July–December 2021

# ENERGY FUTURE

The Complete Energy Magazine

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COVER STORY

## COAL TRANSITIONS IN INDIA: MITIGATING THE SOCIO-ECONOMIC FALLOUTS

FEATURE

## ELECTRIC VEHICLES AND SMART CHARGING

VIEWPOINT

## ADOPTION OF TECHNOLOGY AMONG FARMERS

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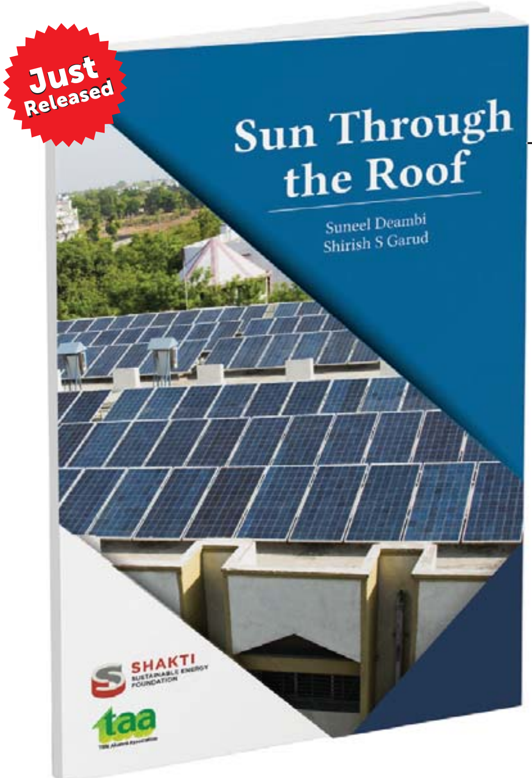
# SOLAR ROOFTOP SYSTEMS EXPLAINED IN LUCID AND EASY TO UNDERSTAND MANNER




**Kind of questions answered in the book:**

- Will I have continuous supply if I install a rooftop solar system?
- What should be the right-capacity (kilowatts) system for me?
- Do I get any subsidy from the government (state or central)?
- How much will I earn by selling surplus electricity?
- What is the difference between net metering and gross metering?

- ISBN: 9788179936832
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*Sun Through th*e Roof introduces its readers to grid-connected rooftop solar systems for the residential sector. Against the backdrop of rising tariffs coupled with fluctuating voltage and continuing shortage of electricity – and the noise and fumes from diesel-powered generators to make up for such poor-quality supply – the book hopes to convince its readers of the many benefits of generating electricity through rooftop solar systems while, at the same time, making readers aware of some of the drawbacks of those systems.

In keeping with the objectives of the 'Concerned Citizen' series, Sun Through the Roof seeks to answer many of the frequently asked questions about rooftop solar systems and also to provide essential information and insights to those who are considering that option not only to reduce their electricity bills but also to do their bit for the environment and sustainable development.

**This book is useful for adults who are concerned about topical issues but lack the understanding to make sense of what they read or watch in the mass media**

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# Editorial

Establishing secure, affordable and sustainable energy is one of the major challenges for the developing Indian economy. India's energy supply is heavily reliant on fossil-based sources, predominantly coal. Conventionally, coal has been the most abundant, though not unlimited and cost-effective resource. Nevertheless, a number of factors are now increasingly causing a dilemma around the role of coal in the future energy mix. Local environmental damage owing to unceasing coal extraction, especially air pollution, and concerns around the adverse impacts of climate change have become a pressing concern. Eventually, this has a spiralling effect and impacts natural resources, local economy, living condition and deepens vulnerability. Hence, India needs to transition from coal and switch towards renewable sources of energy, which could trigger innovation and promote alternative economy.

All said and done, India faces a huge challenge in coal transition today—transitioning entire regions and districts, finding alternative livelihood opportunities for a huge population, aligning existing skill-sets with the changing demands and meeting our sustainable development and climate goals. The scale and size of this transition alone makes it unprecedented in the history of coal transitions across the world. Coal transitions are likely to have the significant impact on the people in the central and eastern states of West Bengal, Jharkhand, Chhattisgarh, Odisha, and Madhya Pradesh, with some parts of Uttar Pradesh, Telangana, Maharashtra, and Andhra Pradesh. Characteristics endemic to the Indian market complicates this process of transition further. These include the large presence of contract/off-roll labour in every sector, a culture of informality and associated complexities, the socio-economic profile of the labour in these sectors, and the overall sectoral roadmaps. Low education and limited skill levels as well as high informality will be barriers to envisaged transition. Further, the technical nature of the green industries necessitates targeted reskilling and training programmes, promotion of an entrepreneurial ecosystem and circular economy without which a just transition will be difficult to achieve in India.

A well-planned transition and advance planning can take care of most of these challenges. The transition will necessitate aligning state, national and sector roadmaps at the planning level as well as participatory planning by aligning needs and aspirations at the local level. Strategies towards decarbonization cannot be undertaken with simultaneous investment and expansion of the coal sector and its allied uses without adequate reflection on implications of the conventional pathway that is over-dependent on coal. This will impede investments needed to meet the net-zero target and continue the carbon lock-in with possibilities of stranded investments. Further, India needs to define a coal transition pathway across different sectors with targeted emphasis on contract/informal labour and risk mitigation. Without this it is possible that a significant chunk of the labour force will not be beneficiaries of the transition policies. Accounting for the contract labour force also helps accounting practices and disclosures as India needs to determine the financial and economic costs required for the transition.

Environment remediation will have to become a necessary component in all regions with increased capacity at the central and state level for their monitoring and implementation. Finally, all stakeholders have a role to play in this transition roadmap. District authorities become the focal point of the transition roadmap since they are the key implementors and the first point of contact for local resistance or support. Industries will need to be brought on board for their input on district-level investments and preparing the transition strategy for the existing labour force. Labour unions have also to become a necessary part of this conversation since they will essentially be the communication bridge between the management, governments, and the larger labour force.

