose; it will create an opportunity for open dialogue on the policies around battery manufacturing and technology development. India's demand for batteries to meet its mobility transformation goals will support global-scale production that could place India among the world's leading battery manufacturers. By 2030, India could account for more than one-third of the global market for batteries for EVs. EF

Radhey Shyam Meena, Dilip Nigam, Dr A K Tripathi, Dr P C Pant, Prof. D K Palwaliya, Dr Rohit Bhakar, and Poonam, Ministry of New & Renewable Energy, Government of India, New Delhi 110 003, National Institute of Solar Energy, Gurugram, Haryana 122005, Rajasthan Technical University, Kota 32009, Malaviya National Institute of Technology, Jaipur 302 017, DMRIPC Pvt. Ltd, Dausa 303501; Email: rshyam.mnre@gov.in

SCHNEIDER ELECTRIC INNOVATION SUMMIT

Schneider Electric, the global leader in digital transformation of energy management and automation, hosted its first Innovation Summit in India on March 19 and 20, 2018, in New Delhi. The summit brought together more than 2,000 customers, policymakers, and industry leaders. Leaders shared critical insights on how automation and digitization are helping to manage energy with disruptive technology tools leading to efficiency in business. The summit also reiterated Schneider Electric's commitment to a sustainability agenda and complete alignment with the Indian government's long-term goal of bringing down the carbon footprint.

Addressing the plenary, Mr Amitabh Kant, CEO of NITI Aayog, said that the country is poised for paradigm shifts with huge disruptions in physical infrastructure. "We are creating 100 smart cities with another 50 cities which will be connected by metro and a few connected with bullet trains. The government is converging physical infrastructure with biometric-based digital infrastructure to improve human lives with uninterrupted water and electricity supplies, efficient public transportation, quality education, and healthcare services."

Opening the plenary session of the summit, Mr Anil Chaudhry, Zone President and Managing Director of Schneider Electric India said, "Schneider Electric's technologies are powering businesses and key government programmes, including Make in India, Smart Cities Mission, and Electric Mobility. Nearly 15% of India's solar capacity is based on Schneider technology. Digitization and the Internet of Things (IoT) are going to transform India's energy ecosystem so that all citizens have access to uninterrupted electricity at affordable rates."

The event featured strategic discussions and interactive deep-dive sessions among over 50 expert speakers from Schneider Electric, besides a diverse group of customers and partners from India and across the Asia-Pacific region. It was designed to further accelerate digital solutions to make New India Energy Positive. The expert sessions included those on intuitive industries, living spaces of the future, leveraging IoT in manufacturing facilities, enabling digital hospitals, re-imagining data centres for a connected tomorrow, empowering industrial original equipment manufacturers (OEMs) for the digital era, and inclusive growth of India through skill development and rural electrification.

The summit also showcased Schneider Electric's Innovation Hub, an exhibition of the company's rich portfolio of software, solutions, and services. The integrated zone displayed its next-generation EcoStruxure™ architecture and platform that delivers IoT-enabled open and interoperable solutions across user segments. The company also displayed its new range of IoT-enabled smart home solutions called 'Connected Homes'. It showcased digital demos bringing the innovative platforms closer to its customers as well as to a broader audience.

Given the huge potential in the electric vehicle (EV) charging space, Schneider Electric also displayed its EV charging infrastructure named EVLinks. EVLinks is already available in different markets across the world and the company is keen to tap into the nascent Indian market for the same. The EV charging platform can be installed both at homes as well as public places.

The event showcased the integrated command centre of the Naya Raipur smart city. Schneider Electric is developing the country's first green field smart city at Naya Raipur in Chhattisgarh. The integrated project for Naya Raipur Development Authority (NRDA) will cover the entire gamut of public services, such as transportation, surveillance, citizen applications, end-to-end smart grid solutions, end-to-end water management system, and integrated building management system. It will have a centralized command and control centre to manage emergency responses as well. EF

For further information about the event and the organization, visit <www.schneider-electric.com>

INSTALLATION OF AC & DC ELECTRIC VEHICLE CHARGING STATION BY EXICOM

Exicom Tele-Systems, headquartered in Gurugram, India, with growing global presence. The company has over two decades of experience in designing, engineering and manufacturing efficient, reliable and cost-effective power and energy solutions for electric vehicles, information technology, telecom and renewables. All deployments are backed by state-of-the-art R&D centre, manufacturing set-up and pan-India service support. Exicom is also the largest supplier of li-ion batteries with deployment of over 600 MWh in stationary storage applications in India.

Exicom Mobility division provides Li-ion battery and charging infrastructure solutions for EV applications including 2 wheeler, 3 wheeler, passenger cars and commercial transport. The company won the EESL bid to supply 125 chargers through a techno-commercial bidding process for installation in the Delhi NCR region.

The objective of the National E-Mobility Programme is to provide an impetus to the entire e-mobility ecosystem including vehicle manufacturers, charging infrastructure, companies, fleet operators, service providers, etc. Energy Efficiency Services Ltd (EESL) will aggregate demand by procuring EVs in bulk to derive economies of scale. These electric vehicles will replace the existing fleet of petrol and diesel vehicles.

Exicom Tele-Systems, headquartered in Gurugram, India, installed AC & DC electric vehicle charging station at Ministry of Power, Government of India, office in Shram Shakti Bhawan, New Delhi, during March 2018. It is part of the plan to develop electric vehicle (EV) charging points across the country. The Government of India has already set the deadline to move to electric by 2030. The Government has already announced their intentions to move to alternate fuels or electric cars to cut emissions and the step will help reduce pollution in the country. In continuation of their initiatives in this direction, the Ministry of Power launched the National E-Mobility Programme in India.

