April–June 2021

ENERGY FUTURE

The Complete Energy Magazine
Volume 9 • Issue 3 • Annual ₹800

COVER STORY

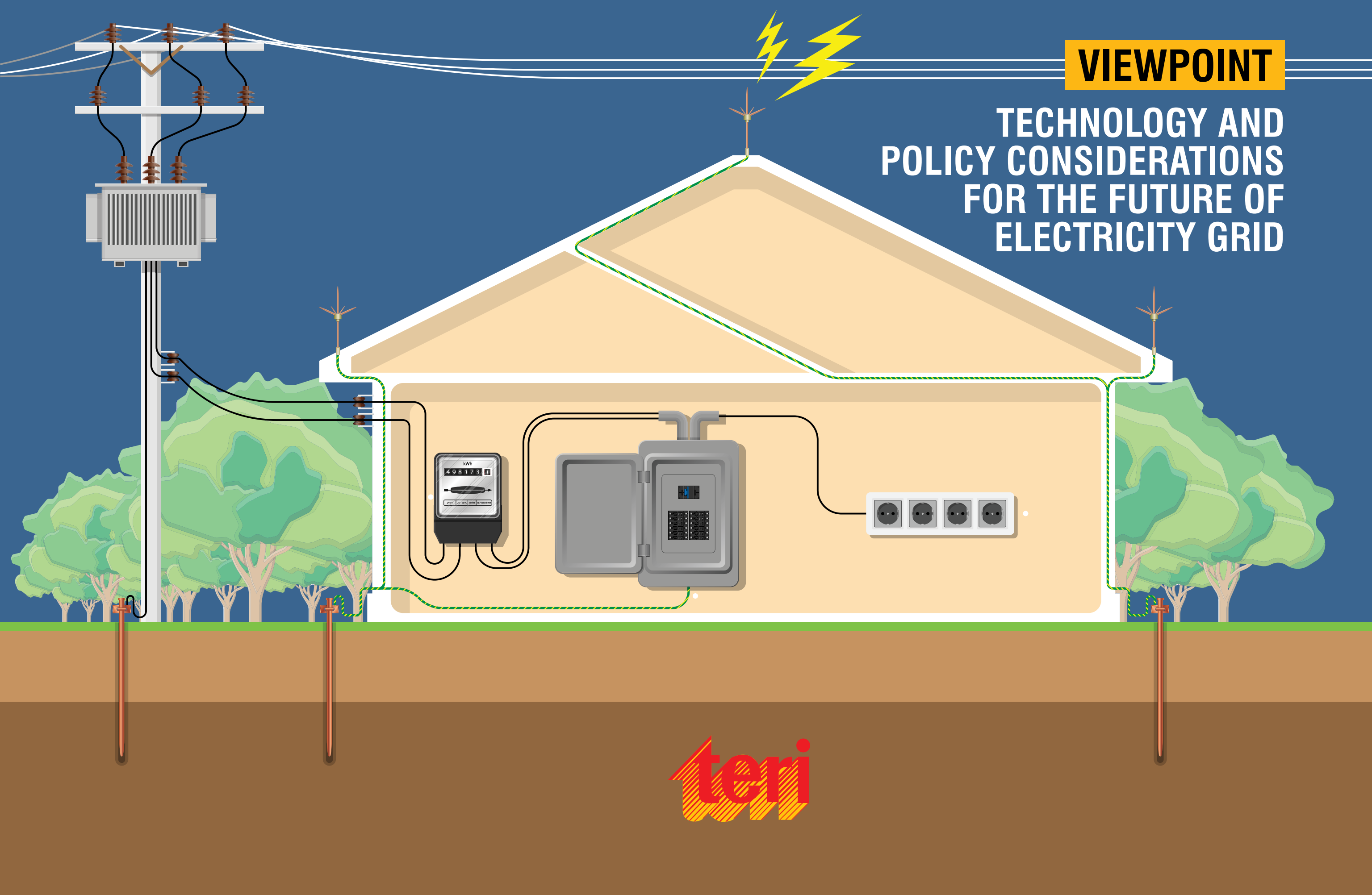
TECHNOLOGY TRANSITIONS IN THE ELECTRICITY SECTOR

FEATURE

BATTERY STORAGE AND OPERATIONAL USE-CASES AT ELECTRICITY DISTRIBUTION NETWORK LEVEL

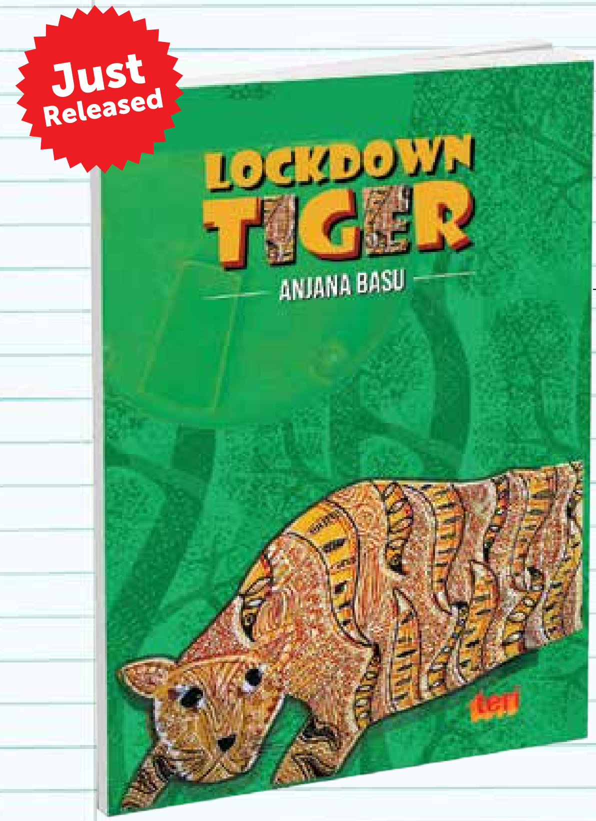
VIEWPOINT

TECHNOLOGY AND POLICY CONSIDERATIONS FOR THE FUTURE OF ELECTRICITY GRID



teri

Join Manjul, Rohan and Carpet Sahib in their Adventure to Save a Tiger Cub



- Realizes the spirit of adventure which is locked up inside children
- Sparks interest in children about nature and wildlife
- Creates curiosity among children (and adults) about tigers and their habitats
- Educates children about illegal wildlife trade

Ages: 14+ years • ISBN: 9788179936948 • Price: ₹275

It was a young tiger barely old enough to hunt for itself. It was still very confused as to how it had got itself into this narrow space.

A tiger is kidnapped and so is a girl - though not at the same time. They find themselves sharing isolation in a hunting lodge that is rumoured to be haunted, at the mercy of an unknown enemy. Who has locked them in and why? What happens when a young tiger is terrified out of its wits and a girl finds herself locked in and forced to fend for herself? Perhaps call for a ghost to come to the rescue?

The Energy and Resources Institute
Attn: TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003/India

Tel. 2468 2100 or 4150 4900
Fax: 2468 2144 or 2468 2145
India +91 • Delhi (0)11
Email: teripress@teri.res.in
Web: http://bookstore.teri.res.in

To purchase the book, visit our online bookstore at http://bookstore.teri.res.in or send us your demand draft or cheque in favour of TERI, payable at New Delhi (outstation cheques are not accepted).

**Price is subject to change*

Head Office
TERI
Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi – 110 003
Tel. +91 (11) 2468 2100 or 711
Fax +91 (11) 2468 2144 or 2468 2145

Regional Centres
Southern Regional Centre
TERI, CA Site No. 2
4th Main, 2nd Stage Domlur
Bengaluru – 560 071
Email: terisrc@teri.res.in

North-Eastern Regional Centre
TERI, Chachal Hengrabari
Express Highway, VIP Road
Guwahati – 781 036

Western Regional Centre
TERI, F-9, La Marvel Colony
Dona Paula, Panaji – 403 004 (Goa)
Email: teriwrc@goatelecom.com

Overseas Representation
TERI Japan
C/o IGES
Nippon Press Centre Building (8th Floor)
2-2-1, Uchisaiwai-cho, Chiyodi-ku
Tokyo, Japan - 100-0011
Email: teris@iges.or.jp

From the editor's desk...

Energy transition has become a buzz-term nowadays, especially in the context of net-zero emissions ambitions. The fact that we have been able to realistically imagine a future based on clean energy - as opposed to the present one that is predominantly dependent on fossil fuels - speaks volumes about the recent technological advances. Not only renewable energy technologies, notably solar and wind, have become cost-efficient but the key enablers like intelligent grid management systems too progressed to a level where their combined effect has been greater than the sum of the constituents. But energy transition is not simply about changes in sources of electricity generation. Thus, energy transition has to deal not only with supply-side options (renewable energy and other cleaner options) but also with demand-side management, including adoption of energy efficient processes and value-chains. And there is more to it than only technology transition. Since any economic system is not uni-dimensional, energy transition too entails social dimensions.

The social costs of energy transition must be viewed at two distinct levels. First, the envisaged energy transition addresses energy poverty and energy access squarely. So, while transiting to clean energy, the principle of `no one is left behind' has to follow in terms of affordable, reliable, and on-demand energy supply. The second level pertains to the populace and communities affected by this shift. If one looks at it closely, one would realize that the issues here are developmental ones only, ranging from lack of basic infrastructure to livelihood opportunities. These challenges require a well-coordinated approach. And more importantly, while discussing energy transition or net-zero targets, we must not lose sight of the fact that electricity is but only one component of energy. Particularly from the Indian perspective it is equally important to consider energy in cooking and industrial sectors - especially MSMEs. Ultimately, energy future is intrinsically linked with the overall wellbeing of the economy.

Amit Kumar

Amit Kumar
Senior Director, Social Transformation, TERI

Editor: Amit Kumar Radheyshayam Nigam
Printed and published by Dr Ajay Mathur for The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi- 110 003. Tel. +91(11) 24682100, Fax +91(11) 2468 2144 or Email: teripress@teri.res.in, and printed by Batra Art Press, A-41 Naraina Indl. Area PH- II, New Delhi-28.

"The theme of the January-March 2021 issue of Energy Future is quite apt indeed. In fact, air pollution in India is a very serious problem. I have read that rising urbanization, booming industrialization, and associated anthropogenic activities are the prime reasons that lead to air pollutant emissions and poor air quality. Air pollution is one of the key global health and environmental concerns and has been ranked among the top five global risk factors of mortality by the Health Effects Institute (HEI 2019). Over the years, there has been a massive-scale expansion in industries, population density, anthropogenic activities, and the increased use of automobiles has degraded the air quality in India further. In the last few decades, the greenhouse gas (GHG) emissions and other emissions resulting from anthropogenic activities have increased drastically."

B K Yadav
New Delhi

"Article by Dr Bhola Ram Gurjar, featuring in Cover Story of Energy Future 's January–March issue is undeniably a thought-provoking text, as it made me informed about the cause and effect of air pollution in the India context. The comparative analysis put forward by the author about death tolls—out of COVID-19 and air pollution—aptly clarifies where do India stands when it comes to air pollution and its associated hazards. Rising urbanization and rapidly expanding industrial sector are the principal factors attributed to continuous degradation of air quality. The air pollution is not just a problem, it has nearly entered into realms of crisis and hence requires national-level immediate attention so that appropriate measures can be developed to curb both its spread and generation."

K. Babar
Jaipur, Rajasthan

"I always enjoy reading Energy Future because its editions are developed on particular themes. Contents of the last issue were woven around the central theme of air pollution. In the Viewpoint section, in Dr Parikh's words, how poor air quality is responsible for a country's poor health status was detailed. The connection between air pollution and waste management was skillfully established, in addition, how prefabrication construction could be an innovative and sustainable option in the building sector to limit pollution levels was aptly explained."