Girish Sethi

**Girish Sethi**
Senior Director – Energy Program, TERI

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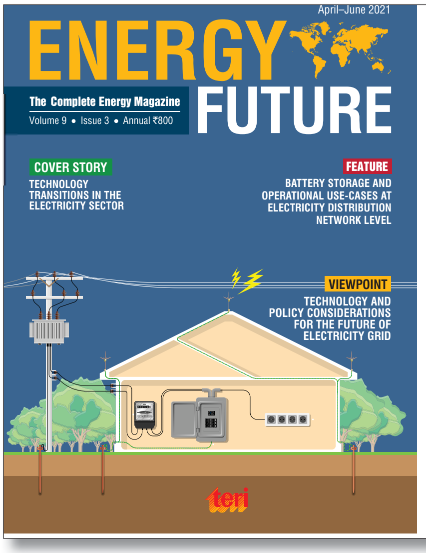



New Message

teripress@teri.res.in

Letter to the Editor

The theme of the April-June 2021 issue of *Energy Future* is quite apposite indeed. I agree with the author that 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 INR10,000 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 April 1, 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.

**M K Ghoshal**
New Delhi

Send

"I liked reading the feature article on VRE Grid Integration Costs published in the April–June 2021 issue of Energy Future. The article 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."

Harpreet Garewal
Mumbai, Maharashtra

Thank you very much for your encouragement. The editorial team of Energy Future will ensure that the magazine caters to your information and knowledge needs. We welcome your suggestions and comments to further improve our content and presentation.

Email: teripress@teri.res.in
Editor
Energy Future

"The feature article on Energy-Efficiency and Demand Side Management published in the April-June 2021 issue of *Energy Future* is quite suitable indeed. International experience shows that energy management systems such as ISO 50001 can reduce company-level demand by 10–30% within the first year of adoption. But by end of 2017, only 1613 sites in India had ISO 50001 certification compared to more than 30,000 in Germany alone, where uptake has been promoted through tax incentives. The government could also consider incentivizing the use of energy management information systems that enable real-time monitoring and management of energy use. Implementation of such systems in industry shows an average of 10–20% reductions in energy use. Also required is expanded coverage of India's mandatory minimum energy performance standards and labels to industrial equipment such as compressors, pumps, fans, and boilers."

**Mihir Kumar**
Chennai, Tamil Nadu

"There will be a huge surge in demand for omnipresent lithium-ion battery with growing popularity of electric vehicles. However, disposal of lithium ion battery will remain a major concern as the environmental impact of these batteries, as lithium is a reactive alkali metal, are still unexplored. Dumping of spent batteries to landfills will certainly contaminate the soil and pose a serious threat to the ecological balance of the local area. Dumping of lithium ion batteries is not only dangerous to ecological system but also considered as missed opportunity from the economical perception. Hence, recycling can bring down the cost by extracting precious materials, curb detrimental emission, reduce energy consumption, and preserve the natural resources."

**Renuka Sharma**
Guwahati, Assam

# CONTENTS


4 **NEWS**

**COVER STORY**

12 Coal Transitions in India

**FEATURES**

20 Electric Vehicles and Smart Charging

28 Recycling Batteries

36 End-use Power Demand Estimation in Residential Sector

44 Energy–Food–Water Nexus

52 Energy Transitions

**SOLAR QUARTERLY**

56 Fostering DER Integration in Distribution Grid

**ENERGY INSIGHTS**

60 Ablest Faecal Sludge Management

**VIEWPOINT**

70 Adoption of Technology Among Farmers

**SPECIAL EVENT**

74 29th Convergence India

76 'Investing for Impact: Food, Agri and Agritech' Report

78 **ABSTRACTS**

80 **BOOK ALERT**

82 **TECHNICAL CORNER**

86 **ENERGY UPDATE**

88 **RE STATISTICS**

# GOA'S DEMAND FOR POWER WILL DOUBLE IN NEXT 15 YEARS: TERI

The Energy and Resources Institute (TERI) has said that power demand in Goa has increased steadily over the past six years, and is expected to double over the next decade and a half.

The per capita consumption of power in Goa is almost double the national average, TERI found in a recent study. TERI added that despite achieving 100 per cent electrification, various challenges continue to hamper the state's efforts in ensuring 24x7 supply to all citizens.

TERI stated that it is important not only to meet the ever-growing demand for power, but also to progressively increase the share of renewable energy (RE) to achieve overall energy security. In the detailed study to identify strategies for 'greening the sector and improving the reliability of power supply', it said it was also important to meet the renewable purchase obligation as per the target fixed by the joint electricity regulatory commission (JERC) from time to time. EF

*Source: https://timesofindia.indiatimes.com/*

# INDIA'S CLEANEST CITY INDORE TURNS WASTE INTO FUEL, MONEY

The efforts taken by the Indore Municipal Corporation (IMC) to keep the city clean not only earn it bragging rights as India's cleanest city year after year but also some hard cash. Indore was adjudged the cleanest city for the fifth year in a row in the Union government's annual survey recently. The IMC earns ₹8 crore annually from the plants which convert waste into useful products such as bio-CNG, an official said. The corporation employs about 8500 sanitary workers in three shifts from 6 am to 4 am—22 hours a day—to keep the city clean. "A new 550-tonne capacity bio-CNG plant is going to be commissioned soon, which will take the civic body's annual earnings from waste treatment to ₹10 crore," said Asad Warsi, the IMC's advisor for the Swachh Bharat Abhiyan. EF

*Source: https://www.deccanherald.com/*

# INDIA'S 450 GW RENEWABLE ENERGY GOAL BY 2030 DOABLE, SAYS JOHN KERRY

US Special Presidential Envoy for Climate John Kerry has said India's goal of reaching 450 GW of renewable energy (RE) by 2030 is doable as it has already crossed the 100 GW RE mark. "It is really terrific to see India leading the International Solar Alliance (ISA). India is a close partner and the United States strongly supports India's goal of reaching 450 GW of renewable energy by 2030. "We believe that it is absolutely doable and will be done. India has already set an example for emerging economies by reaching 100 GW of renewables," Kerry said while addressing a session of ISA general assembly. He further said, "What India has demonstrated with its low-cost solar auctions and build out of the transmission grids and massive solar parts program and other innovative policy tools can be replicated all over the world." EF

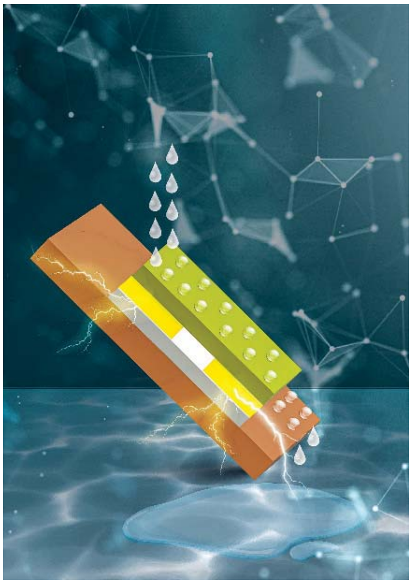
*Source: https://economictimes.indiatimes.com/*