The launching of National E-Mobility Programme was led by Shri R K Singh, Minister of State for Power, New and Renewable Energy, Government of India

On the occasion, Shri R K Singh, Minister of State for Power, New and Renewable Energy, Government of India said, "After the successful tender of 10,000 electric cars last year, the demand for e-vehicle constantly rising across various departments of the Union and state governments. To cater to the growing demand, EESL will issue a fresh tender for procuring additional 10,000 electric cars. This second tender is testimony to the fact that India offers a huge market potential for e-mobility."

Anant Nahata, Managing Director of Exicom said, "We are very happy to take part in the EV movement and take pride to work for India's vision of achieving 100% EV by 2030. We are progressively looking to expand and strengthen the charging infrastructure for electric vehicles with intent to popularize and promote clean transportation."

Exicom EV AC Charger supports BEVC-AC001 specifications. It is designed with 3 sockets to charge up to 15A per socket (or 3.3KW). It is suitable for installation at wide range of places including parking, service stations, commercial, and residential through pedestal mount/wall mount or pole mount. The Exicom DC charger comes with a single vehicle charging, and two connector architectures where connector A can charge at 48V/60V/72V at 3.3 kW and connector B can charge at 48V/60V/72V at 15 kW using GB/T 20234.3 connector. Whereas, AC charger comes with three outputs of 230V, 15A each using IEC 60309 Industrial sockets. The Exicom charger is Open Charge Point Protocol (OCPP) compliant, which offers a stable solution for communication between charge point and the central system. These chargers allow consumers to pay through multiple options (Debit/Credit Card, BHIM – cashless payment system, Bharat QR or UPI compliant mobile payment). EF

THE FUTURE OF SMART METERS IS BEING DEFINED AS GRID DIGITALIZATION CONTINUES

What, according to you, are the key information technologies (IT)-infrastructure requirements of the Indian power industry in the next decade? What are the main issues and challenges you foresee?
In our opinion, the Indian power industry has, so far, put in tremendous efforts to set up foundational systems, such as GIS, SCADA, and asset management that are key for day-to-day planning and operational processes. While these efforts will continue as part of the wider adoption of advanced technologies towards grid modernization, we think the next priority should be towards creating a comprehensive blueprint to address how to make these systems safer and more secure and reliable. With the increasing number of personal assets (be it storage devices or small-scale generation units) connecting to the grid, data protection and cyber security become extremely important both for IT systems and electric grids. We foresee this as a major challenge that can possibly hurt the rapid digitalization of the grid.

In the context of the remote sensing services, provided by your organization, how according to you are the GIS base maps useful for agriculturalists and for maintaining the road networks?
Remote sensing plays an unprecedented role in both the urban and rural environment. GIS maps enable decision and policy

For a great degree of its energy needs, the world depends on fossil fuels, such as crude oil, coal, and natural gas. However, these energy sources are exhaustible and will be depleted in a few decades. In addition, they also lead to environmental issues, such as global warming, pollution, and the like. It is therefore imperative to look for alternative, cleaner, smarter, and renewable energy sources, such as wind, solar, geothermal, and biomass that can be used to meet the daily requirements. In this context, geospatial technology has an important role to play. As a tool, the technology is positioned to analyse and monitor these processes and ensure that renewable power generation sites work optimally and that the power generated is delivered efficiently. In this background, **Mr John Renard, President – Utilities & Geospatial BU, Cyient**, in an email interview with **Anushree Tiwari Sharma** for *Energy Future*, presents his views on the significance of geospatial technology, among others, for a sustainable future. The organization, Cyient, founded in 1991, provides engineering, manufacturing, geospatial, network, and operations management services to global industry leaders through the deployment of robust processes and state-of-the-art technology.

makers to save cost and time and to provide better services to citizens. Agriculture has become more advanced and has adopted various remote sensing technologies and GIS maps (using satellite or UAV-based imagery) for mapping and predicting changes throughout the crop cycle. Cities are growing and evolving and a holistic view is required to plan and build smart and suitable infrastructure. Remote sensing through High Resolution Satellite Imagery, VHRSI via UAVs, and high precision LiDAR are some intelligent sources that can be used for urban infrastructure planning.

Please elaborate on the initiatives by the utilities sector over the next few years, specifically under power storage.

Utilities across the world are taking

various green energy initiatives to decrease carbon pollution by scaling up renewable energy deployment. While solar and wind energy is largely getting established, energy storage and electric vehicles are also fast emerging. According to the market research firm IHS, the global energy storage market is growing exponentially to an annual installation size of over 40 GW by 2022. Energy storage technology is diverse, ranging from well-established pumped hydro to experimental batteries and flywheels. Similar to utility companies, academic institutions continue their research to identify good technology options; electrochemical and thermal storage are the front runner storage technologies at the moment.

How can real-time data have substantial benefits on energy efficiency, conservation, and ensuring a sustainable environment?

The increasing amount of real-time data creates huge opportunities for utilities to improve their understanding of the grid leading to energy efficiencies, energy conversion, and optimized grid operations. Smart meter data driven analytics can help consumers change their energy consumption patterns and become more energy efficient. Utilities can also leverage real-time data for condition-based asset management of their critical infrastructure.We believe that there is a great degree of improvement in the accuracy of load profiling and forecasting that can be done with the availability of real-time data feeds from renewable energy sources thereby creating a sustainable environment for utilities to perform better.

What is the significance of maintaining the navigational database?