Maya Sharma
Chandigarh

CONTENTS

INDIA'S POWER CONSUMPTION GROWS 41% IN APRIL

Power consumption in the country grew 41% in April 2021 to 119.27 billion units (BU) over the same month last year, showing robust recovery in industrial and commercial demand of electricity, according to the Power Ministry data. Power consumption in April 2020 was recorded at 84.55 BU. On the other hand, peak power demand met, which is the highest supply in a day, during the first half of April 2021 remained well above the highest record of 132.20 GW in April 2020.

During April this year, peak power demand met or the highest supply in a day touched the highest level of 182.55 GW and recorded a growth of nearly 38% over 132.73 GW recorded in the same month in 2020. Power consumption in April last year had dropped to 84.55 BU from 110.11 BU in the same month in 2019. This happened mainly because of fewer economic activities following the imposition of lockdown by the government in the last week of March 2020 to contain the spread of COVID-19. EF

Source: https://www.hindustantimes.com/

IMPLEMENTATION OF ENERGY EFFICIENCY MEASURES IN INDIA SAVES CO_2 EMISSIONS IN THE COUNTRY

The Ministry of Power is implementing measures to save energy with an objective to reduce CO_2 emission levels in the environment from industries, establishments and by using equipment/appliances. In this regard, Perform Achieve and Trade (PAT) Scheme is a key programme for large industries and establishments. This scheme aims to enhance the cost-effectiveness of energy savings by upgrading technologies or by taking in-house actions to minimize energy consumption. The scheme provides mandatory targets for the identified large units and the excess energy saved by them is issued as Energy Saving Certificate, which are tradable instruments. The different industries and establishments are assigned separate energy efficiency targets based on their levels of energy consumption and the potential for energy savings.

By the year 2020, the scheme coverage has been extended to 13 most energy intensive sectors in the country including cement, iron and steel, fertilizer, thermal power plants, refineries, petrochemicals, railways, and others. This initiative is currently leading to energy savings of about 17 million tonnes of oil equivalent and has resulted into mitigation of about 87 million tonnes of CO_2, per year. EF

Source: https://pib.gov.in/

CESL AND LADAKH SIGN AN MOU TO MAKE THE UNION TERRITORY CARBON NEUTRAL

Convergence Energy Services Limited (CESL), a wholly owned subsidiary of Energy Efficiency Services Limited (EESL) under the Ministry of Power has signed a Memorandum of Understanding (MoU) with the Administration of Union Territory (UT) of Ladakh, to make it a clean and green UT. Under the MoU, various clean energy and energy efficiency programmes will be implemented. Beginning with a pilot in the Zanskar valley area, CESL will take up solar mini and micro grid solutions, energy-efficient lighting, energy storage-based solutions, efficient cooking stoves, and electric mobility solutions in the UT.

Shri R K Mathur, Lieutenant Governor of the Union Territory of Ladakh said that energy access for Ladakh is foremost. Sustainable solutions such as the decentralized energy efficient solutions that can be implemented in difficult terrains of Ladakh is needed. CESL will build the electric vehicle (EV) ecosystem for the UT, focusing on EV charging infrastructure which will utilize renewable sources of power, and EVs that are being tested for high altitudes. Like all CESL's projects, this programme will also be based on innovative business models, using carbon credits. EF

Source: https://pib.gov.in/

KIA BECOMES ENERGY NEUTRAL, SAVES 22 LAKH UNITS OF ENERGY

The Kempegowda International Airport (KIA) achieved net energy neutral status, saving nearly 22 lakh units of energy during the 2020–21 financial year, the airport operator announced on the eve of World Environment Day. The energy saved is enough to power nearly 9000 houses for a month, a Bangalore International Airport Limited (BIAL) spokesperson said. 'BIAL saved nearly 5 lakh units (kWh) from lighting, and has implemented chiller plant optimization in heating, ventilation and air conditioning (HVAC), which has resulted in saving of over 17 lakh units (kWh).' BIAL's energy management initiative is focused on achieving carbon neutrality through the use of renewable, green and clean energy. 'KIA has achieved an energy neutral status since December 2020 through its onsite solar installations as well as Power Purchase Agreements (PPA) from solar and wind energy suppliers.' The airport, BIAL said, had increased the consumption from solar power to over 50 million units through on-site and off-site PPAs. 'In addition, BIAL has entered into a PPA agreement for the purchase of an additional 20 million units of wind power through open access from January 2020.' EF

Source: https://www.deccanherald.comrecord-peak-of-feb-20-121020700192_1.html

INFOSYS REDUCES CARBON EMISSIONS BY 46% IN FY21

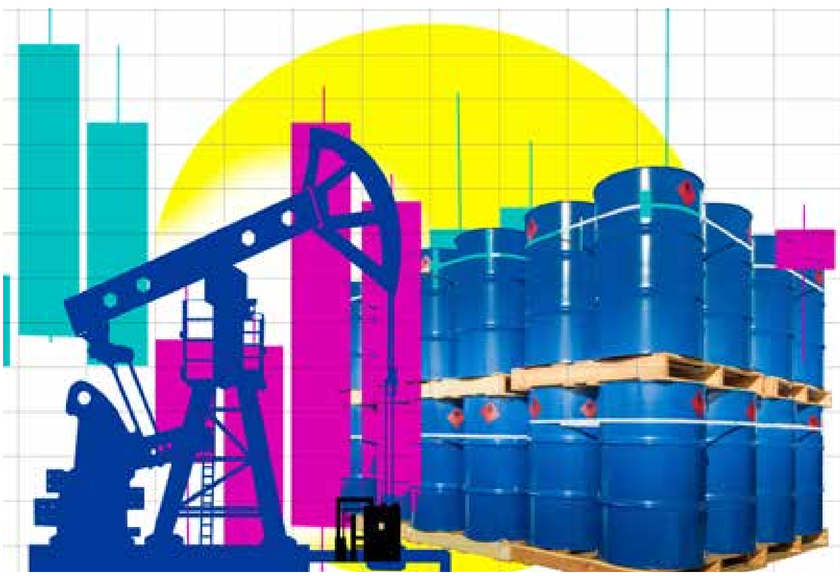
Infosys Ltd has cut its carbon emissions by nearly 46% in FY21 mainly through the successful enablement of work-from-home, the company said in its *Environmental Social and Governance* (ESG) *Report* 2020–21. 'Enabling work-from-home system effectively has helped bring down our overall Scope 1, 2 and 3 emissions by about 46%, while paving the way for a hybrid workplace of the future. With most employees working from home, we moved towards a revenue-based intensity tracking for our environmental KPIs (key performance indicators) as opposed to the conventional employee-based intensity,' Infosys said.

Of the total carbon emissions of 290,865 tonnes in FY21, Infosys attributed 41.4% to capital goods, 23.5% to global energy consumption, and 22.1% to work-from-home. Infosys said its ongoing efforts related to ESG have helped the company in remaining carbon neutral for fiscal 2021, for the second year in a row. Infosys turned carbon neutral in 2020, 30 years ahead of 2050, the timeline set by the Paris Agreement. EF

Source: https://www.livemint.com/

INDIA'S FUEL CONSUMPTION DECLINED TO A FOUR-YEAR LOW IN FISCAL 2020–21

India closed the financial year 2020–21 with a 9% decline in total fuel consumption over the same period last year. This fall is primarily attributed to COVID-19 lockdowns-induced slump in economic activities. According to data shared by the Petroleum Planning and Analysis Cell, India's total fuel consumption stood at 194.63 million tonnes (MT) during the year under review, down from 214.13 MT a year ago. This is a four-year low with 194.60 MT fuel consumption last reported in fiscal 2016–17. It is also the first recorded overall decline in the country's fuel consumption.



Petrol consumption stood 6.75% lower from 30 MT in 2019–20 to 28 MT in 2020–21. The fall was muted on account of a rise in preference for personal mobility in the later months of the financial year as COVID-19 lockdowns were relaxed. Liquefied Petroleum Gas (LPG or cooking gas) consumption stood at 27.59 MT, almost 5% higher than last year. This growth in consumption is driven by the three free LPG cylinders distributed to each of the 8 crore Pradhan Mantri Ujjwala Yojana (PMUY) beneficiaries early in the COVID-19 pandemic lockdowns. EF

Source: https://www.business-standard.com/

INDIA–NORWAY BLUE ECONOMY MODEL FOCUSES ON POST-COVID ECONOMY RECOVERY

Investing in the blue economy can help enable nations to address COVID crisis, and make sure that the global community builds back better and greener. This was the key theme at the fourth India–Norway Task Force on blue economy that met on June 9, 2021. The task force was chaired by Norwegian Ambassador to India, Hans Jacob Frydenlund and Ratan Watal, Member Secretary, Economic Advisory Council to the Prime Minister (EAC to PM). 'Blue economy partnership is the cornerstone of the bilateral cooperation between India and Norway. Since the creation of the Task Force in 2019, our cooperation has expanded and deepened,' the Member Secretary, EAC to PM said at the Task Force meet.

The COVID-19 crisis has caused disruptions to ocean industries and coastal tourism globally, but the potential for growth and job creation is substantial. Investing in the blue economy now can help countries out of the crisis, and make sure that the global community builds back better and greener. 'The Indo-Norwegian blue economy partnership is already contributing to this. In the last year, Norwegian companies have entered into new contracts with Indian counterparts, creating jobs and enabling transfer of green technologies,' Frydenlund said on the occasion. EF

Source: https://www.energyinfrapost.com/

DELHI'S POWER DEMAND TIPPED TO ALMOST DOUBLE IN 20 YEARS

Delhi's population is expected to grow by more than 10 million over the next 20 years and its power needs are projected to double in the same period. The draft Master Plan for Delhi 2041 has laid down strategies that would allow more than 50% of this energy requirement to be met through renewable sources of energy. Envisioning Delhi as a sustainable city and aiming to enhance its global competitiveness, the draft MPD41 says that the capital needs to switch to clean energy. In 2016–17, Delhi per-capita power consumption was 1561 units per annum against the national average of 1122 and 78% of the consumed power was purchased. The remaining comes from installed capacity within Delhi, with coal (59%) being the predominant generator, followed by gas (28%), hydro (10%), and solar power (3%).

The national policy and Delhi's state solar policy of 2016 too target meeting around 20% of power consumption from renewable sources by 2022, MPD41 states, adding that the city has to meet roughly 50.5% of its power consumption from renewable sources by 2041 to fulfil the national level targets set by the Ministry of New and Renewable Energy (MNRE), Government of India. EF

Source: https://www.energyinfrapost.com/

RENEWABLES TO MAKE UP MAJOR PART OF INDONESIA'S 2021–30 ELECTRICITY PLAN

Indonesia aims to increase the proportion of renewable power in its 2021–30 national electricity plan to at least 48%, from 30% in the 2019–28 plan, a senior Energy Ministry official said recently. The national electricity supply plan (RUPTL) is a power supply guideline set by the government for state utility company PT Perusahaan Listrik Negara (PLN) for a 10-year period, but the plan is regularly revised. 'We want this RUPTL to be greener. Meaning, the renewable portion will be bigger than in the previous RUPTL,' Rida Mulyana, the Energy Ministry's Director General of Electricity, said in a statement.

Under the current RUPTL, coal is expected to power 48% of the electricity needs of the country. Indonesia is a major producer and exporter of thermal coal. To reach the planned renewable power guideline, Rida said diesel power plants would be converted into renewable plants, while old plants will be retired, among other efforts. 'Simultaneously, the Energy Ministry is also designing a separate programme to meet a net zero emission goal,' Rida said. EF

Source: https://www.reuters.com/

OIL MAJORS ARE PURSUING RENEWABLE ENERGY PROJECTS

Expected low demand for fossil fuels is compelling major oil and gas companies—including BP, Total and Shell—to actively restructure and add renewable power projects to company's portfolios. This will help these companies reduce carbon intensity and align with the changing energy mix in the long run, according to GlobalData, a leading data and analytics company. Moreover, oil and gas EPC vendors are enabling the energy transition by building capabilities to set up renewable energy infrastructure.