# GLOBAL TWO-WHEELER BRANDS PLAN EV PLUNGE IN INDIA

Global two-wheeler brands operating in India are gearing up for electric vehicle (EV) plunge as the ecosystem for electric two-wheelers continue to improve in the country. Though the EV market is still at an evolutionary stage, it appears to be the future of the automobile sector. Last few months saw growing momentum for electric two-wheelers in India and FY22 is expected to see total electric two-wheeler volumes surpass the one-lakh mark. At present, electric two-wheeler sales in the country are fuelled by a few start-ups and many of them have made a mark with their technology and products. EF

*Source: https://www.thehindubusinessline.com/*

# IIT DELHI RESEARCHERS DESIGN DEVICE TO GENERATE ELECTRICITY FROM RAINDROPS, OCEAN WAVES

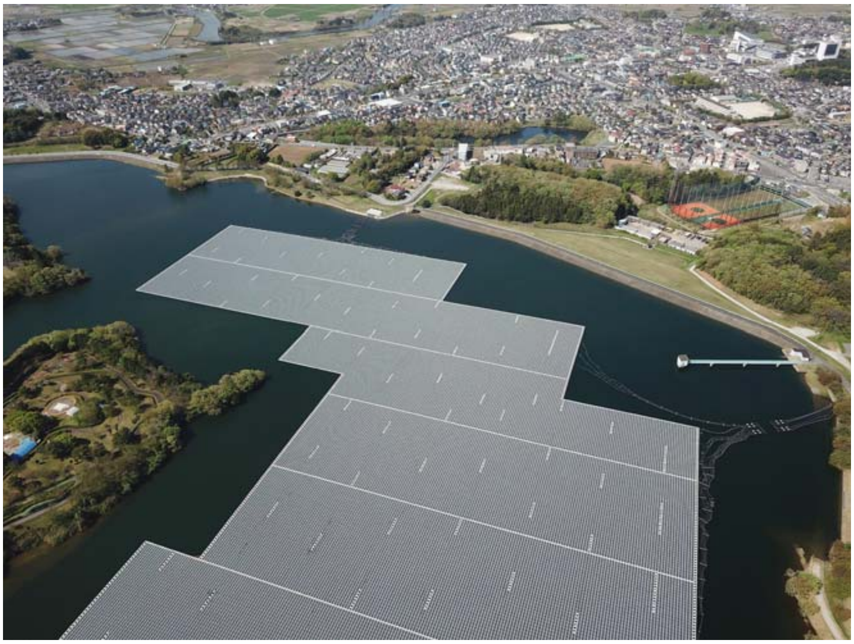


IIT Delhi researchers have designed and fabricated a device that can generate electricity from water drops, raindrops, water streams, and even from ocean waves using "triboelectric effect" and "electrostatic induction". The device is called "Liquid-solid interface triboelectric nanogenerator". The generated electricity can be stored in batteries for further use. The device has a very simple structure consisting of specially designed nanocomposite polymers and contact electrodes and can generate a few Milliwatt (mW) power, which is sufficient to power small electronic devices like watches, digital thermometers, radio frequency transmitters, healthcare sensors, pedometers, and so on. When compared to conventional methods, such as the use of the piezoelectric effect, the present device can generate significantly more electricity.

Prof. Neeraj Khare from the Department of Physics and his group at the Nanoscale Research Facility (NRF), IIT Delhi, have been working on harvesting electrical energy from to be wasted mechanical vibrations using the triboelectric effect. The group has filed an Indian patent on the various aspects of the use of ferroelectric polymer for harvesting mechanical energy including the present device. EF

*Source: https://home.iitd.ac.in/*

# BHEL COMMISSIONS INDIA'S LARGEST FLOATING SOLAR PLANT IN ANDHRA PRADESH



State-owned Bharat Heavy Electricals Limited (BHEL) has recently announced the commissioning of India's largest floating solar photovoltaic plant in Andhra Pradesh. Located at NTPC Simhadri in Andhra Pradesh, the 25-megawatt floating SPV project covers an area of 100 acres, BHEL said. "BHEL has successfully commissioned India's largest floating solar PV plant. Notably, with its unique state-of-the-art design, the project is an engineering marvel, created by BHEL," the company said in a statement. The project will help saving valuable land resources and conserving water by reducing evaporation, it said. It further said this complex module array has been designed for the first time in India to withstand gusts of wind up to 180 km/hr. EF

*Source: https://www.deccanherald.com/*

# INDIA'S POWER CONSUMPTION UP 18.6% TO 129.51 BILLION UNITS IN AUGUST 2021

India's power consumption grew 18.6% in August 2021 to 129.51 billion units (BU) and remained higher than the pre-COVID level due to improved economic activities amid easing of lockdown curbs by states, according to Power Ministry data. The country's power consumption in August 2020 stood at 109.21 BU, lower than 111.52 BU in the same month in 2019, as per the data. Experts say the recovery in power demand and consumption in August 2021 is consistent and robust. Peak power demand met or the highest supply in a day stood at 196.24 GW in August, which is 17.1 per cent higher compared to a year ago.

The peak power demand in August 2020 stood at 167.52 GW, lower than 177.52 GW in the same month in 2019, showing the adverse impact of the pandemic on power demand.

Power consumption in the country witnessed 6.6 per cent year-on-year growth in May 2021 at 108.80 BU despite a low base of 102.08 BU in the same month of 2020. EF

*Source: https://indianexpress.com/*

# IISC-BENGALURU SCIENTISTS DEVELOP LOW-CARBON BRICKS USING CONSTRUCTION WASTE

Researchers have developed a technology to produce energy-efficient walling materials using construction and demolition (C&D) waste and alkali-activated binders. These are called low-C bricks, do not require high-temperature firing, and avoid the use of high-energy materials such as Portland cement. The technology will also solve the disposal problems associated with C&D waste mitigation.