As users become more reliant on navigation systems to make decisions on their behalf, these will need to be ever more accurate, detailed, and up-to-date. Changes to road networks (even temporary ones) will need to be reflected in databases in real-time, thus placing an increasing reliance on cloud-based navigation databases that supplement data held locally by navigation systems. Road networks need to be mapped to a much higher level of content and precision due to autonomous vehicles and highly automated driving. Cyient has adopted a number of techniques for updating navigation databases, from using remote sensing (satellite and aerial data), through tracking large-scale infrastructure changes, to using crowdsourced or live video feeds to capture dynamic changes to roads.

How do you view the future of smart meter data technology?

The future of smart meters is being defined as grid digitalization continues. Given the existing challenges with last mile connectivity, and increasing smart appliancies, IP-based next generation smart meters will be the future. These will be capable of connecting to the customers' Wi-Fi networks, and communicating with central systems. This will eliminate redundant infrastructure between smart meter and IT systems. However, increased home automation and connected smart devices will necessitate superior edge analytics capability built into the next generation smart meter, which is currently missing. This will reduce the processing burden on central systems and enable instantaneous decisions. EF

CURRENT R&D RENEWABLE

Whose land is it anyway? Energy futures & land use in India

Energy Policy, Volume 110,
November 2017, Pages 257–262
Aniruddh Mohan

Modelling studies which project pathways for the future of energy in India currently have several implicit assumptions with regards to the social, institutional, and political changes necessary for energy transitions. This paper focusses on the specific question of land use change required for realizing ambitious clean energy targets. Demand for land is likely to be a critical question in India's energy future given the challenges with land acquisition in the country as a result of high population density and significant rights enjoyed by landowners. Yet, there is a lack of literature relevant to India which makes a quantitative assessment of the land use impacts of different types of low carbon technologies. The author calculates and compares the land requirements of ground-based solar photovoltaic (PV) power, nuclear power, and wind energy in India. All three types of technologies are expected to grow substantially as a share of India's electricity mix in the coming years. The analysis suggests that land demands of ground-based solar PV are likely to be substantial compared to wind energy and nuclear power, and some policy suggestions are provided which may help mitigate that challenge. EF

Online algorithms for storage utilization under real-time pricing in smart grid

International Journal of Electrical Power &
Energy Systems, Volume 101,
October 2018, Pages 50–59
Amrit S Bedi, P V Aditya P, Md. Waseem, Ahmada S Swapnil, Ketan Rajawat, Sandeep Anand

With the rapid proliferation of the advanced metering infrastructure, the smart grid is evolving towards increased customer participation. It is now possible for a utility to influence the customer demand profile via demand side management techniques such as real-time pricing and incentives. Energy storage devices play a critical role in this context, and must be optimally utilized. For instance, the peak power demands can be shaved by charging (discharging) the batteries during periods of low (high) demand. This paper considers the problem of optimal battery usage under real-time and non-stationary prices. The problem is formulated as a finite-horizon optimization problem, and solved via an online stochastic algorithm that is provably near-optimal. The proposed approach gives rise to a class of algorithms that utilize the battery state-of-charge to make usage decisions in real-time. The proposed algorithms are simple to implement, provably convergent for a wide class of non-stationary prices, easy to modify for a variety of use cases, and outperform the state-of-the-art techniques, such as those based on the theory of Markov decision processes or Lyapunov optimization. The robustness and flexibility of the proposed algorithms is tested extensively via numerical studies in MATLAB and real time digital simulator (RTDS). EF

Microbial pre-treatment of water hyacinth for enhanced hydrolysis followed by biogas production

Renewable Energy, Volume 126,
October 2018, Pages 21–29
Visva Bharati Barua, Vaibhav V Goud, Ajay S Kalamdhad

Biological pretreatment with novel isolated microbial pure culture was utilized to pretreat water hyacinth to enhance its solubilization followed by biogas production. Lignocellulose degrading bacterial strains isolated from soil (*Bordetella muralis* VKVVG5) (UN3d2), the gut of silverfish (*Citrobacter werkmanii* VKVVG4) (SFa2), and millipede (*Paenibacillus sp.* VKVVG1) (BrB2) were employed to optimize the ideal bacterial strain illustrating accelerated hydrolysis of water hyacinth. *Citrobacter werkmanii* VKVVG4 pretreatment of water hyacinth with an optimum dosage of 109 CFU/mL and time of 4 days helped in achieving the highest solubilization of 33.3%. Biochemical methane potential (BMP) test was conducted between untreated and *Citrobacter werkmanii* VKVVG4 pretreated water hyacinth. Biochemical methane potential (BMP) test of pretreated water hyacinth illustrated faster start up period than the untreated water hyacinth. *Citrobacter werkmanii* VKVVG4 (SFa2) pretreated water hyacinth illustrated a cumulative biogas production of 3737 ± 21 mL whereas untreated water hyacinth illustrated a cumulative biogas production of 3038 ± 13 mL on the

50th day. Scaled up batch (20 L) study demonstrated a three times increase in the cumulative biogas generation of the microbial pretreated water hyacinth than the untreated water hyacinth.

Estimation of daily and monthly diffuse radiation from measurements of global solar radiation: a case study across China

Renewable Energy, Volume 126,
October 2018, Pages 226–241
Hong Wang, Fubao Sun, Tingting Wang, Wenbin Liu

With increasing demand for energy, broaden renewable energy of income and reduce expenditure is becoming more and more important. Diffuse radiation (Rd) is an important consideration in building energy saving. Hundreds of methods were developed to calculate Rd because it is seldom available in many countries and its spatial-pattern is strongly station-dependent. There are only 13 stations that monitor both global solar radiation (Rs) and Rd after 1993 across China. Based on 812,640 measurements of daily `and Rd collected from 80 stations across China during 1957–2014, the authors wished to calibrate and validate a simple approach, which can be easily used to predict Rd over both daily and monthly periods for all locations in China and gave the accurate values of parameters. The approach, of the case study method, is based on `and extra-terrestrial solar radiance (Ra). Results showed that the daily method can be employed well, while the monthly approach was applied well in the Southern Region (SR) only. The monthly approach of the Northern Region (NR) was improved using its regional characteristics. The methods achieved can effectively estimate Rd and strongly apply in engineering for only two parameters, wherein accurate values for all stations have been offered.