Ravindra Puranik, Oil and Gas Analyst at GlobalData, comments: 'Global power demand is expected to grow at a compound annual growth rate (CAGR) of 2.5% from 2020 to 2030, according to GlobalData. A significant portion of this will be fulfilled by renewable power generation. This growth outlook makes renewable power a key market for players across the energy sector, including oil and gas companies whose traditional market is at risk amid the transition to low-carbon sources.' Within the renewable power sector, solar and wind energy are expected to show the highest growth rates over the next 10 years. EF

Source: https://www.energyglobal.com/

THE TIDES HELP POWER CARS IN SCOTLAND

Nova Innovation has announced that vehicles in Shetland, Scotland are now fuelled by the power of the sea, courtesy of the creation of the first-ever electric vehicle (EV) charge point where drivers can 'fill up' directly from a tidal energy source. The EV charge point is located on the shores of Bluemull Sound, at Cullivoe harbour on the island of Yell in Shetland. Beneath the water, Nova's tidal turbines have been powering homes and businesses in Shetland for more than five years. The island's vehicles can now be powered purely by the tide. 'Our technology generates electricity from the immense power of the seas, and it is changing the way we power our lives—from how we make a cup of tea to how we travel,' said Simon Forrest, CEO of Nova Innovation. 'We now have the reality of tidal-powered cars, which demonstrates the huge steps forward we are making in tackling the climate emergency and achieving net zero by working in harmony with our natural environment.' EF

Source: https://www.worldenergynews.com/

ABB AND SMC PARTNER ON 80-MW ENERGY STORAGE PROJECT IN THE PHILIPPINES

SMC Global Power Holdings Corp. (SMC), a major supplier of power to the national grid in the Philippines, has partnered with ABB to install battery energy storage systems (BESS) as part of its BESS Project. In countries such as the Philippines, several challenges negatively impact grid performance, such as the length of power lines required to connect the diverse archipelago, as well as intermittent energy supply from wind and solar, which needs storage to act as a frequency regulator. The BESS solution, the largest-of-its-kind in the region according to ABB, is designed to avoid large frequency deviations, which can result in costly equipment damage and disruptive power system failure.

Not only will the system increase grid reliability, it will also support the Philippines' ambitious plans to decarbonize energy generation, ensuring that 54% of its energy mix comes from renewables by 2040. 'Battery energy storage systems are transforming the market, driving wider adoption of renewable energy solutions, and helping to improve grid performance across the globe,' said Alessandro Palin, president of ABB's Distribution Solutions Division. EF

Source: https://www.renewableenergyworld.com/

IEA EXPECTS ANNUAL GLOBAL ENERGY INVESTMENTS TO HIT $1.9 TRILLION IN 2021

The International Energy Agency (IEA) has released its latest report on 'World Energy Investment 2021'. According to the report, the annual global energy investment is set to rise to $1.9 trillion in the current year, rebounding nearly 10% from 2020 and bringing the total volume of investments back towards pre-pandemic levels. The report also noted that investment prospects have improved greatly along with economic growth, although country-to-country variation remains. Global energy demand is set to increase by 4.6% in 2021, more than offsetting the 4% contraction in 2020, it said.

The study noted that the rise in investments in 2021 is due to a cyclical response to recovery and a structural shift in capital flows towards cleaner technologies. The energy investment composition will continue to shift towards the power sector for the sixth consecutive year instead of the conventional oil and gas supply. According to the IEA, the global power sector investment would increase by 5% in 2021 and exceed $820 billion—a substantial peak after staying relatively flat in 2020. Meanwhile, renewables dominate investment in new power generation capacity and are expected to account for 70% of the total share this year. EF

Source: https://mercomindia.com/

FIRST SOLAR TO EXPAND US SOLAR MANUFACTURING CAPACITY

First Solar, Inc. has announced that it will invest US$680 million to expand America's domestic photovoltaic (PV) solar manufacturing capacity by 3.3 GWDC annually, representing an implied capital expenditure of approximately US$0.20 per watt. The company intends to fund construction of its third US manufacturing facility, in Lake Township, Ohio, with existing cash resources.

Contingent upon permitting and pending approval of various state, regional and local incentives, the new facility is expected to commence operations in 1H23. It is projected to achieve its throughput entitlement (modules produced per day) by the end of the same year with over 3 GWDC of nameplate capacity, and is expected to attain full nameplate capacity, based on the company's module efficiency roadmap, in 2025. When fully operational, the facility will scale the company's Northwest Ohio footprint to a total annual capacity of 6 GWDC, which is believed to make it the largest fully vertically integrated solar manufacturing complex outside of China. EF

Source: https://www.world-energy.org/

GREEN BUILDINGS TO HELP POLAND REACH CLIMATE GOALS

Poland needs to decarbonize the country's construction sector as buildings play a crucial role in Poland's effort to meet the 2050 net-zero emissions goal, a new study shows. The Polish Green Building Council (PLGBC) in cooperation with the European Bank for Reconstruction and Development (EBRD) published on June 9 a report on the buildings sector, including construction, is responsible for about 38% of the country's carbon emissions. Whole-life carbon emissions are those that result from the construction and use of a building over its entire life, including demolition and disposal, the EBRD said in a press release.

The report provides a 'roadmap' to illustrate and navigate the complex challenge that Poland faces to decarbonize the construction sector by 2050. The decarbonization of buildings requires continuous engagement and the cooperation of many parties and this cooperation is a key task for all stakeholders, the report reads. Poland is a signatory to the Paris Agreement, which requires that global net greenhouse gas emissions reach zero by 2050. The European Union aims to reduce greenhouse gas emissions by 55% by 2030. These targets will be achieved by decarbonizing all sectors of the economy. EF

Source: https://www.world-energy.org/

TAIWAN ON TRACK TO REPLACE NUCLEAR ENERGY WITH SOLAR AND WIND BY 2025

Taiwan's nuclear power installed capacity decreased from 4.9 GW to 3.8 GW, at a compound annual growth rate (CAGR) of minus1.2%, according to leading data and analytics company GlobalData. If this trend continues, the country is set to meet the government's target of zero capacity by 2025. Taiwan intends to fill the gap created by the retirement of its nuclear power plants with renewable power capacity, which is targeted at 27 GW of installed capacity by 2025.

Rohit Ravetkar, Power Analyst at GlobalData, says: 'Renewable power capacity in Taiwan is estimated to increase to 40.6 GW in 2030 from 7.4 GW in 2020, at a CAGR of 18.6%, a significant jump for a country that relies mostly on coal for electricity generation. The government has been actively encouraging the use of renewable sources for energy generation to reduce dependence on fossil fuels. Solar PV and offshore wind will be the most installed renewable technologies in the country by the forecast date.' EF

Source: GlobalData.com

TECHNOLOGY TRANSITIONS IN THE ELECTRICITY SECTOR

Policy and Technology Perspectives in India

Innovation and technology have the potential to transform the electricity sector. Digitalization has had a major impact in the power system operation. Termed as 'smart grid', it brought in efficiency and optimization at the generation, transmission, and distribution levels. In this article, **Pankaj Batra** discusses how digitalization can help distribution system operators and suggests that the technology needs to be placed at the hands of the distribution system operator so that the problems can be rectified and streamlined.

Introduction

In the 1970s, Indians generally distinguished engineering qualification in electricity on the basis of two streams – electrical engineering that dealt with bulk power or the power system with electric power of the order of hundreds and thousands of amperes and kilovolts, and electronics engineering with electric power less than 1 ampere, i.e. in milliamperes and sub-hundred volts. Later over the years these two distinct subjects were merged and relatively newer subjects including power electronics were introduced.

Till the 1990s, electronics did not find much application in production, transmission, and utilization of bulk power. It, however, did find some usage in getting information in the bulk power area, using remote terminal units, as well as automating processes of start-up of generating units. This information was then fed into SCADA (Supervisory Control and Data Acquisition System), Sequence-of-Events Recorder, Trend Recorder, etc. Solid state relays were then followed, at first by duplicating electro-mechanical relays, and later by replacing them. Electro-mechanical governors in generating stations were then replaced by electronically controlled governors.

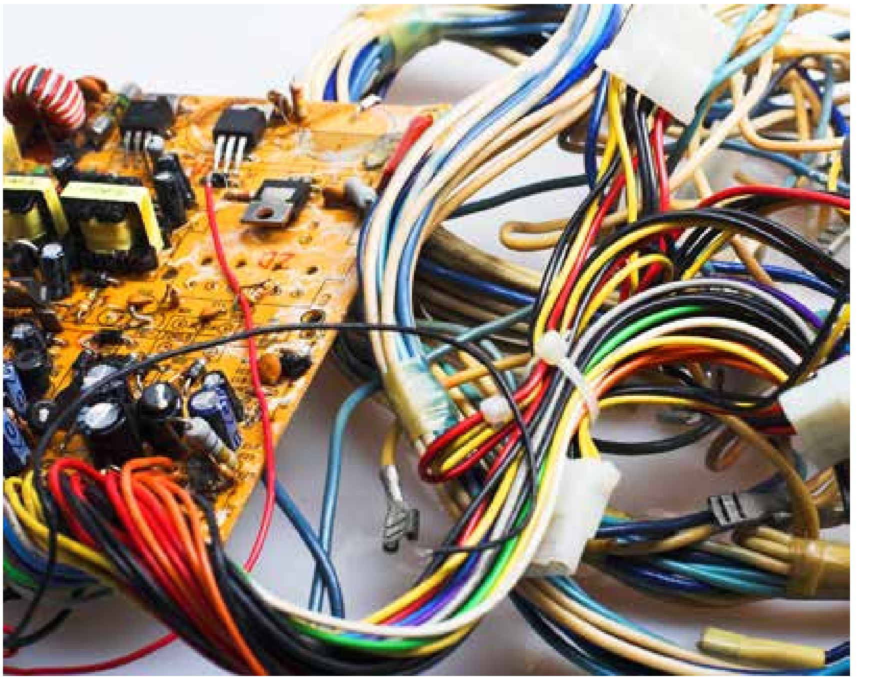
Digitalization has had a major impact in the power system operation. Termed as 'smart grid', it brought in efficiency and optimization at the generation, transmission, and distribution levels. Sensing the increasing importance of smart grid, the Indian government in 2010 started an inter-ministerial forum called India Smart Grid Task Force (ISGTF) and India Smart Grid Forum (ISGF), a public–private partnership. Headed by Sam Petroda, ISGTF's main aim was to serve as the government's focal point for activities related to 'Smart Grid' including a road map for implementation of Smart Grids in India. ISGF, on the other hand, provided a mechanism through which academia, industry, utilities, and other stakeholders participated in the development of Indian smart grid systems, and relevant inputs to the government's decision-making process. ISGF was headed by Mr Reji Pillai, who was also Chairman, Global Smart Energy Federation and an ex-IBM Vice President. Later, ISGTF was replaced by the National Smart Grid Mission (NSGM), an operational body under the Government of India.

From then on, India has come a long way. In the generation segment, the country has transitioned from sub-critical technology to super-critical technology in coal-based plants. India has also massively ramped up its renewable energy, notably solar and wind generation.