Conventionally, building envelopes consist of masonry walls built with burnt clay bricks, concrete blocks, hollow clay blocks, fly ash bricks, light-weight blocks and so on. Such materials consume energy during their production, leading to carbon emission (high embodied carbon) and consume mined raw material resources which lead to unsustainable constructions. The masonry units are manufactured either through the process of firing or using high energy/embodied carbon binders. The annual consumption of bricks and blocks in India is about 900 million tonnes. Besides, the construction industry generates vast amounts (70–100 million tonnes per annum) of construction and demolition waste (CDW). In order to promote sustainable construction, two important issues need to be addressed while manufacturing the masonry units—conserving mined raw material resources and emission reduction. EF

*Source: https://dst.gov.in/*

# SPEED UP YOUR NET-ZERO PLANS: COP26'S MESSAGE TO COMPANIES

The Glasgow Climate Pact is a message to investors and executives that the march to net zero is accelerating. The agreement, negotiated by almost 200 nations over two weeks, isn't the pact that some were hoping for. But it sets out a vision for a world that radically cuts back coal usage, eliminates fossil-fuel subsidies and commits governments to the most ambitious targets of the Paris Agreement. The outcome of COP26 "made it crystal clear to businesses that they need to move away from fossil fuels," said Nick Molho, executive director of Aldersgate Group, which represents companies worth 550 billion pounds ($740 billion) pushing for sustainability. Businesses will travel in that direction whether or not governments back up their pledges with policies, he said. EF

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


# AFRICA'S RARE GLACIERS TO SOON DISAPPEAR

Africa's rare glaciers will disappear in the next two decades because of climate change, a new report has warned amid sweeping forecasts of pain for the continent that contributes least to global warming but will suffer from it most. The report from the World Meteorological Organization and other agencies, released ahead of the COP26, is a grim reminder that Africa's 1.3 billion people remain 'extremely vulnerable' as the continent warms more, and at a faster rate, than the global average. And yet Africa's 54 countries are responsible for less than 4% of global greenhouse gas emissions. The new report seizes on the shrinking glaciers of Mount Kilimanjaro, Mount Kenya and the Rwenzori Mountains in Uganda as symbols of the rapid and widespread changes to come. EF

*Source: https://www.thestatesman.com/*

# PUTTING HONEYBEE HIVES ON SOLAR PARKS COULD BOOST THE VALUE OF UK AGRICULTURE

The value of UK agriculture could be boosted by millions of pounds a year if thousands of honeybee hives were deployed on solar parks across the country, a new study reveals. However, scientists caution that the benefits of managing solar parks for wild pollinators over honeybees should be prioritized where appropriate and should be assessed on a site-by-site basis. A team of researchers from Lancaster University and the University of Reading has for the first time quantified the potential economic benefits and costs of installing honeybee hives on solar parks across the UK. Solar parks are playing an increasingly important role in UK's national shift towards net zero carbon emissions as their contribution to electricity generation rises. EF

*Source: https://www.sciencedaily.com/*

# GOOGLE TO REPLENISH 20% MORE WATER THAN IT USES BY 2030


Google aims to replenish 20% more water than its offices and data centres use by 2030, the company said recently, addressing concerns about water-guzzling tech facilities amid record droughts. "We are pledging to a water stewardship target to replenish more water than we consume by 2030 and support water security in communities where we operate," Google Chief Sustainability Officer Kate Brandt wrote in a blog post. "This means Google will replenish 120% of the water we consume, on average, across our offices and data centres." Brandt said the tech giant is focusing on three areas to replenish water. EF

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

# JAPAN BOOSTS RENEWABLE ENERGY TARGET FOR 2030 ENERGY MIX

Japan will raise its target for renewable energy in the country's electricity mix for 2030 as it pushes to cut emissions to meet commitments under international agreements on climate change, according to a draft of its latest energy policy. The country's revised basic energy strategy leaves unchanged its target for nuclear power, even though the country has struggled to return the industry to its former central role after the Fukushima disaster of 2011. The industry ministry's policy draft says renewables should account for 36%–38% of power supplies in 2030, double the level of 18% in the financial year to March 2020. The earlier target was for renewables to contribute 22%–24% of electricity in 2030. The use of coal, the dirtiest fossil fuel, will be reduced to 19% from 26% under the new plan. Gas, which comes to Japan in the form of imported liquefied natural gas, will make up most of the rest of the fossil fuel portion of the target energy mix, which was set at 41%, down from 56%. EF

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

# THE IMPACT OF CLIMATE CHANGE ON KENYA'S TANA RIVER BASIN

Many species within Kenya's Tana River Basin will be unable to survive if global temperatures continue to rise as they are on track to do—according to new research from the University of East Anglia. A new study published in the journal *PLOS ONE* outlined how remaining within the goals of the Paris Agreement would save many species. The research also identifies places that could be restored to better protect biodiversity and contribute towards global ecosystem restoration targets.

Researcher Rhosanna Jenkins carried out the study as part of her PhD at UEA's School of Environmental Sciences. She said, "This research shows how many species within Kenya's Tana River Basin will be unable to survive if global temperatures continue to rise as they are on track to do. EF

*Source: https://www.uea.ac.uk/*

# TURNING HAZELNUT SHELLS INTO POTENTIAL RENEWABLE ENERGY SOURCE

Biomass is attracting growing interest from researchers as a source of renewable, sustainable, and clean energy. It can be converted into bio-oil by thermochemical methods, such as gasification, liquefaction, and pyrolysis, and used to produce fuels, chemicals, and biomaterials. In *Journal for Renewable and Sustainable Energy*, researchers from Heilongjiang Academy of Agricultural Machinery Sciences in China share their work on the physicochemical properties and antioxidant activity of wood vinegar and tar fraction in bio-oil produced from hazelnut shells' pyrolysis at 400°C to 1000°C. Wood vinegar is often used in agricultural fields as insect repellent, fertilizer, and plant growth promoter or inhibitor, and can be applied as an odour remover, wood preservative, and animal feed additive.