Impact of tropical desert maritime climate on the performance of a PV grid-connected power plant

Renewable Energy, Volume 125,
September 2018, Pages 729–737
Daha Hassan Daher, Léon Gaillard, Mohamed Amara, Christophe Ménézo

This paper provides experimental results on the performance of a grid-connected PV power plant operating under dusty, desert maritime climate conditions using data from the first installation of its kind in Djibouti. The first 4 years of operation were evaluated in terms of IEC 61724 measures, and the impact of climate factors was estimated using a novel combination of analysis techniques. The monthly average daily array yield and final yield were 5.1 kWh/kWp and 4.7 kWh/kWp, respectively. The average performance ratio for respective PV arrays and the global grid-connected system were 90% and 84%, corresponding to monthly average daily PV module and system efficiencies of 12.68% and 11.75%. The seasonal variation in PV module efficiency was found to follow a funnel-shape with a sharp minimum centred on July. The impact of ambient temperature and soiling-induced losses were evaluated, revealing a reduction in the performance ratio by 0.7% for each 1 °C rise in daily ambient temperature. Losses due to soiling varied from 0.03% following rainfall events to 14.23% during dry dusty periods. Finally, to maintain the modules performances losses less than 5%, a cleaning schedule is recommended every two weeks.

Adsorptive decontamination of synthetic wastewater containing crystal violet dye by employing *Terminalia arjuna* sawdust waste

Groundwater for Sustainable Development, Volume 7,
September 2018, Pages 30–38
Sadia Shakoor, Abu Nasar

In the present work, *Terminalia arjuna* sawdust (TASd) has been employed as an effective adsorbent for the elimination of crystal violet (CV) dye from synthetic wastewater. The adsorbent was characterized by scanning electron microscopy (SEM), energy dispersive X-ray analysis (EDAX), thermogravimetric analysis (TGA), transmission electron microscopy (TEM), and Fourier transform infrared (FTIR) spectroscopy. Batch adsorption experiments have been conducted to optimize different factors affecting adsorption. The findings were observed to be best followed by Freundlich adsorption isotherm with 0.9964 as the correlation coefficient. The equilibrium was attained in 120 min and the highest adsorption capacity was observed to be 45.99 mg g^{-1} at the optimum adsorbent dose and pH of 0.4 g L^{-1} and 7, respectively. Kinetic experiments revealed that the removing process of CV by TASd obeys pseudo-first-order kinetic model and the k1 value was found to be 0.013 min^{-1}. The thermodynamic investigation indicates that the process of adsorption of CV by TASd is feasible, endothermic, and associated with an increase of entropy. Desorption analysis shows that the used adsorbent could be better regenerated in sodium hydroxide.

UNWRAP SCIENTIFIC KNOWLEDGE THROUGH THE BOX OF SCIENCE

Education is vital to development and growth. All development achievements, from health advances and agricultural innovations to efficient administration and private sector growth, are contingent on the application of the human mind. For countries across the world to reap these benefits, the power of the human mind needs to be unleashed. And there is no better tool for doing this than education. Investing in education is one of the most important ways with which the world may be improved, empowered, and enabled.

A solar energy seminar in progress

The idea to create awareness amongst people about the latest developments in science and transmitting knowledge about unknown things led to the establishment of a science communication group in Ahmednagar in 2003 which transformed into 'Box of Science' in 2012. Initially, as part of the venture, public lectures on astronomy, talks by scientists, slide shows, sky observation programmes, science festivals in schools, etc., were organized. Increasingly, the venture and its focus moved towards imparting activity-based science education due to presence of a huge gap between talent and skills and knowledge and actuation within kids. Providing hands-on experience to students is a verified method for their growth, analytical skills, and logical thinking. It is accepted as a proper education method in many developed countries.

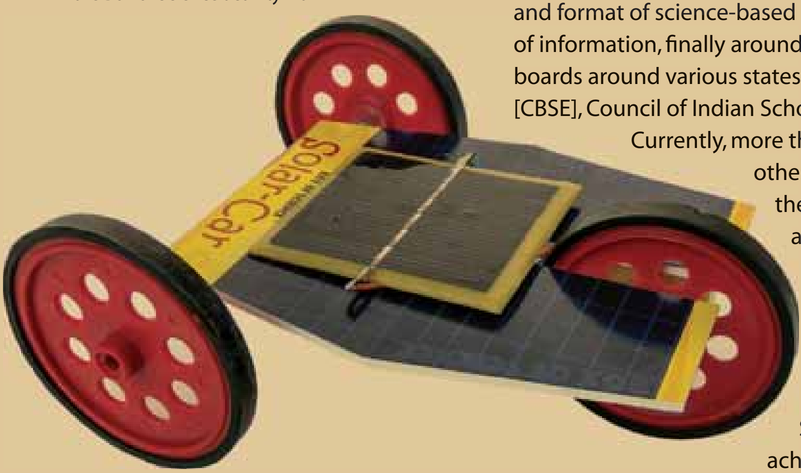
So far, Box of Science through its activities has reached more than 50,000 students through events, workshops have been in more than 100 schools, and training imparted to 1000+ teachers.