Technology in the Electricity Sector Over the Years

In the transmission segment, in 2010 the Government of India started the Central Electricity Regulatory Commission, the central regulator of India. The

government approved a pilot project proposed by Powergrid Corporation of the country, which is the central transmission utility in the country. The project dealt with Phasor Measurement Units (PMUs), as an aid to the System Operator (POSOCO in India) to pre-empt grid instability. These acted as the barometer of the power system, in terms of stability limit, for the system operator. It gave a lot of other information to the system operator, as it could detect cycle-level aberrations. This was followed by the Central Electricity Regulatory Commission approving the PMUs to be employed on a wider scale for the entire inter-state transmission grid in the country. The exercise was completed in 2017. In addition, many of the latest technologies are being deployed, including glass and synthetic insulators for polluted areas, hot line washing of insulators. The home-grown R&D efforts of generation and transmission companies have helped in increasing efficiency, based on the local conditions. It has emerged that the most important use of information technology or smart grid would be in the distribution segment of the power sector, which required maximum optimization. With increasing use of intermittent renewable energy, which could cause problems related to grid stability, it became necessary to have an automated demand response. Smart meters as well as smart electric vehicle chargers helped in achieving this. On the basis of the availability of power in the grid, the smart electric vehicle chargers could vary the rate of charging. The smart meters, on the other hand, had an additional advantage; it made available a lot of information, both consumer-related and transformer-related, to the state distribution company (DISCOM). The helped the DISCOMs in generating the load profiles of the customers and the transformers. On the basis of this information, the DISCOMs could then decide when transformer and electric line/cable augmentation were required. They could also do a cost-benefit analysis to see if system augmentation or installation of battery proved to be cheaper. By meeting the peak demand, which hardly lasted for more than an hour in a day, batteries can defer augmentation and sometimes put it off altogether. In Delhi, Tata Power Distribution Company Ltd has already put up a 10-MW pilot project of lithium-ion battery. BSES also plans to put up three pilot projects in three different locations in the capital. Moreover, the smart meters would help in accurately estimating the 15-minute demand, which will help in the efficient procurement of power by the state DISCOMs. This would help in monitoring the rooftop solar PV generation, which would be especially required when these come in a large quantity. At present, about 6000 MW of rooftop solar PV generating capacity has been installed, whereas the Government of India has set a target of 40,000 MW by 2022.



Digitalization of DISCOMs

Digitalization can help distribution with endless possibilities; among them reconfiguration of feeders, outage management system, customer management system being a few important ones. One of the simple, yet very effective means of consumer engagements is providing information to the consumer at their fingertips. The Urja Mitra App launched by the Government of India gives useful information to the customer about when maintenance work is scheduled to be carried out in their locality. The portal gives the users the opportunity to compare the performance of power availability between the distribution companies within each state as well as with other states. In fact, it also gives the performance circle-wise. The top performing distribution companies get ranked, depending on power availability; this encourages the poorly performing utilities to improve. This is only one of the Apps brought out by the Ministry of Power, Government of India to encourage efficiency. The other Apps include Merit (**M**erit Order Despatch of **E**lectricity for **R**ejuvenation of **I**ncome and **T**ransparency) that shows the price of power from available sources during the day at different times, so that everyone can see if the distribution companies are procuring the cheapest power

available, as per the merit order. There is also Uday App that gives the status of financial indicators and operational indicators, such as status of financial restructuring, AT&C losses, difference between ACS (Average Cost of Supply) and ARR (Average Revenue Realized) per unit, status of Feeder metering, distribution transformer metering, electricity access, smart meters installed. Electricity is a concurrent subject, with jurisdiction of both the Central and the State governments. So, the Central Government cannot force reforms by the States, other than what is given in law, i.e. The Electricity Act 2003. Putting the data on the public platform is a way, and a very effective way, for the utilities to perform better.

Policy Initiatives

Initiatives always start with law and policy. A number of forward looking laws and policy initiatives have been taken by the Government of India in the 2000s. It started in 1991 with bringing in participation of the private sector in generation. A number of private players evinced interest initially. The model was that the State government would guarantee 16% profit after tax to the generators, which were called IPPs (Independent Power Producers). The payment would be further counter guaranteed by the Government of India. However, it did not meet success, as the IPPs soon realized that most of the distribution companies were broke, and the government would be unable take such a burden. Also, the Government of India, realizing that all the burden would finally come on to it, also withdrew to some extent, and instead decided that it would counter guarantee only eight projects. Subsequently, many IPPs withdrew from the model.

Next came in the Electricity Act 2003 that brought about radical changes in the sector, including restructuring the erstwhile State Electricity Boards into corporate entities, defining the functions of various players, introducing a new entity for trading, i.e. power traders, for efficient buying and selling of short-term surpluses of power, speedily getting legal agreements into place, and generally facilitating power trade. The Act brought in competition in generation and distribution segments, offering a level playing field for the government and private players, through common technical standards and regulations.

The National Electricity Policy was brought out in 2005 and the Tariff Policy in 2006, as mandated in the Act. In January 2016, the revised Tariff Policy was brought out, which had a number of new forward-looking provisions, including the mandate for installing smart meters, Distribution SCADA with energy audit functions, a number of provisions for encouraging setting up of renewable energy plants, etc. The

Distribution SCADA, in conjunction with energy audit functions, had the advantage of being able to detect theft of power in real time. It also brought about a number of provisions that encouraged installation of renewable energy sources, by offering advantages.

Distribution Sector Reforms

However, much still needs to be done. The distribution sector needs to be further reformed. The distribution system operators need to be put in place for all the distribution utilities in India, similar to the private distribution utilities, such as Tata Power Distribution Company Ltd and BSES. The technology needs to be placed at the hands of the distribution system operator, so that faults in the feeders are immediately located and rectified, using fault locators, and, at the same time, the affected customers can be informed about the fault through automatically generated SMSes, including the time that power supply is expected to be restored. This is all possible through the Outage Management System, which simultaneously sends a message to the maintenance team about the fault and its location, so that minimum time is wasted in attending to faults. There also has to be an incentive system for the employees to be motivated. A carrot and stick policy must be adopted.

Renewable Energy Integration

The other big area, where technology can help in dealing with, is intermittent renewable energy such as wind and solar power. What is the need of the day is flexible generation and energy storage. The world is trying to adapt the existing technologies to the required technologies. The typically base load plants are being conditioned to become flexible power plants by carrying out some modifications, including incorporation of a bypass valve, using temperature sensors to ensure that the temperature differential in the thick metal parts do not lead to heat stresses and consequent cracks in them. What is also required is regulations for enabling demand response, by incentivizing consumers to reduce demand, when required by the grid. Demand response has been used in developed countries since long. Flexible AC transmission by the use of SVC (Static VAR Compensators), TCSC (Thyristor Controlled Series Compensation) would help in optimal utilization of the transmission system by changing the line parameters depending on reactive power flows, and enabling maximum use of the transmission system to carry active power. These have started getting deployed to a greater extent in the Indian grid. Dynamic Line Rating

should be used to maximize power flow depending on ambient conditions. Gujarat is already using this. The CEA has also issued guidelines on the same for use by all transmission utilities. Phase shifting transformers help to evenly load two parallel transmission paths, and are especially useful in places where the flows keep changing, like in areas of high renewable energy. These are being used in green corridors to evacuate bulk renewable power from the renewable-rich states. These are also used in the distribution system. Interruptible supply tariff and reliable tariff for the consumer to choose from would help in the consumers acting as frequency control ancillary services, and, therefore, reduce the need for the same by the system operator. Ancillary services, although given in the Tariff Policy 2016, is being presently used through generators with a regulated tariff in India, and not through competitively bid ancillary services. These are under finalization in the CERC. Once these come into place, they will give a boost to energy storage and hydro power plants flexible thermal power plants.

Addressing Environmental Concerns

The need of the hour is to care for our environment. One way of achieving this would be through reduction of emissions from fossil fuel fired power plants, notably coal. While no new coal-based plants are being conceived, the only ones that would come up are those under construction. Even those have necessarily to be of the high efficiency super-critical type or ultra-super critical type. Governments are shifting to improving efficiency of electricity consumption, such as substituting the normal filament and CFL bulbs with LED bulbs, encouraging electrical appliances of increasing efficiency, and making consumers aware of the star rating system. LED bulbs in India have alone saved 10,000 MW. System efficiency is being brought about by the proposed expansion of the balancing areas for balancing the intermittencies of demand and variable renewable energy, by expanding beyond the states' boundaries, and then transcending the national boundaries to other South Asian nations. The Government of India's

amended Guidelines on Cross Border Electricity Trade dated December 2018, the follow up Regulations of CERC dated March 2019, and the Procedure for approval of cross border transactions by the Designated Authority, Member (Power System), CEA, dated February 2021, are a few such proofs. The first

transaction, through this method, has already commenced in April 2021, with Nepal purchasing power from the Indian Energy Exchange, after approval of the designated authority. Electrification of remote villages is sought to be done through microgrids, rather than by drawing long transmission lines to these villages. This would help in avoiding waste of material for the long lines, transmission losses, and voltage drop. DC microgrids are also coming up in these places, so as to increase efficiency, using LEDs and DC fans that use DC, avoiding conversion from DC to AC and back to DC.

FAME II Scheme

The shift to electric vehicles (EVs) is another global effort in reducing emissions from fossil fuelled vehicles, and thereby making efforts to prevent climate change. The Government of India, launched the (FAME II) Scheme for Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles. The scheme has a total outlay of Rs 10,000 crore to be used for upfront incentives on the purchase of EVs, as well as supporting the development of charging infrastructure. The programme will be implemented over a period of three years, effective from 1 April 2019. The Government of India also launched the National Mission on Transformative Mobility and Battery Storage in 2019, which will drive clean, connected, shared, sustainable, and holistic mobility initiatives. The Mission aims at creation of a Phased Manufacturing Programme (PMP) for five years, to support setting up of large-scale, export-competitive integrated batteries and cell-manufacturing giga plants in the country, as well as localizing production across the entire electric vehicle value chain. A number of charging stations are in the process of being set up in big cities under the FAME II Scheme.

So, as far as technology is concerned, India is at par with using the latest technologies available globally, for generation and transmission areas. The area that is still lacking is the distribution area. This is also gradually picking up owing to the Government of India's 100 Smart cities programme.

Sometimes transition in processes themselves is good enough to bring about energy transition, and technology may not be needed. For example, Telangana and a number of other states have set up large capacities of solar power and stipulated that agriculture supply be given during daytime, when solar power is at its peak. This has led to optimal utilization of solar power, without the need for curtailment, and without the need for reducing their coal-based generation.

Innovative ideas are galore in various states. Policies can, therefore, also be made practical through rational thinking. This, therefore, demonstrates that it is innovation that matters, and when aided with technology, can really transform the electricity sector. EF

Mr Pankaj Batra is Project Director, SARI/EI - Integrated Research and Action for Development, and Ex-Chairperson, Central Electricity Authority.

BATTERY STORAGE AND OPERATIONAL USE-CASES AT ELECTRICITY DISTRIBUTION NETWORK LEVEL

Battery Energy Storage System (BESS) is being considered to be one of the most prominent technological solutions to manage the electricity supply and demand gap. Several types of BESS technologies are being deployed at different levels within the electricity network for a variety of applications. In this article, **Neshwin Nigel Rodrigues** and **Ram Krishan** discuss a few pilot demonstrations of BESS, which are being undertaken within the urban distribution network in the National Capital Territory (NCT) of Delhi.

Introduction

With the increasing penetration of distributed energy resources (DERs), in particular solar PV and wind energy, and the intervention of smart monitoring and control devices, the modern electricity grid is undergoing a paradigm shift wherein effective and reliable operation of the electricity network has become imperative. Distribution utilities have a challenging task-at-hand in terms of managing the peak loading and ensuring reliable and quality power supply. They also need to address the operational challenges posed by DERs, including those of electric vehicle (EV) chargers. The situation has become more pronounced in the case of metropolitan areas that face increasing load and space constraints and extreme weather variations, such as those in New Delhi. Hence, it was felt that there is a need for controllable balancing fleets at the distribution system level to maintain reliability and avoid periodic distribution network augmentation. Battery Energy Storage System (BESS) is being considered to be one of the most prominent technological solutions that can manage electricity supply and demand gap in an efficient way courtesy the rapid technological advancements and falling prices of lithium-ion batteries in addition to their quick response feature. Several types of BESS technologies are being deployed at different levels within the electricity network for a variety of applications (such as energy arbitrage, peak shaving, power back-up, power ramp control, frequency regulation). On the basis of their technological advantages and limitations, BESS technologies can help in avoiding power scheduling mismatch penalties (known as 'deviation settlement mechanism' control in India). However, appropriate sizing and siting of BESS is imperative for any particular application in order to optimize the overall system operation.