"After these results, wood vinegar and tar obtained from residual hazelnut shells could be considered as potential source of renewable energy dependent on their own characteristics," said author Liu Xifeng. The researchers found the wood vinegar and tar left over after burning the shells contained the most phenolic substances, which laid a foundation for the subsequent research on antioxidant properties. EF

*Source: https://www.sciencedaily.com/*

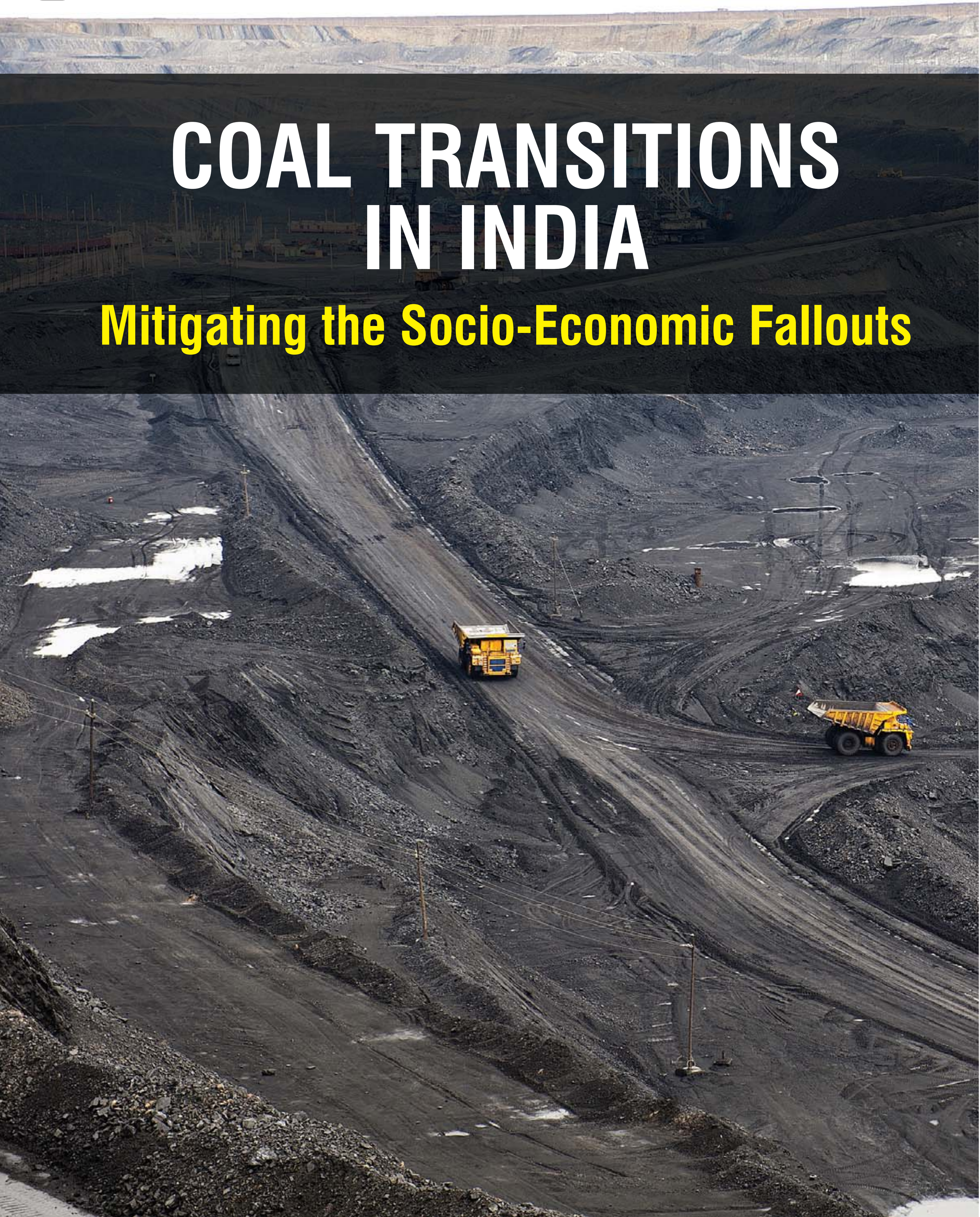
# HIGH GROWTH OF SOLAR PV INSTALLATIONS IN AUSTRALIA BY 2030

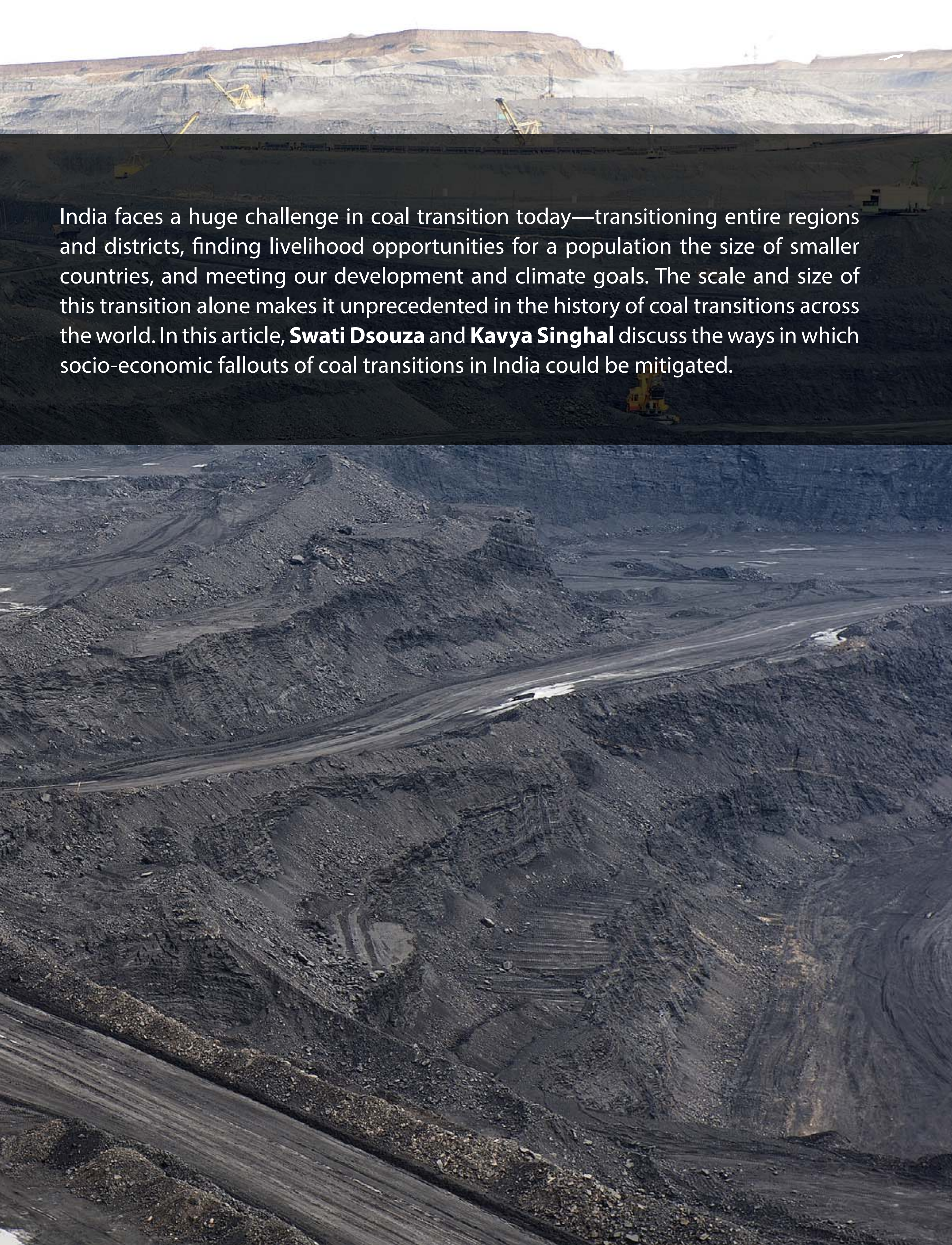
The solar photovoltaic (PV) capacity in Australia, which stood at 17.99 GW in 2020, is estimated to reach 80.22 GW by 2030. The solar PV accounted for 21.7% of Australia's total power capacity in 2020 and it is estimated to reach 47.56% in 2030, according to GlobalData, a leading data and analytics company. GlobalData's report reveals that during 2000–2020, thermal power dominated Australia's power mix with 58.6% share in the total power capacity in 2020. Aditya Sharma, Power Analyst at GlobalData, commented: "Australia plans to compensate the decline in thermal and hydropower capacity with renewable power capacity growth. By 2030, the share of renewable power capacity is set to reach 69.9%, driven mostly by solar PV installations." EF