Currently, Box of Science deals with a number of activities ranging from teacher's training programme to developing 'Box of Science hubs' across a number of cities, such as Mumbai, Pune, Ajmer, Surat, Vadodara, Goa, etc. They have designed diverse programmes ranging from one-day workshops, annual science clubs to robotics programmes for activity-based education. The concept of science hub goes with the formation of local centres across cities and villages where children may gather once a week to acquire hands-on science-technical education. A number of do-it-yourself kits, available for the general public and schools, have also been developed. As the name suggests, 'Box of Science' is a teaching and learning tool. The box contains necessary material for doing specific activity from school curriculum. One such programme is based on promoting an experiential understanding of renewable energy sources.

Guided activities as part of solar energy conversion

A teacher training camp on solar energy conversion

A solar car created as part of the Box of Science activity kit



However, in their endeavour to impart knowledge of science and develop cognitive skills of children, Box of Science has also grappled with certain challenges. In the initial stages, there was scarcity of funds and resources and lack of a proper structure and format of science-based activities. After going through all the possible sources of information, finally around 50 activities, mapped with the school syllabus of major boards around various states (including the Central Board of Secondary Education [CBSE], Council of Indian School Certificate Examination [ICSE], etc.), were created. Currently, more than 200 activities in science, robotics, astronomy, and other fields, are in place. After developing programmes, the next significant task was reaching out to the schools and parents and convincing them of the significance of knowledge and its training. Paying capacity for things other than academic entities is a bit secondary in Indian society and so, effective ways were devised to reduce cost of the kits and programmes, both in rural and urban India. The people behind the Box of Science work towards assisting the future generation in achieving their best via boosting creativity, imagination, and hands-on activity promotion. This works not only towards increasing their curiosity but their entire attitude towards life.

A telescope making workshop underway

Since the past few decades, there has been a decline in rate of innovations which could change, prosper human lives or life on the planet itself. According to a recent study, six out of every ten, of nearly 2,000 Indian women PhDs (surveyed in science) were unemployed. Lack of adequate job opportunities was the primary reason cited, thus proving that one of the highest degree offered by the universities has probably no economic value as on date. The increasingly rampant social and migration nowadays, has been attributed to the somewhat centralized industrial development in certain places in the country. Students and workers from rural areas shift to urban areas to meet their daily needs. If the students are empowered with more activity-based or practical education, the number of employers can be increased and this will aid in achieving decentralized development of the nation.

Most of the youth are engaged in outsourcing business and the services sector dominates the economy. This is, thus, a reflection of the theoretical or conceptual learning primarily due to rote learning. This situation, in the long term will baffle the future of the nation. By equipping children with activity-based knowledge, it is possible to strengthen their ability to construct something eternal. It is important that they understand Newton's Laws, magnetism, rather than just elaborating those with pictures. Thereafter, it is possible that these curious minds produce desired results out of their consciousness. Rote learning methods, merely reproduce an outsourcing mass of service persons. Balance therefore is imperative as a prodigious force of scientists and entrepreneurs.

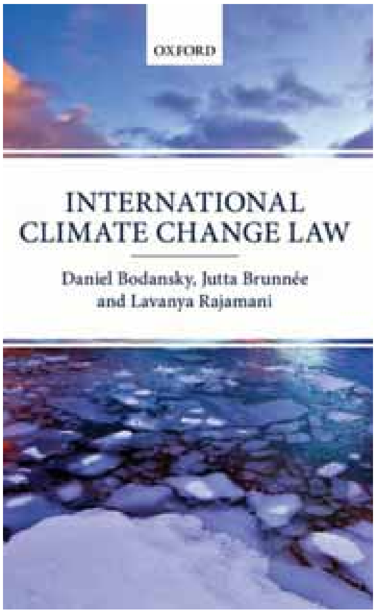
Summer camps and sessions on robotics, wind energy, and other renewable forms of energy are a regular feature at Box of Science

The process of learning involves two major domains—theoretical and hands-on learning. Today, current classroom teaching is devoid of experiential education. Every lecture needs to be designed on the principle of 'activity-based education', not only for science but mathematics, history, geography, economics, and all other subjects as well. In this context, innovative methods of learning/teaching, such as those created at Box of Science are the perfect answer since these can be used for classroom as well as laboratory teaching since the kits are an ideal combination of theoretical and experiential learning.

*For more information visit **https://boxofscience.com/***

International Climate Change Law

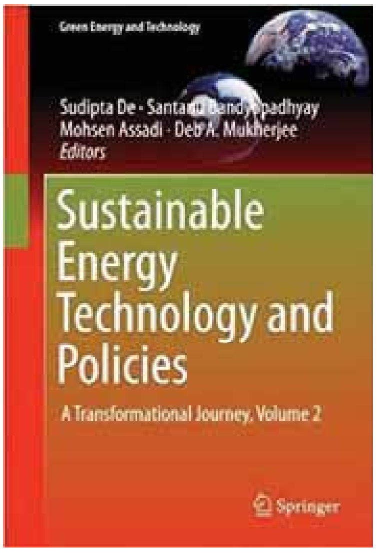
This textbook, by three experts in the field, provides a comprehensive overview of international climate change law. Climate change is one of the fundamental challenges facing the world today, and is the cause of significant international concern. In response, states have created an international climate regime. The treaties that comprise the regime—the 1992 United Nations Framework Convention on Climate Change, the 1997 Kyoto Protocol, and the 2015 Paris Agreement establish a system of governance to address climate change and its impacts. This book provides a clear analytical guide to the climate regime, as well as other relevant international legal rules. The book begins by locating international climate change law within the broader context of international law and international environmental law. It considers the evolution of the international climate change regime, and the process of law-making that has led to it. It examines the key provisions of the Framework Convention, the Kyoto Protocol, and the Paris Agreement. It analyses the principles and obligations that underpin the climate regime, as well as the elaborate institutional and governance architecture that has been created at successive international conferences to develop commitments and promote transparency and compliance. The final two chapters address the polycentric nature of international climate change law, as well as the intersections of international climate change law with other areas of international regulation. This book is an essential introduction to international climate change law for students, scholars, and negotiators. EF