Pilot BESS Projects

Under the US-India Collaborative for Smart Distribution System with Storage (UI-ASSIST), we undertook a few pilot demonstrations of BESS within the urban distribution network in the National Capital Territory (NCT) of Delhi. These pilot demonstrations are being done for three different applications (serving three distinct consumer categories). These were identified after carrying out a pre-feasibility assessment. A preliminary study has also been performed. It comprises techno-economic analysis of different BESS technologies, load research, identification of plausible revenue streams, and development of operational strategy. The battery size and operational control scheme for these applications were determined so as to ensure system operation within the technical constraints of the selected battery technology. These included the state of charge (SoC) operating window, battery degradation, and charge/discharge rate limitations.

We identified the locations for the pilot project of BESS implementation in consultation with the distribution utility based on the prefeasibility study that was carried out for each site. Consequently, three different applications of BESS were identified for the selected category of consumers, as listed in Table 1. Further, the usable energy along with power requirement were evaluated for these applications, and accordingly these requirements were specified in a tender document (calling for installation bids), which also mentioned the use of multiple battery technologies such as Lithium Ferro Phosphate (LFP), Nickel-Manganese Cobalt (NMC), and Advanced Lead Acid. However, LFP batteries emerged to be the most suitable technology for the selected applications during tender evaluation process as they were found to be thermally more stable and cheaper than NMC batteries and having lesser footprint than Advanced Lead acid

Table 1: BESS size and application for various consumer categories under the UI-ASSIST

Pilot Locations	Usable Energy	Power Converter Rating	BESS Design Capacity	Battery Chemistry	Application	Benefit to Utility/ Consumer
Category A (DT level)	230 kWh	140 kVA	288 kWh (4*72kWh stack)	Lithium-ion (NMC/LFP**) or Adv. Lead Acid	Overload management of DT and energy arbitrage	Investment deferral Savings in peak power purchase Reliability improvement Increases the DT life
Category B (Housing society)	120 kWh	270 kVA	216 kWh (3*72 kWh stack)	Lithium-ion (NCM/ LFP**)	Back-up power and energy arbitrage	Diesel savings Savings in peak power purchase Emission curtailment
Category C (Institutional campus)	60 kWh	56 kVA	72 kWh (1 stack of 72 kWh)	Lithium-ion (NCM/ LFP**)	Energy time shift and solar PV smoothening	Savings in power purchase cost Absorbing the intermittency of solar PV

**Suitable battery technology identified during the tender evaluation process

batteries. The design capacity of the battery pack was calculated considering technical characteristics of the selected battery technology, such as Depth of Discharge (DoD), round-trip efficiency, and auxiliary consumption.

Pilot Locations

Under Category A, BESS will be primarily utilized to manage the overloading of an 11 kV/415 V Distribution Transformer (DT) as it is one of the most critical components of a distribution network. A DT involves huge capital investments apart from requiring special care during operation. Overloading of DTs must be avoided beyond a certain threshold after which the capital-intensive process of their augmentation or replacement becomes inevitable. Installation of a BESS at the secondary side of the selected DT is expected to provide techno-economic benefits in mitigating these conditions. A two-stage modular approach (preliminary and advance stages) for BESS sizing was followed to evaluate the appropriate capacity of the battery pack and the power converter system (PCS) to manage the peak load. The operational control algorithm for BESS charge/discharge was designed considering several technical constraints pertaining to safer system operation, such as charge/discharge rate limitations, different modes of charging (CC and CV), and SoC operating window.

Under Category B, which is essentially a power back-up application for common facility loads of a housing complex, the BESS is proposed to be integrated with the utility grid at a common interconnection point of an existing back-up diesel generator (DG) set, and will be operated in synchronization with the DG set. As the average load on the DG set during power outages was found to be higher than the BESS usable energy, we considered 2C discharge rate for system operation to meet the high power demand, and accordingly the power

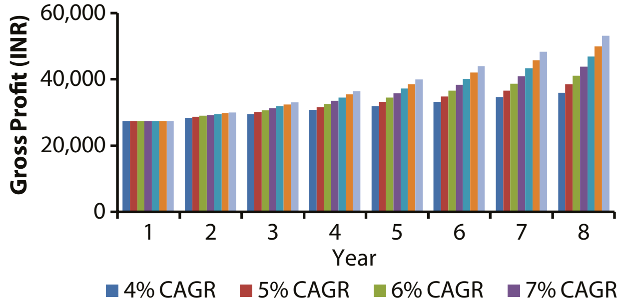


Figure 1: Annual profit envisaged under Category B operation in different years with distinct growth rate of diesel prices

Major Assumptions

DG Rating: 320 kVA

DG Loading: 60%

Power Outage Duration: 2 hours per month

Diesel Price: 70 INR/ l

Battery Useful Capacity & Power Rating: 120 kWh/240 kW

Maximum Load Demand during Outage: 192 kW

BESS Efficiency: 92%

converter rating was determined. The estimated profit from BESS operation in different years has been shown in Figure 1 considering annual growth rate of diesel price and several other assumptions as illustrated in the figure. Energy arbitrage has also been proposed as a secondary application under this category. The primary application under category C is energy arbitrage wherein BESS will be utilized to save the peak power purchase cost of an institutional campus that has opted for utility Time of Day (ToD) electricity tariff. The system will be interconnected at the secondary terminal of a local DT

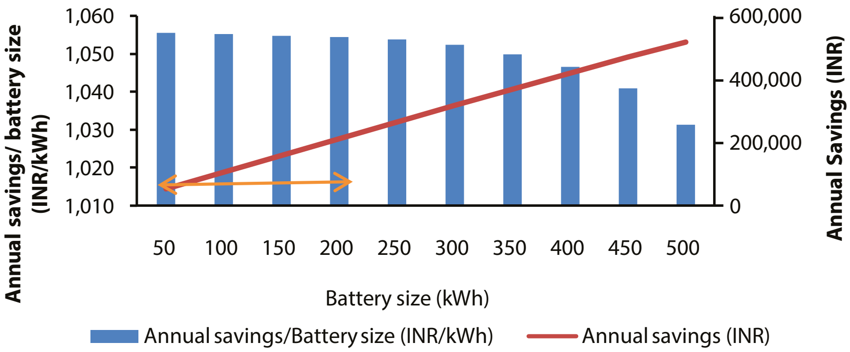
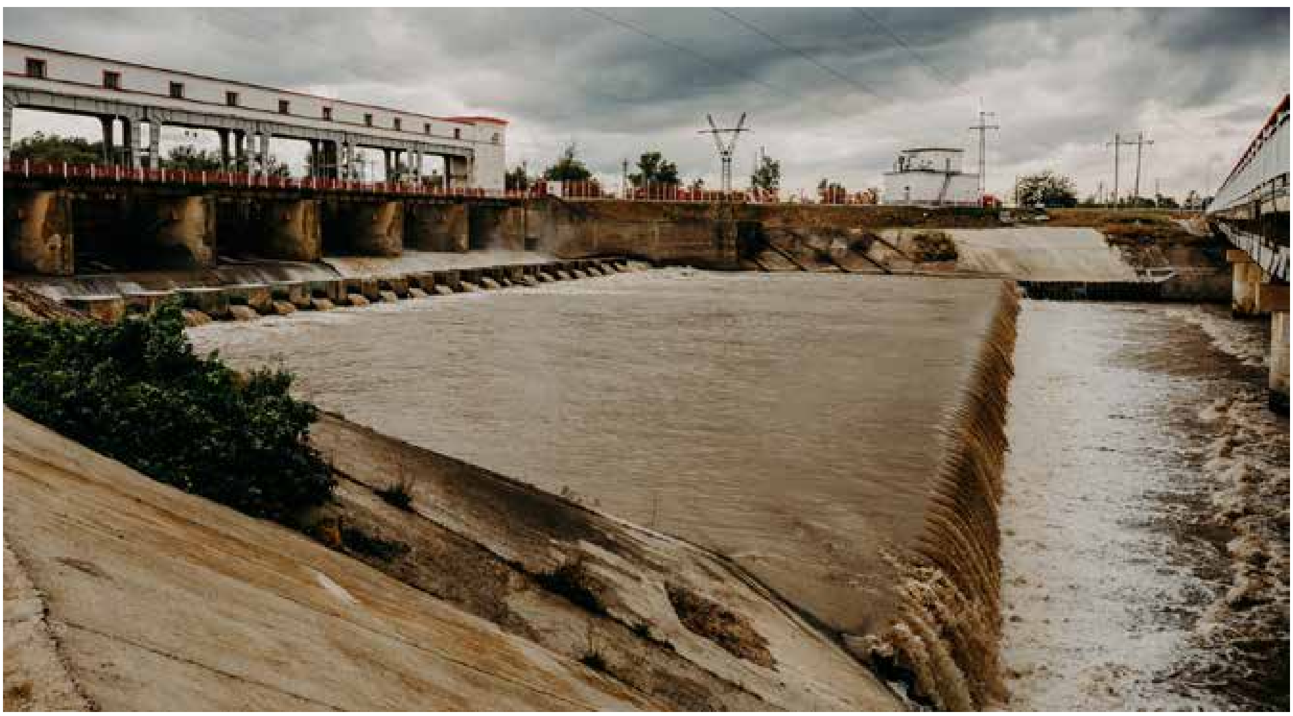


Figure 2: Savings with different battery size

dedicated for power supply within the campus and owned by the institution. The control scheme for BESS operation was designed in order to optimize the benefit to the consumer. The estimated benefit with different battery size was calculated, as shown in Figure 2, considering a few assumptions as listed in Table 2. As the BESS is a costly asset considering the current price of battery packs, it is wise to utilize the system for multiple use-cases so as to maximize the benefit to end-users and optimize overall system operation. Accordingly,

Table 2: List of assumptions for calculating benefits from BESS operation under category C

Projected Savings due to Battery Pperation			
Mid-Peak Operation		**No Mid-Peak Operation**	
Battery cycle life (years)	6	Battery cycle life (years)	10
No. of cycles completed (Year 1)	545	No. of cycles completed (Year 1)	312
Energy cost without BESS installed (INR)	7,531,826	Energy cost without BESS installed (INR)	7,531,826
Energy cost with BESS at end of year 1 (INR)	7,457,768	Energy cost with BESS at end of year 1 (INR)	7,471,812
Annual Savings (INR)	74,058	Annual Savings (INR)	60,014
Savings per cycle (INR)	135.89	Savings per cycle (INR)	192.35
41.2 % increase in savings by keeping battery idle at mid-peak			