*Source: GlobalData*

# COAL TRANSITIONS IN INDIA

## Mitigating the Socio-Economic Fallouts





India faces a huge challenge in coal transition today—transitioning entire regions and districts, finding livelihood opportunities for a population the size of smaller countries, and meeting our development and climate goals. The scale and size of this transition alone makes it unprecedented in the history of coal transitions across the world. In this article, **Swati Dsouza** and **Kavya Singhal** discuss the ways in which socio-economic fallouts of coal transitions in India could be mitigated.

Coal transitions in India are likely to be a messy and complicated exercise. A recent study by Dsouza and Singhal (2021) found that at conservative estimate, more than 13 million people (Figure 1) are employed in coal mining, transport, power, sponge iron, steel, and bricks sectors. This is more than the population of at least 160 countries around the world, or the population of a country such as Zimbabwe. This figure does not include those in the informal sector in coal mining, labour involved in coal imports (at the ports or transport from ports to thermal plants), indirect activities in the iron and steel sector including third party sellers, warehousing staff, iron ore mining, etc., and also the dependents of workers or even third party vendors such as equipment manufacturers. Conversations with stakeholders suggest that only including the informal coal economy would likely take this dependency to more than 20 million people or the population of Sri Lanka.

If one were to exclude the bricks sector (which is mostly informal and the numbers fluctuate year on year), the number of people dependent on coal would still be around 2.5 million people. Of the 1526 sponge iron and steel units producing crude steel, 610 or 40% is situated in the four states of Odisha (12%), Jharkhand (9%), Chhattisgarh (10%), and West Bengal (9%). Of the 229 thermal power plant units (including captive), 40% are located in Uttar Pradesh (12%), Chhattisgarh (10%), Maharashtra and Madhya Pradesh (9% each). Coal is mined across eleven states in India, with four states—Chhattisgarh, Jharkhand, Odisha, and Madhya Pradesh—accounting for ~80% of the 730 million tonnes (MT) of production (CCO, 2020). These states will be the most affected in the coming decades when India transitions away from coal to meet the net zero target in 2070.

Coal transitions are likely to have the most impact on the people in the central and eastern states of West Bengal, Jharkhand, Chhattisgarh, Odisha, and Madhya Pradesh, with some parts of Uttar Pradesh, Telangana, Maharashtra, and Andhra Pradesh. At the national level, 266 districts have at least one asset linked to the coal sector, and 135 of these 266 districts have two or more assets dependent on coal, i.e., a coal mine, thermal power plant, sponge iron plant, steel plant. At least half of all the districts in Jharkhand (15) and West Bengal (11), 30% of districts in Odisha and Chhattisgarh (9) are likely to be impacted in some form or the other due to the impending coal transitions (Figure 1).

This is the real challenge that India faces today. Transitioning entire regions and districts, finding livelihood opportunities for a population the size of smaller countries, and meeting our development and climate goals. The scale and size of this transition alone makes it unprecedented in the history of coal transitions across the world.

Characteristics endemic to the Indian market complicates this transition process further. These include the large presence of contract/off-roll labour in every sector, the socio-economic profile of the labour in the sectors, and the overall sectoral roadmaps. The share of off-roll labour accounts for at least 70% of the total labour across all sectors, reaching as high as 92% and 80% in transport and bricks, respectively (Figure 2). Official labour estimates in different sectors do not account for this labour since they are employed by job contractors. Without their inclusion from the get-go, it is likely that they may not be beneficiaries of the transition policies and the costs of transitioning them will be discounted. The informality limits institutional support mechanisms like unions. The coal transport by road, for example, is the most vulnerable to the transition given increasing mechanisation, and probably the first to be impacted, but lacks a union or other institutional mechanism to make a case for them as coal transition workers. The brick sector may not even be viewed as a coal transition sector, given the labour is employed for 6 months in a year, is migratory by nature and, therefore, there are no official records on the number of people employed in the sector or a platform for the labour to be a part of the discussion. Figure 3 shows share of contract labour across coal and its major consumers.