Authors: Daniel Bodansky, Jutta Brunnée, Lavanya Rajamani
Publisher: OUP Oxford
Year: 2017

Sustainable Energy Technology and Policies: A Transformational Journey, Volume 2 (Green Energy and Technology)

This book presents a state-of-the-art compilation focussing on both technological and policy aspects of sustainable energy production and consumption, which deals with issues like the need for and planning of smart cities, alternative transport fuel options, sustainable power production, pollution control technologies, etc. The book comprises contributions from experts from all over the world and addresses energy sustainability from different viewpoints. Specifically, the book focusses on energy sustainability in the Indian scenario with a background of the global perspective. Contributions from academia, policymakers, and industry are included to address the challenge from different perspectives. The contents of this book will prove useful to researchers, professionals, and policymakers working in the area of green and sustainable energy. EF

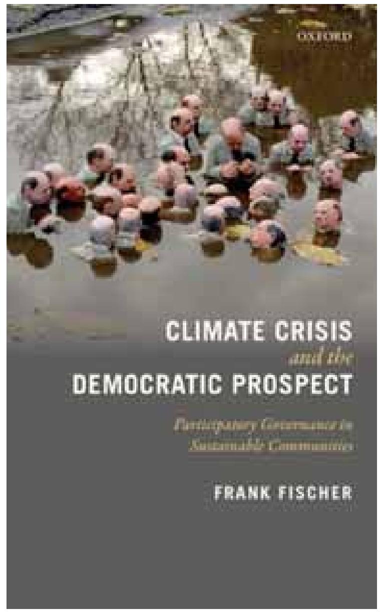


Authors: Sudipta De, Santanu Bandyopadhyay, Mohsen Assadi, Deb A Mukherjee
Publisher: Springer
Year: 2018

Climate Crisis and the Democratic Prospect: Participatory Governance in Sustainable Communities

Can contemporary democratic governments tackle climate crisis? Some argue that democracy has to be a central part of a strategy to deal with climate change. Others argue that experience shows it not to be up to the challenge in the time frame available—that it will require a stronger hand, even a form of eco-authoritarianism. A question that does not lend itself to an easy assessment, this volume seeks out to assess the competing answers.

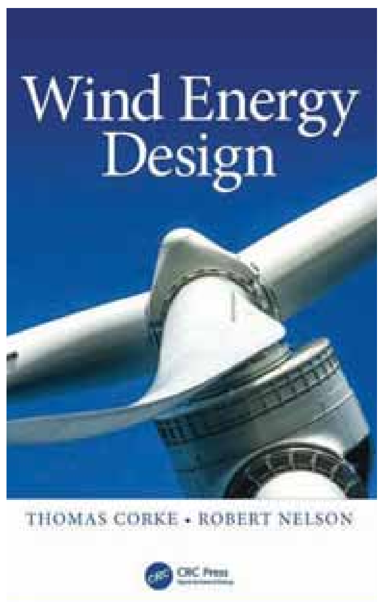
While the book supports the case for environmental democracy, it argues that establishing and sustaining democratic practices will be difficult during the global climate turmoil ahead, especially in the face of state of emergencies. This inquiry undertakes a search for an appropriate political-ecological strategy for preserving a measure of democratic governance during hard times. Without ignoring the global dimensions of the crisis, the analysis finds an alternative path in the theory and practices participatory environmental governance embodied in a growing relocalization movement, and global eco-localism generally. Although such movements largely operate under the radar of the social sciences, the media and the political realm generally, these vibrant socio-ecological movements not only speak to the crisis ahead, but are already well established and thriving on the ground, including eco-villages, eco-communes, eco-neighbourhoods, and local transition initiatives. With the help of these ideas and projects, the task is to influence the discourse of environmental political theory in ways that can be of assistance to those who will face climate crisis in its full magnitude. EF



Authors: Frank Fischer
Publisher: OUP Oxford
Year: 2017

Wind Energy Design

Wind Energy Design is designed for undergraduate engineering courses, with a focus on multidisciplinary design of a wind energy system. The text covers basic wind power concepts and components—wind characteristics and modelling, rotor aerodynamics, lightweight flexible structures, wind farms, aerodynamics, wind turbine control, acoustics, energy storage, and economics. These topics are applied to produce a new conceptual wind energy design, showing the interplay of various design aspects in a complete system. An ongoing case study demonstrates the integration of various component topics, and MATLAB examples are included to show computerized design analysis procedures and techniques. EF



Authors: Thomas Corke, Robert Nelson
Publisher: CRC Press
Year: 2018

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Research gets closer to producing revolutionary battery to power renewable energy industry

New research verges on development of a commercial hydrogen-bromine flow battery, an advanced industrial-scale battery design that engineers have strived to develop since the 1960s. The boom in wind energy faces a hurdle of how to effectively and cheaply store energy generated by turbines when the wind is blowing, but energy requirements are low. To overcome this issue, a team of researchers have initiated research to develop an advanced hydrogen-bromine flow battery, an advanced industrial-scale battery design -- roughly the size of a semi-truck that engineers have strived to develop since the 1960s. It could work just as well to store electricity from solar farms, to be discharged overnight when there's no sun.