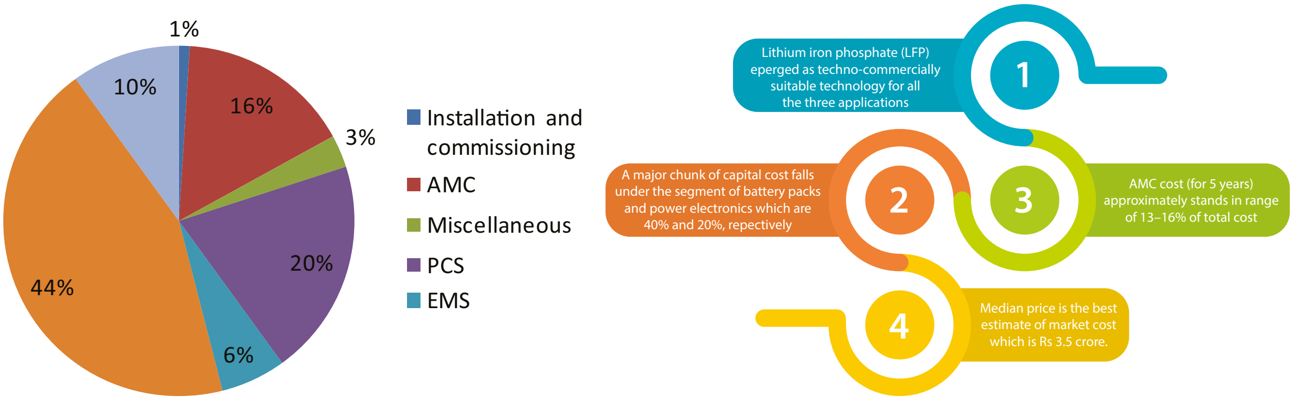


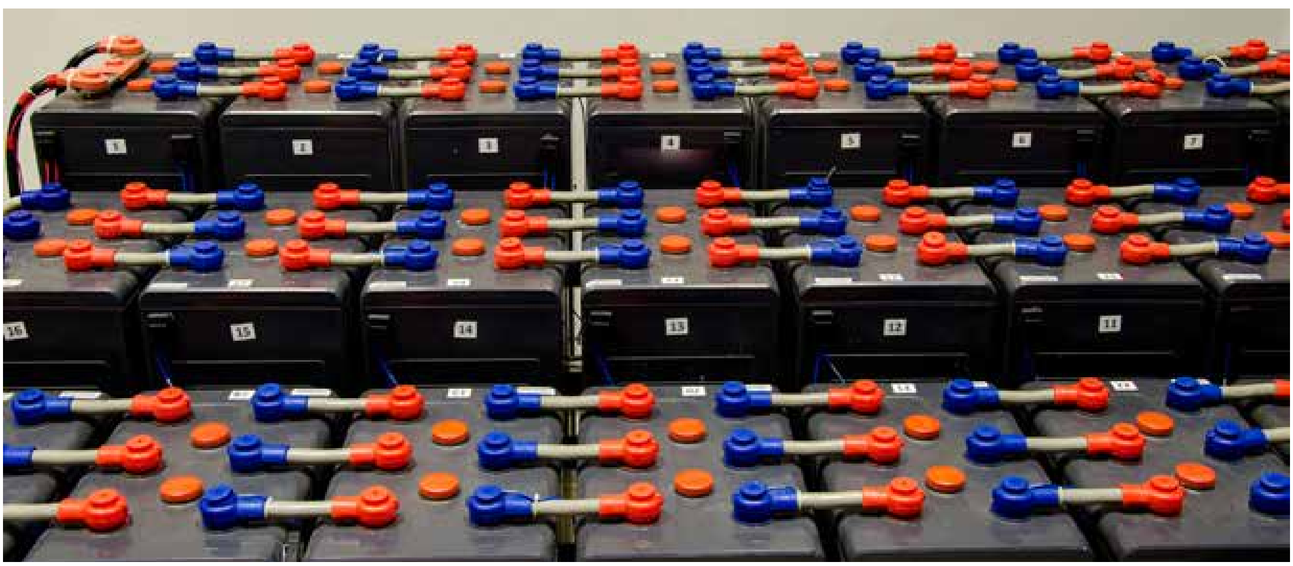
Figure 3: Key findings of TERI's tender

secondary applications for BESS operation were also explored under all the three pilots. As an example, peak shaving application shall be operated only for a few months in summer; however, the system may remain under-utilized if it is only operated under peak shaving mode. Hence, BESS is proposed to be operated under energy arbitrage mode for the remaining months provided that it does not overload the DT during charging under this particular mode. Similarly, smoothening of local solar PV generation has been proposed as secondary application for category C. The control algorithms for all these identified applications were initially designed in-house on the basis of preliminary research and simulation and laboratory testing. However, further refinements and modification are being done in consultation with the vendor who is installing the system at the pilot sites.

Key Features and Findings

As the project is focused towards technology demonstration and carrying out further research, the customizable EMS is one of the important features of this pilot which will leverage distribution utility to demonstrate more than one application at each site, as mentioned previously. The system will be interconnected with existing SCADA system of utility through appropriate communication protocol which will enable the system to monitor and control from both central and locally placed (at site) control stations. In addition to this, more emphasis was given on technical specification (70% weightage) as compared to financial (30% weightage) while evaluating the bid for pilot installation. Moreover, instead of upfront cost, per unit cost (INR/kWh) of desired output (total throughput) was taken as the basis of financial evaluation; therefore, this encouraged bidders to bid for most techno-commercially suitable technology. The major cost was observed for battery pack (in the range of 40–50%) while the cost of PCS and AMC was also considerable (20% and 16%, respectively), as it can be seen in Figure 3.

Neshwin Nigel Rodrigues is Associate Fellow and Ram Krishan is Research Associate, TERI.



VRE GRID INTEGRATION COSTS: A MODEL-BASED ASSESSMENT

Persistently falling utilization factor of coal plants and stranded gas assets are burdening the already strained finances of DISCOMs. The profile cost of the grid integration cost is the largest grid integration cost owing to huge sunk costs in the form of conventional generators. In this article, Shubham Thakare and Raghav Pachouri explain why investment in certain technologies can impact the power system. They also discuss how short-term renewable energy deployment can generate long-term benefits.

India is determined to add large amount of solar and wind energy in the Indian grid in the coming decade. This ambitious push to renewable energy is attributed to Government of India's vision to decarbonize the power system and enhance the country's NDC ambitions to reduce emissions intensity of GDP to 35% by 2030. Fall in prices and advancement in technologies in solar and wind energy have led to historically low tariffs in the competitive auctions. By year 2030, India's 25–30% of electricity generation will be contributed through renewable energy sources in comparison to approximately 9% as of today's share. As India moves ahead to add 450 GW of generation capacity from renewable energy, challenges have been arising from operational, reliability, and economic fronts.

Solar and wind energies are highly intermittent in nature with spatial and temporal variations, which make daily balancing a challenging task for system operators. In recent years, the government has continuously focused on power system flexibility including norms on technical minimum for coal generators, AGC control, and hydro as fast response ancillary services with many others. There are a number of studies detailing the operational and technical requirements for India to integrate higher shares of variable renewable energy (VRE) (Palchak *et al*. 2017, Spencer *et al*. 2020)[1,2]. However, to integrate VRE in the grid, certain costs are induced, known as grid integration costs, and need focus.

VRE Grid Integration Costs

Integrating such high amount of VRE in the grid has financial implications on the DISCOMs. First, states having existing PPAs with coal generators will face the double brunt on paying fixed costs for contracted capacities which have to be backed down. Second, to comply with RPO obligations, the DISCOMs have to pay tariff for purchasing power from renewable generators. Hence, it is imperative that we assess how VRE grid integration costs can affect and their implications on the utilities. Grid integration costs can be broken into three categories: transmission, balancing, and profile costs.

- Transmission cost includes the cost of using transmission assets to evacuate power to the load centres.
- Balancing cost arises from high intermittency from renewable energy owing to forecasting errors which make obligatory for other generators to be ready in the case of contingencies; the cost of holding such assets makes up for the balancing cost.
- Profile cost considers the cost of generating from back up assets when wind and solar are unavailable and can be broken into fixed and variable profile costs. When VRE is unavailable, such assets operate at low CUF; hence, it has high per unit fixed cost, which is a fixed component of profile cost. When these generators are running, the part load operation brings other costs due to ramping and frequent startups. This considers the variable component of the profile cost.

In a recent study, we published findings on the costs of high VRE grid integration through an integrated

[1] Palchak, David and Jaquelin Cochran, et al. 2017. *Greening the Grid: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid, Vol. II—Regional Study*. Golden, CO: National Renewable Energy Laboratory

[2] Spencer, Thomas et al. 2020. Renewable Power Pathways: Modelling the Integration of Wind and Solar by 2030 in India, TERI, July

resource planning (IRP) model that co-optimizes investment decisions and power system dispatch for planning year. In this article, we addressed the profile cost of the grid integration cost which is the largest grid integration cost owing to huge sunk costs in the form of conventional generators. In the study, we selected MSEDCL case study as it has a good capacity mix of conventional and renewable assets and has plans to add substantial amount of renewables in the coming years. In the study we tried to highlight crucial aspects for undergoing an IRP study for states. The key summary of the findings are as follows:

- 35–40% VRE grid integration is possible and this can be integrated with balancing support from baseload and peaker plants.
- High renewable energy grid integration comes at a cost of substitution between fixed cost assets and zero marginal costs of renewable energy plant. However, this tradeoff varies as per quantum of variable cost substitution.
- VRE supports incremental demand growth with decreasing storage prices; hence, it can be fairly good for daily and seasonal balancing.

Assessing the share of VRE integration that is economically viable

Aggregate shares of VRE is persistently increasing with state policies mandating to procure renewable energy power and comply to the RPO obligations, but how much investment is economically worthwhile needs to be assessed. In Figure 1, we have analysed scenarios by exogenously expanding solar and wind shares from the current level which is indicated by 'W_0_S_0' at 6% renewable energy penetration. Here the per unit system cost remains highest amongst all which is also 4.7% higher than the optimal VRE penetration. On the other hand, maximum VRE penetration reaches 55% of the total. Minimal change in the total system costs is observed throughout owing to the substitution between fixed and variable costs. As the share of VRE increases in the system, the levelized variable costs go down as zero marginal cost VRE substitutes for high marginal cost conventional generators. At a point where the fixed cost substitution due to increase in VRE investments outweighs the benefits of removing high marginal cost generators, the overall system cost increases. It is observed from Figure 1 that 35–40% of VRE penetration in the system remains cost optimal. Other factors which drive the optimal VRE include capital intensity of residual assets in the system and the correlation between VRE output and the load met.

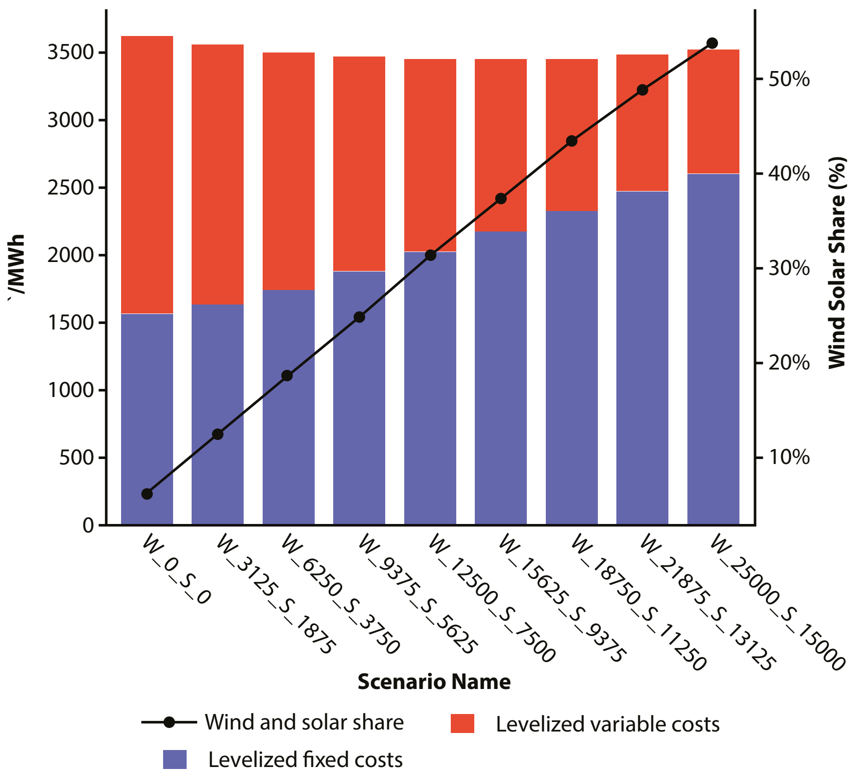


Figure 1 System cost and RE penetration comparison

Role of Technologies Influencing RE Integration Costs

As discussed earlier, persistently falling utilization factor of coal plants and stranded gas assets are further burdening the strained finances of DISCOMs. So investment in certain technologies can impact the power system, which is further discussed here. The model determines this in a way how grid services can be served by the pool of generating portfolio to meet the incremental load. As shown in Figure 2, we assess this by comparing system cost and capacity built in each of our scenarios listed in x-axis. The model does not find it economical to build new coal though restrictions on low VRE (22% share in generation) and gas forces coal to be built in the system only with higher coal PLF (>55%), which further increases the total system cost. Although high marginal cost drives up the system cost, the last mile option to deliver the load is provided by gas. The lower capital cost will enable in building gas even though per unit levelized cost is high, which indicates a low utilization. Further, the role of brownfield expansion of existing hydro reservoirs to pumped storage in the analysis is seen to be economical; pumped hydro replaces the need for new peaking gas capacities and acts as a form of seasonal balancing resource. Uncertainty over gas availability can aid brownfield hydro to be an economical option owing to lower sunk costs than gas.