No official dataset captures the socio-economic profile of the labour employed in these sectors. Capturing socio-economic profiles becomes necessary while designing policies on retraining and reskilling, since the baseline differs between sectors, and even within different job profiles in the same industry. The Periodic Labour Force

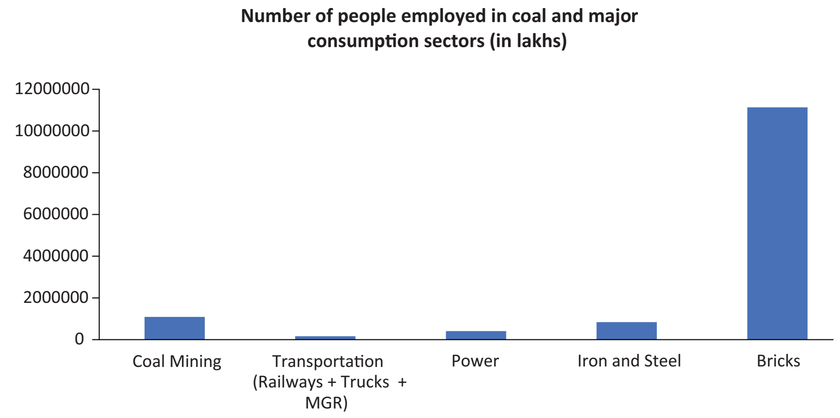



**Figure 1:** Aggregate estimates of people employed across coal and main consuming sectors in India

*Source: Dsouza & Singhal, 2021*

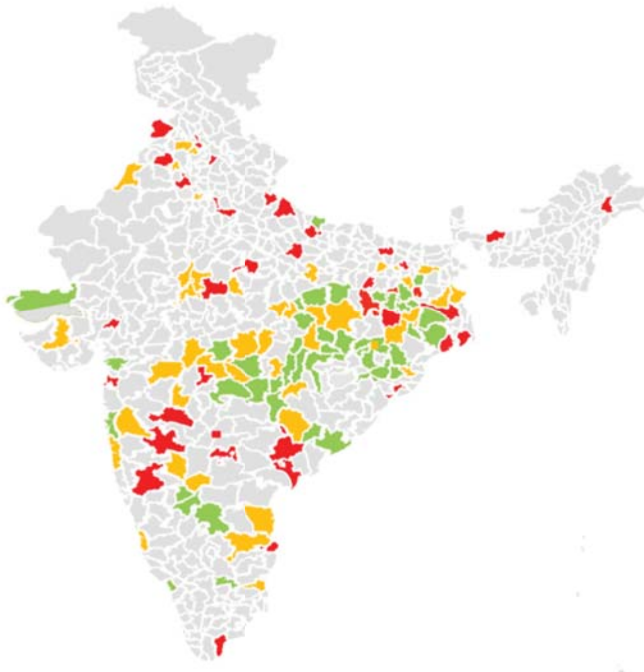


**Figure 2:** Most vulnerable districts with two or more coal-linked industry

*Source: Dsouza & Singhal, 2021*

| | |
|---|---|
| **Highly vulnerable districts** | Pakur,Palamu,Tinsukia, Aligarh,Muzaffarpur,South 24 Parganas,YamunaNagar,Krishna,Ranchi,Akola,Bina,Gonda,Kheri,Pilibhit,Aurangabad,Begusarai,Solapur,Bhatinda,Gautam Budh Nagar,Kota,Raebareli,Koderma,Kokrajhar,Seoni,EastMedinipur,Thoothukudi,Bardhaman,Beed,Kadapa,Khammam,Kheda,Ropar,Tapi,Belgaum,Durgapur,Hyderabad,Khordha,Mahbubnagar,Chennai,Hisar,Jhansi,Thane,Thiruvallur |
| **Moderate vulnerable districts** | Bhagalpur,Murshidabad,Raichur,SriGanganagar,Chhindwara, Deoghar, JayashankarBhoopalpally, Komaram,Bheem,Korea, Latehar,Shahdol,Surajpur,Patna,Wardha,Birbhum,Allahabad,Amravati,Baran,Cuddalore, Gondia,Jalgaon,Jamnagar, Jhajjar, Jhalawar,Mansa,Mumbai,Rajpura,Ratnagiri,Shahjahanpur,Udupi, Warangal,Bilaspur,Chittoor,FatehgarhSahib,Jalna,Ludhiana,Pune,Rourkela,Jaipur,Nellore,Umaria,Saraikela,Bijapur,Lalitpur,Purulia |
| **Least vulnerable districts** | Giridih,Sambalpur,Hazaribagh,Ramgarh,Singhbhum,Godda,Peddapalli,Surguja ,Yavatmal,Dhanbad,Durg,Burdwan,Balrampur,Janjgir-Champa,Salem,Surat,Anantapur,Keonjhar,Koppal,South Goa,West Medinipur,Bankura,Betul,Karimnagar,Chatra,Paschim Bardhaman,Vishakhapatnam,Nagpur,Chandrapur,Kutch,Dhenkanal,Raipur,Anuppur,Raigad,Angul,Bellary,Sonbhadra,Jharsuguda,Korba,Singrauli,Bokaro,Mancherial,Sundergarh,Raigarh, |

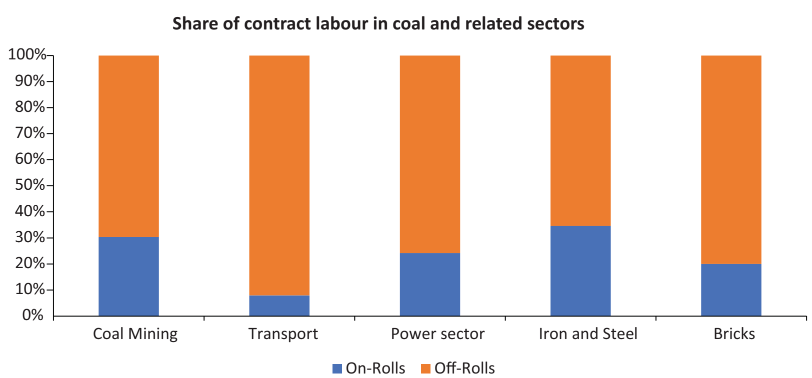



**Figure 3:** Share of contract labour across coal and its major consumers

*Source: Dsouza & Singhal, 2021*

Survey (PLFS) studies broader dynamics of the labour market, but the intent of the survey is not to ascertain socio-economic indicators within particular sectors. Nevertheless, it is the only available official dataset to understand labour patterns. Using the PLFS dataset, the study identified key socio-economic indicators such as education, wages, training, gender split, job contracts. The results are endemic of the larger trend in the Indian labour market. Eighty-one per cent of the labour force in India is employed in the informal sector/shadow economy (with no social benefits) and if one were to include the portion of informal sector workers (contract/casual labourers), then the proportion is as high as 92% (Punia, 2020). As Mehrotra (2019) has detailed one of the reasons for growth and informal economy has been low education and skill levels of the workforce. This trend is captured in Figure 4 for coal and its major consumers. Mirroring broader national labour trends, women fare worse off than men across most coal-dependent sectors. Low education and skill levels and high informality will be barriers to transition. Low education levels enable information asymmetry since the labour who is likely to be transitioned is not informed of their rights. Further, the technical nature of the green industries necessitates targeted reskilling and training programmes, without which a just transition will be difficult to achieve in India.