» An electrode is developed by the researchers. A battery's electrode is where the electrical current enters or leaves the battery when it's discharged. To be maximally efficient, an electrode needs a lot of surface area. The team has developed a higher-surface-area carbon electrode by growing carbon nanotubes directly on the carbon fibers of a porous electrode.

In comparison to the paper carbon electrode, they have planned to make tiny carbon nanotubes directly on top of carbon fibers inside of electrodes—like tiny hairs—and boosted the surface area by 50–70 times. This has solved the high-surface requirement for hydrogen-bromine battery electrodes. A key issue

remaining before a hydrogen-bromide battery can be marketed successfully is the development of an effective catalyst to accelerate the reactions on the hydrogen side of the battery and provide higher output while surviving the extreme corrosiveness in the system. The researcher said the rise of renewable energy would depend on technology breakthroughs that make the economics attractive to energy producers and investors and their new battery design could play a part.

https://www.sciencedaily.com/releases/2018/03/180314120221.htm

Researchers developing renewable energy approach for producing ammonia

Researchers at the University of Notre Dame are developing a renewable energy approach for synthesizing ammonia, an essential component of fertilizers that support the world's food production needs. The Haber-Bosch process developed in the early 1900s for producing ammonia relies on non-renewable fossil fuels and has limited applications for only large, centralized chemical plants. The new process utilizes a plasma—an ionized gas—in combination with non-noble metal catalysts to generate ammonia at much milder conditions than is possible with Haber-Bosch.

» The energy in the plasma excites nitrogen molecules, one of the two components that go into making ammonia, allowing them to react more readily on the catalysts. Because the energy for the reaction comes from the plasma rather than high heat and intense pressure, the process can

be carried out at a small scale.

» This makes the new process well-suited for use with intermittent renewable energy sources and for distributed ammonia production.

» The research team discovered that because the nitrogen molecules are activated by the plasma, the requirements on the metal catalysts are less stringent, allowing less expensive materials to be used throughout the process. This approach overcomes fundamental limits on the heat-driven Haber-Bosch process, allowing the reaction to be carried out at Haber-Bosch rates at much milder conditions.

https://www.sciencedaily.com/releases/2018/04/180404143400.htm

Obtaining energy from marine currents

A team of researchers have developed procedures and designs to obtain energy from marine currents in areas of great depths optimizing the costs.

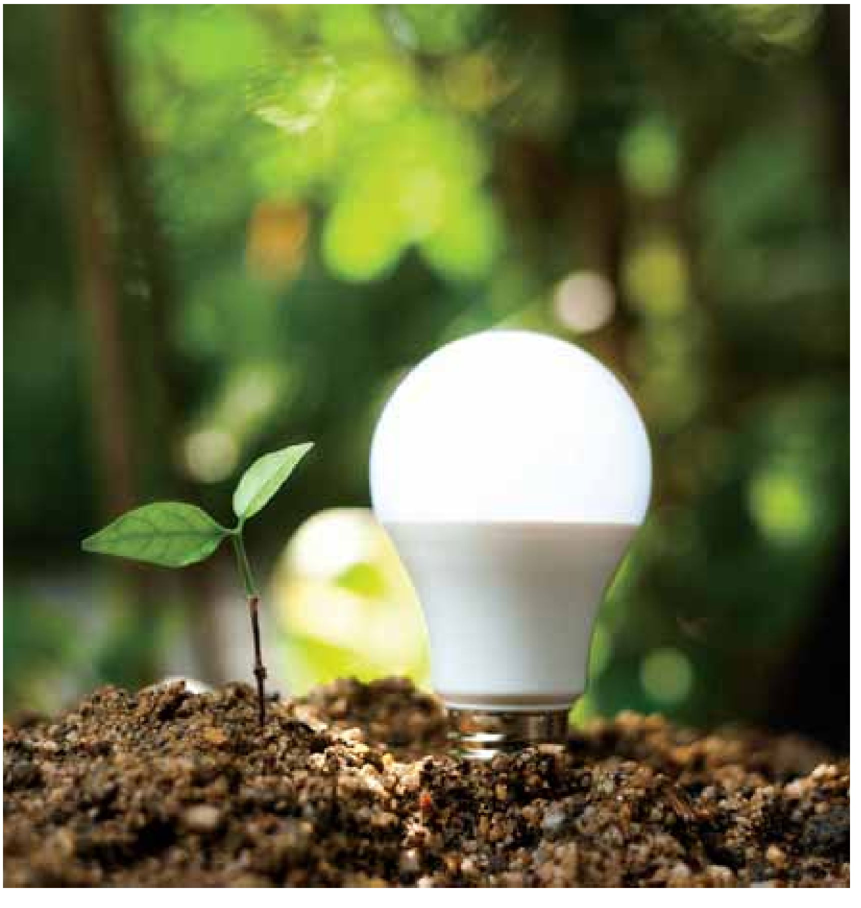
The new devices using the energy from marine currents in great depths pose the problem of high cost of manufacturing, installation, and maintenance. To tackle this issue, members have developed a method to assess the life-cycle cost of a power generation park based on these devices that can be used in the early design stages. After wide development of offshore wind power, experts agree that the next step is the use of the energy from marine currents, mainly produced by the tides. It is estimated that about 80% of the energy from tides are located in areas of over 40 m of depth. Therefore, it is necessary to use a new design device that can operate in areas where it is expensive to install first generation devices, such as large structures held to the seabed. These systems of the second generation have anchors and a series of cables that hold the device to the seabed. This has been the first design worldwide tested in the sea and fit to operate fully submerged.