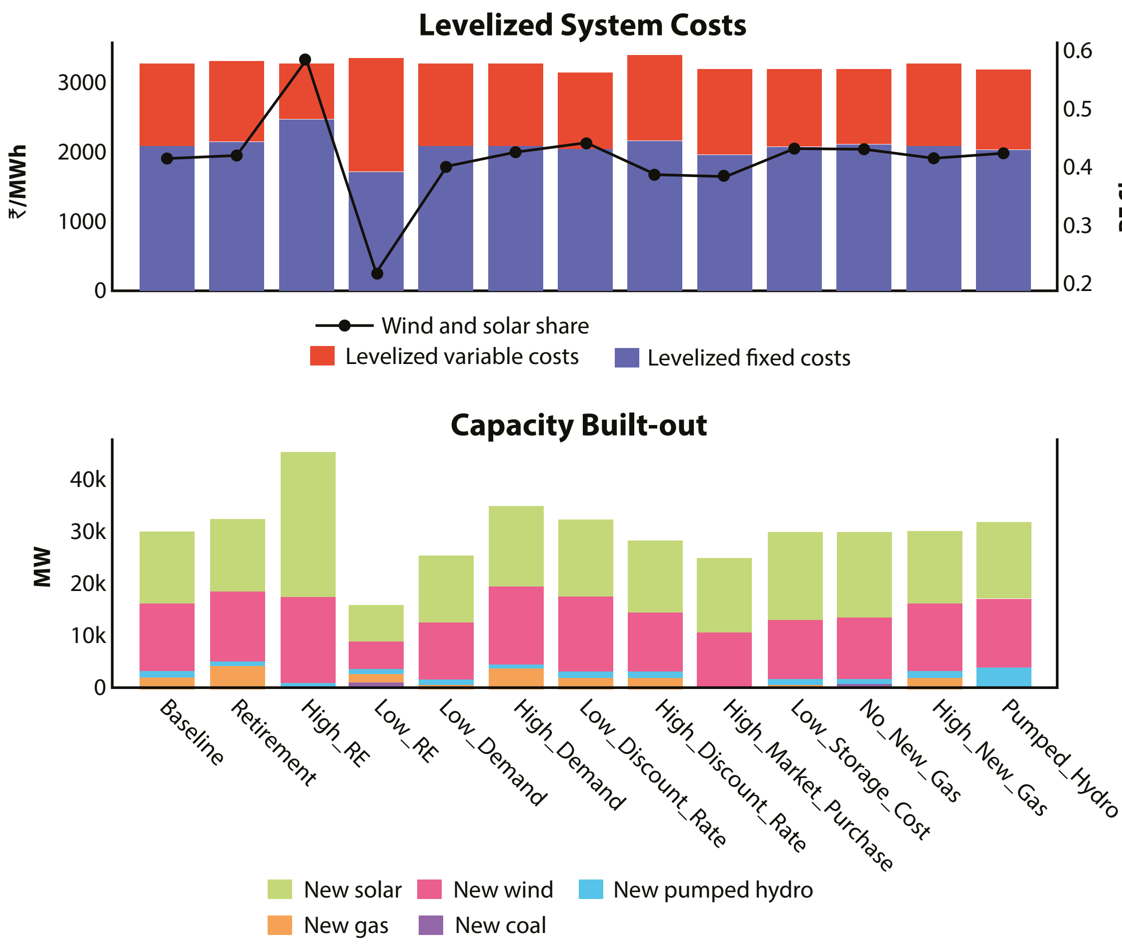


Figure 2 Capacity built-up and system costs across scenarios

Role of Various Flexibility Resources Driving Energy Transition

As discussed in the previous section, various technological characteristics can guide investment decisions towards VRE grid integration cost. Now we move to some aspects of how different flexibility resources change the VRE grid integration landscape. First, we look at the energy storage and compare to other flexibility resources. Battery Energy Storage (BES), being cost sensitive to duration, needs to cycle daily to allow low delivered cost of energy. The role of BES in daily versus seasonal balancing lies in the threshold at which

the energy cost of storage reaches. With prices of battery decreasing, it is expected to reach 80–110 USD/kWh by 2030, and thus substantial changes in investment decisions can be observed. This has been encompassed in the form of scenarios as indicated in Figure 3. With decreasing BES prices, there is preference to invest in solar energy and, hence, the share of new gas capacities has been decreasing subsequently.

One has to understand the economics behind flexibility of battery storage and how gas and pumped hydro compete. Gas as a flexibility resource has a competitively low capacity cost, which indicates that its sunk cost is low. Since variable component of BESS is a sunk cost, it is sensitive to CUF, which means BES will be preferred if and only if its utilization is uniform. As the duration of net load increases and is infrequent, the model prefers gas or pumped hydro to serve the flexibility. This suggests that BES is preferred to serve daily balancing and gas/hydro for seasonality. When battery prices fall below 80 USD/kWh, complete substitution of gas takes place giving an indication for long-duration storage options.

The above backdrop suggests that the short-term VRE grid integration of up to 35–40% of total generation is substantively possible with minimal effect on the total system costs. Considering the trade-off between variable cost savings and marginal increase in fixed costs, the advantage lies in the way generation portfolio exists. Regions with high variable cost generation have an added advantage to gain variable cost savings and vice versa. Thus, enhanced grid integration will help better utilization of sunk assets. As demand grows further and energy cost of storage falls, the role of longer hour storage will play substantial role. The highlight of the study validates that adding new coal fleet is not economically feasible and short-term renewable energy deployment can generate long-term benefits.

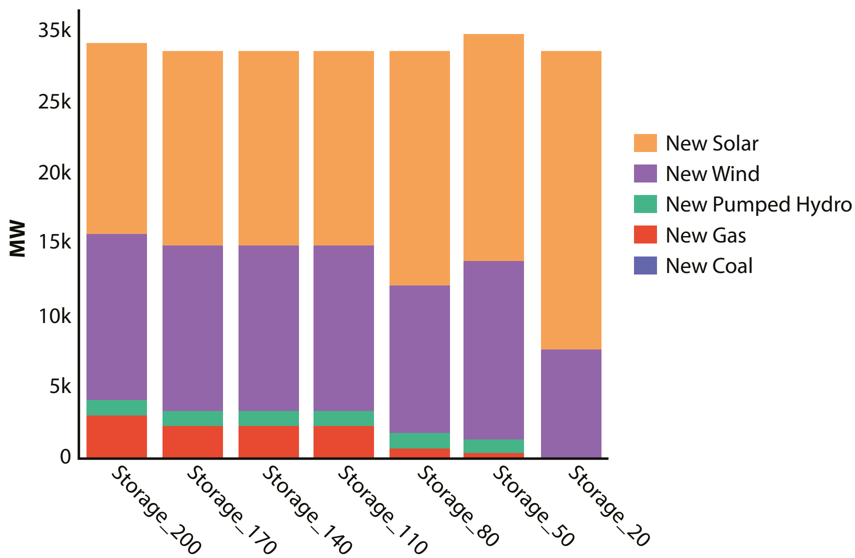
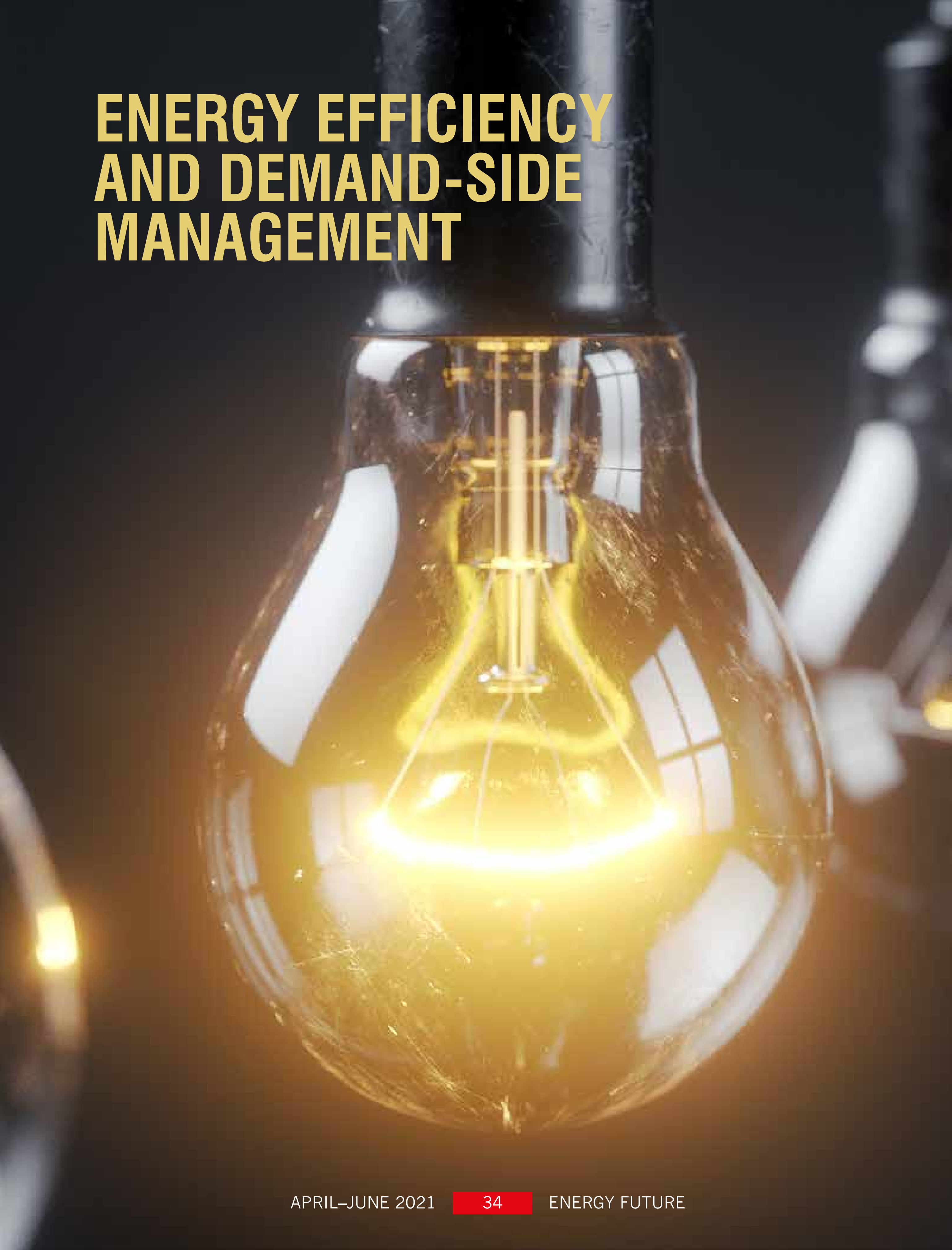


Figure 3 New capacity built-up in storage scenario family

Raghav Pachouri is Associate Fellow and Shubham Thakare is Research Associate, TERI.

ENERGY EFFICIENCY AND DEMAND-SIDE MANAGEMENT



COVID-19 has led to a huge shift in energy consumption, particularly during the lockdown phase when there was a dramatic reduction in energy consumption among the service and other industries. Residential energy consumption increased marginally due to the work-from-home shift, with several organizations continuing to working online. In this article, **Anita Khuller** discusses the role of energy efficiency (at both the retail appliance level and on industrial scales) and demand-side management.