The research group keeps working to achieve a future successful commercialization of tidal renewable energy devices since they have great potential to generate power from the marine currents. According to one of the researchers, the energy from currents is a renewable source that has an additional value in a future energy market regarding other renewable energy sources due to its high predictability. Besides, tidal energy technologies are characterized by a carbon dioxide (CO_2)-free energy that contributes to the economic growth and job creation in coastal and remote areas.

https://www.sciencedaily.com/releases/2018/03/180320102402.htm

Fungal enzymes could hold secret to making renewable energy from wood

An international team of researchers has discovered a set of enzymes found in fungi that are capable of breaking down one of the main components of wood. The enzymes could now potentially be used to sustainably convert wood biomass into valuable chemical commodities such as biofuels. As an alternative to coal and oil, wood is increasingly one of the more promising sources of advanced biofuels. However, despite its potential, it is a difficult material to break down. Current wood bio-refineries have to use pre-treatment processes, making the conversion of wood into fuels and products expensive and energy-consuming. In ecosystems, fungi play a significant role in breaking down wood within the carbon cycle, releasing nutrients back into soil. This property of fungi inspired the researchers to investigate the mechanisms that allow this process to take place.



According to one of the researchers, these enzymes may underpin the development of improved enzyme cocktails for bio-refinery applications using wood unlocking its conversion into a wide-range of valuable commodities in a sustainable way. The research reported has shown that the family of enzymes, called lytic polysaccharide monooxygenases (LPMOs), are capable of breaking down xylans—carbohydrate molecules commonly found in wood biomass that are particularly resistant to degradation. The researchers said that this discovery unlocks the key scientific challenge of how bio-refineries can convert wood into biofuel in an environmental and cost-effective way, bringing us a step closer to a sustainable 21st century. EF

https://www.sciencedaily.com/releases/2018/02/180216110522.htm

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Website: www.sdn-i.com

NATIONAL AND INTERNATIONAL EVENTS

NATIONAL

EV Charge India 2018
June 7, 2018
Bengaluru, Karnataka
Website: http://firstviewgroup.com/index.php/business-conferences-trainings-and-meets-2/upcoming-events-2/business-events/ev-charge-india-2018

Solar Roofs Tamil Nadu
June 8, 2018
Chennai, Tamil Nadu
Website: http://solarquarter.com/solarroofs/index.php/past-edition/45-solarroofs-tamil-nadu-2018-8-june

Solar South 2018 Expo
June 14–16, 2018
Chennai, Tamil Nadu
Website: http://www.solarsouth.in/index.html

Electric Vehicle India Summit supported by NITI Aayog (EV India 2018)
June 18–19, 2018
New Delhi
Website: https://www.evsummitindia.com/

Green Power 2018
July 12–13, 2018
Chennai, Tamil Nadu
Website: http://www.greenpower-cii.com/

India Solar Week 2018
July 12–13, 2018
New Delhi
Website: http://solarquarter.com/indiasolarweek/index.php/home-none/the-event

INTERNATIONAL

International Conference on Electrical Engineering and Green Energy (CEEGE 2018)
June 1–3, 2018
Tokyo, Japan
Website: http://www.ceege.org/

2018 KPMG Global Energy Conference
June 6–7, 2018
Houston, USA
Website: https://www.kpmg-institutes.com/institutes/global-energy-institute/events/2018/01/global-energy-conference-2018.html

World Conference on Photovoltaic Energy Conversion (WCPEC)
June 10–15, 2018
Waikoloa, Hawaii
Website: http://www.wcpec7.org/WCPEC-7/

Brazil Solar Power
June 12–13, 2018
Rio de Janeiro, Brazil
Website: http://www.brazilsolarpower.com/

2nd World Congress on Wind & Renewable Energy
June 14–15, 2018
London, United Kingdom
Website: https://windenergy.conferenceseries.com/

International Conference on Renewable Energy and Conservation (ICREC)
June 15–17, 2018
Sydney, Australia
Website: http://www.icrec.org/

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy			
Programme/Scheme wise Physical Progress in 2017-18 & Cumulative upto the Month of March, 2018			
Sector	**FY- 2017-18**		**Cumulative Achievements (as on 31.03.2018)**
	Target	**Achievement (April-March, 2018)**	
I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)			
Wind Power	4000.00	1766.25	34046.00
Solar Power - Ground Mounted	9000.00	9009.81	20587.83
Solar Power - Roof Top	1000.00	352.83	1063.63
Small Hydro Power	100.00	105.95	4485.80
Biomass (Bagasse) Cogeneration)	340.00	519.10	8700.80
Biomass (non-bagasse) Cogeneration)/Captive Power	60.00	9.50	662.81
Waste to Power	10.00	24.22	138.30
Total	**14510.00**	**11787.66**	**69685.17**
I. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWEQ)			
Waste to Energy	15.00	5.50	172.15
Biomass Gasifiers	7.50	0.92	163.37
Aero-Generators/Hybrid systems	0.50	0.14	3.29
SPV Systems	150.00	216.63	671.41
Total	**173.00**	**223.19**	**1010.22**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Family Biogas Plants (numbers in lakh)	1.10	0.40#	50.05#
Water mills/micro hydel (Nos)	150/25	0.00	2690/72

Tentative figures upto 31.03.2018

Tentative State-wise break-up of Renewable Power target to be achieved by the year 2022 (Posted on 30.03.2015)

Source: www.mnre.gov.in

DELENG/2012/49326

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