During the 25 March 2020 to 31 May 2020 lockdown (in phases), the demand for energy commodities dropped by 25% to 30% in India, according to KPMG estimates, leading to plant closures and inventory pile-up. As per International Energy Agency (IEA), in September 2020, driven by higher demand for electricity in irrigation and in industrial and commercial sectors, the country's recovery in electricity demand was confirmed as 3.4%, an increase in comparison to September 2019 on average. In October 2020, ralaxation of restrictions and a stronger economic environment led to a 10% increase in electricity demand above the October 2019 levels, in line with the pre-Covid-19 trends.

By November 2020, the upwards trend inverted again due to strikes in the agriculture sector and the onset of an early winter, but improved in December.

Consumption Analysis

Residential energy consumption accounts for 30% of the total final consumption (TFC) in India, the second highest after the industrial sector, which is more than 42%[1]. This energy is consumed in a variety of applications, such as cooking, lighting, water heating, ventilation, refrigeration, and air conditioning. The different energy sources used in households include electricity, liquefied petroleum gas (LPG), kerosene, firewood, and biomass, with the types of energy sources and usage trends varying widely between rural and urban households.

[1] Details available at http://mospi.nic.in/sites/default/files/publication_reports/Energy%20Statistics%202019-finall.pdf

A study by CLASP and Environmental Design Solutions in 2019–20 on end-use monitoring found that appliances such as cell-phone chargers, TV sets, set-top boxes, cooktops/stoves (fueled by liquid/gas fuel), refrigerators, and ceiling fans have penetrated 80% or more of the market, while washing machines, electric cooking products, lighting products, air coolers and air conditioners are expected to reach higher ownership levels.

Space and water heating appliances are major contributors towards winter peak demand while summer peak is attributed to space cooling devices. Energy consumption also increases with increase in family size and socio-economic strata. Moreover, energy consumption of households with air conditioners is higher than that of non-air conditioner households throughout the year. One reason for this could be

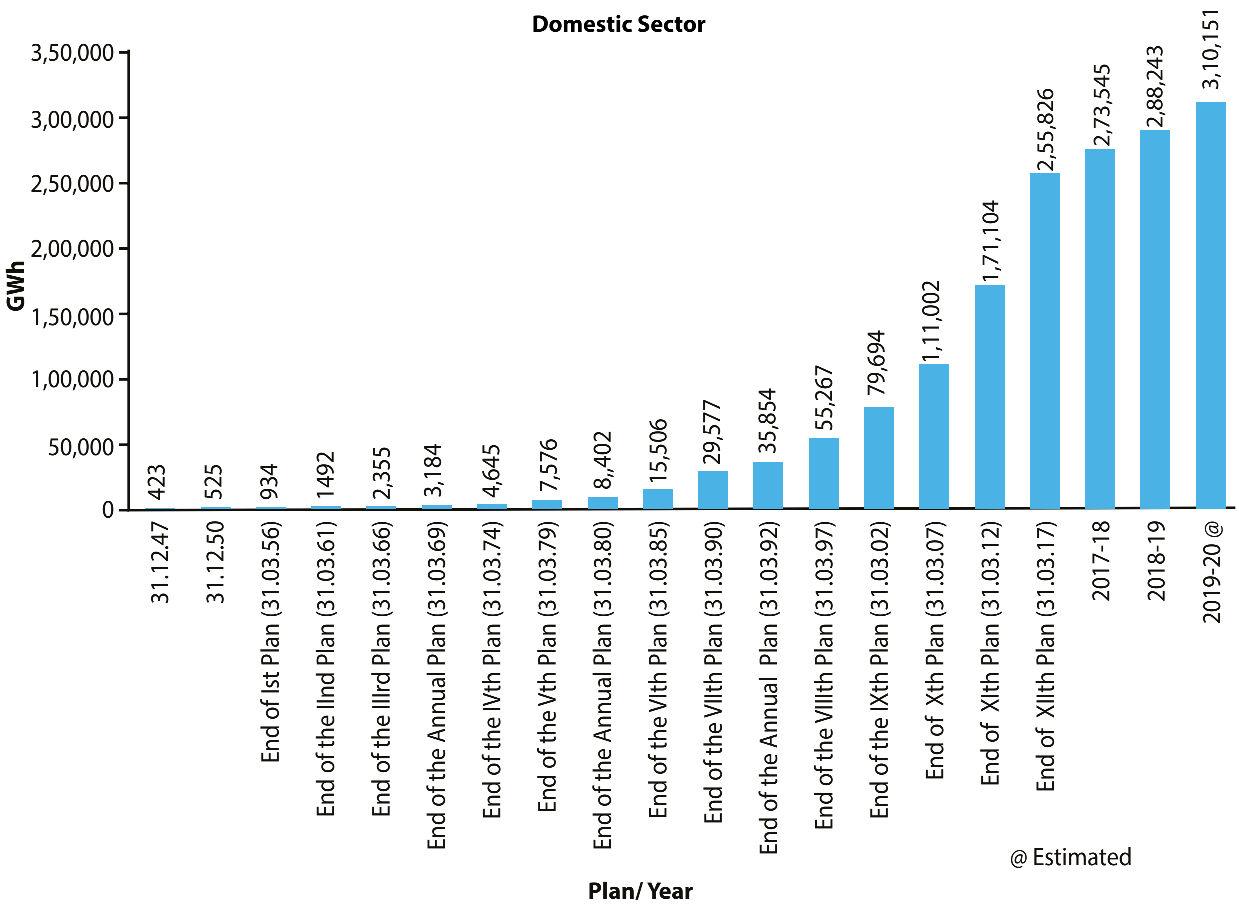


Figure 1: Plan-wise growth of electricity consumption in India

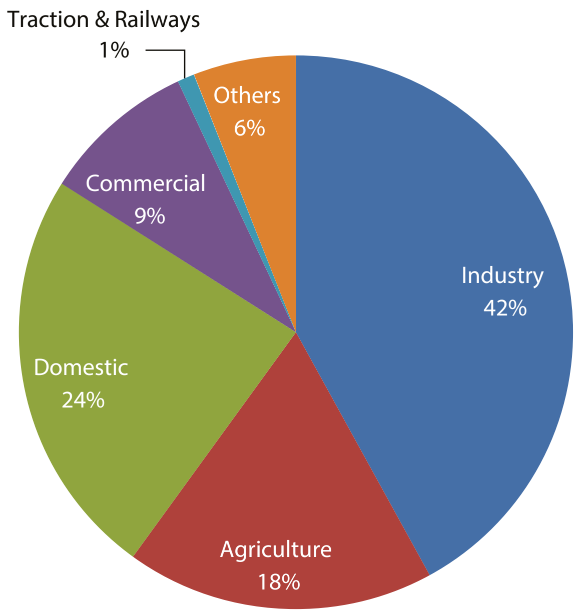


Figure 2: Consumption of Electricity by sectors in India during 2017-19

Energy Efficiency: The Need of the Hour

COVID-19 has further highlighted the importance of cutting costs. One of the most pressing areas is space cooling given that India's building stock continues to increase at a rate faster than anywhere in the world. Energy efficiency opportunities should be a priority in urban planning, with options that help in reducing cooling demand such as reflective surfaces, green and blue zones, and shading. A commendable step in paving the way is the Indian Cooling Action Plan (ICAP), the first of its kind globally. The ICAP[2] was launched in March 2019 by the Ministry of Environment, Forests and Climate Change (MoEFCC), and provides a 20-year perspective and outlines actions needed to provide access to sustainable cooling. Training and certification of 34,000 refrigeration

higher socio-economic strata. Despite the surge in demand for appliances, India's ownership rates are still among the lowest in the world.

Appliance ownership was expected to increase dramatically over the coming decades, but the COVID-19 scenario could lead to shifting priorities.

[2] Details available at http://moef.gov.in/wp-content/uploads/2020/09/On-World-Ozone-Day-India%E2%80%99s-Cooling-Action-Plan-gets-UN-applaud-16-09-2019.pdf

Table 1: Variation in energy consumption with family size, socio-economic strata and climatic zones

Category	Family Type	Socio-Economic Strata	Climatic Zone
Energy Consumption	Energy consumption increases with increase in family size and is highest in summers	Energy consumption increases with increase in socio-economic classification, i.e. the higher the SEC, the higher the consumption. Energy consumption is highest in summers	Composite and warm and humid climatic zones consume highest energy in summers, except cold climate, where highest energy is consumed in winters

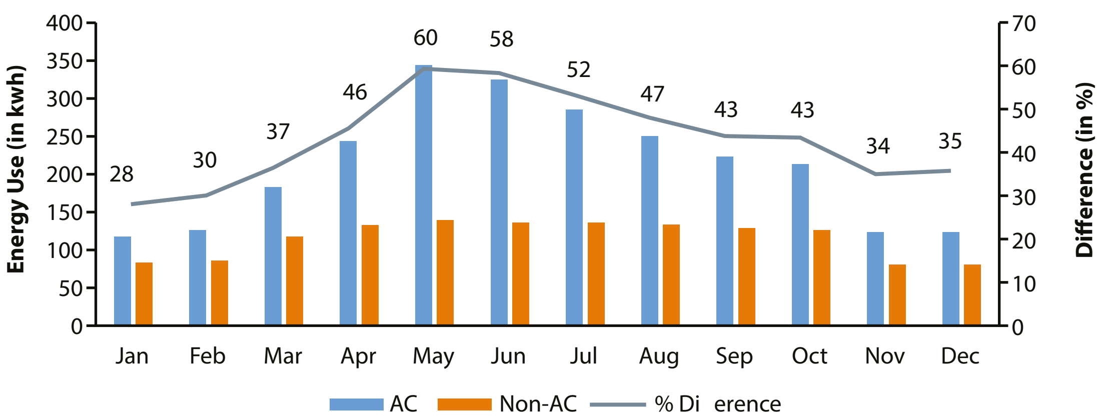


Figure 3: Monthly energy use comparison for AC and non-AC households

Table 2: Variation in energy use with seasons for AC and non-AC households

Category	Family Type	Household Size	Climatic Zone
AC household	Joint family had highest energy consumption throughout the year, while nuclear with elders had high energy consumption in monsoon and winter	Energy consumption increases significantly with increase in the size of household, the variation peaking in summers	Composite zone consumes highest energy consumption, while temperate zone consumes lowest
Non-AC household	Energy consumption increased with increase in family size. Joint family had highest energy consumption throughout the year	Energy consumption increases marginally with increase in household size	Composite zone had highest energy consumption throughout the year, particularly peaking in summers and monsoons

and air conditioning (RAC) service technicians was conducted on the benefits of sustainable cooling and to enhance their skills – one of the important milestones achieved as of September 2020.

India's size, scale, and stage of development have allowed large and timely energy savings, and have stimulated a national market for energy-efficient products and services. India has already demonstrated an impressive ability to develop, replicate, and scale up innovative, market-based approaches to energy efficiency. It has a strong community of non-governmental organizations, industry associations, research institutes, and think-tanks that are active in the energy-efficiency area. India also has competitive appliance, equipment, electronics and automotive industries, and is a global leader in information technology and related services. By stimulating the development and use of digital solutions for energy efficiency, the country can grow its leadership in this area and access rapidly expanding markets across the world.

There is also significant scope for expanding the coverage of the Bureau of Energy Efficiency's (BEE) Standards & Labeling (S&L) programme in the country. For example, China's voluntary/mandatory energy-efficiency labelling programme covers more than 80 products and the US programme, one of which is the Energy Star endorsement labeling programme, covers more than 60 categories of products.

International experience also indicates that insufficient compliance and enforcement of standards and labeling programmes can result in 25–50% lower energy savings than projected.[3] The effectiveness of such programmes could be boosted by increased capacity building at the state level, increased testing, coupled with expansion of laboratory and testing facility capacity, and further efforts in label compliance.

DSM Measures/Impact

Various demand-side management (DSM) programmes are being implemented to shape the energy

[3] CLASP, 2019