The third complication is the trend of the broader sectoral roadmap. National-level trajectories and policies on sectoral roadmaps are not yet aligned with the impending coal transition or with the recently announced net zero target. This prevents future planning and investments for a post-coal world. Some sectors like the Indian Railways are heavily reliant on coal, with ~44% of their revenues coming from coal. In our conversations with stakeholders, the roadmap for railways remained unclear in a post-coal world. Freight revenues are important since they help

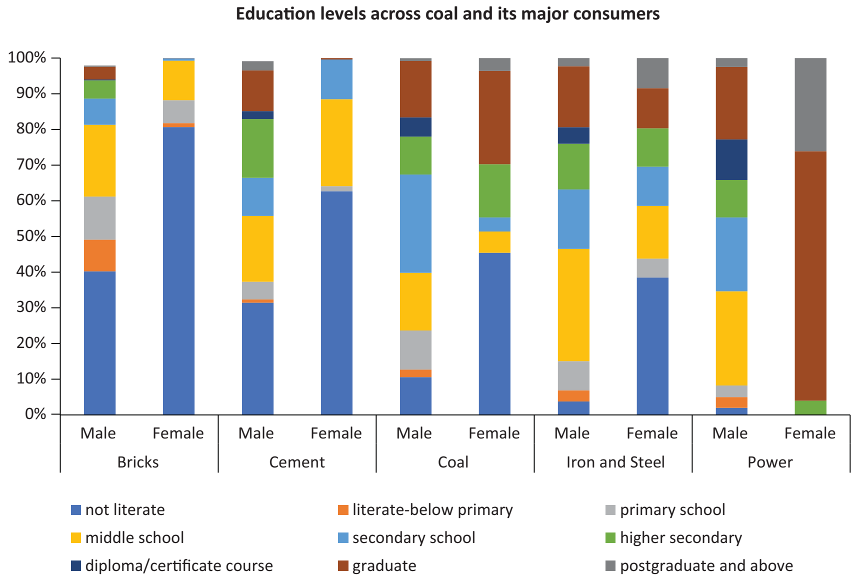



**Figure 4:** Education profile of workers by gender across all sectors

*Source: PLFS, 2021*

bridge the gap in operational cost of passenger movement. The coal sector itself has been undergoing an expansion with recent reforms in commercial coal mining and auctioning of new coal blocks. Coal India has only recently announced plans for diversification, but these are limited forays in solar and possibly aluminium production. Despite 112 mine closures since 2008, there is very little evidence of environment remediation and land rehabilitation in these areas. In the power sector, until very recently (August 2021) there were no guidelines on plant decommissioning and environment remediation. In iron and steel, there are some indications that the sector will have to undergo a consolidation (98% of the industry has plants with less than 1 MT capacity), since not all firms have the capital to transition to new technology. However, it is still not clear the technology pathway the sector is likely to undertake. A pathway that chooses electrification, hydrogen or natural gas or any low-carbon technology will necessitate retraining and reskilling. It will also result in retrenchment of the contract labour that is involved in coal handling.

But a well-planned transition and advance planning can take care of most of these challenges. The transition will necessitate aligning state, national and sector roadmaps at the planning level. Strategies towards decarbonization cannot be undertaken with simultaneous investment and expansion of the coal sector and its allied uses. This will impede investments needed to meet the net zero target and continue the carbon lock-in with possibilities of stranded investments. Further, India needs to define a coal transition worker across different sectors with targeted emphasis on contract/informal labour and their socio-economic profile. Without this it is possible that a significant chunk of the labour force will not be beneficiaries of the transition policies. Accounting for the contract labour force also helps accounting practices as India needs to determine the financial and economic costs required for the transition. Environment remediation and decommissioning or closure plans have to become a necessary component for all sectors with increased capacity at the central and state level for their monitoring and implementation. Without this, it will be impossible to design strategies for economic regeneration in the 135 likely to be impacted districts. These coal bearing regions will need to be made productive again through regional strategies. The current governance structure is unlikely to yield results for the transition. Decision making for energy is concentrated at the central government level, while planning and implementation of the resulting challenges (labour, education, health, etc.) is the purview of the states. This leads to an imbalance since revenues are accrued more to the central government than state governments. This structure needs to be corrected. Centre-state councils like the GST Council can help bridge this imbalance. Lastly, India will need to communicate at the global level about the scale of these transitions and demand climate finance to manage and implement the strategy. Without external funding, it is unlikely that the scope of the transition only on livelihoods can be met solely by domestic funding. Multilateral Development Banks will need to de-risk coal bearing areas during the transition period to facilitate green investments. In the short term, funds from the District Mineral Fund can be leveraged. Domestically, the country will also need to prepare its financial system for early closures.

Finally, all stakeholders have a role to play in this transition roadmap. District authorities become the focal point of the transition roadmap since they are the key implementors and the first point of contact for local resistance or support. Industries will need to be brought on board for their input on district-level investments and preparing the transition strategy for the existing force. The existing labour force will have to be bucketed into categories of those who can be voluntarily retired (and the financial cost of this), those that can be transitioned within the same company and or another similar profile in the same area. Labour unions have to become a necessary part of this conversation since they will essentially be the communication bridge between the management, governments, and the larger labour force. In sectors with no unions, it is incumbent upon local authorities to seek an 'influencer' or group leader to lead the discussions. Local and community leaders will have a big role to play in this transition. They are essentially entrenched in the existing political economy and without their support, local resistance may increase. Therefore, their influence needs to be cultivated for the success of this transition strategy through involvement in district- and state-level planning.

The next steps highlighted here determine near-term strategies while we prepare for the broader transition. All efforts have to be made to not only transition the existing work force, but also put in place strategies that will prevent future generations from working in coal and related sectors.

## Coal Mining

- **A mine-wise estimate of reserves:** Given a target date of net-zero by 2070 and endorsements on clean technology, typically, the big and other mines which produce 85% of the coal in the country will likely be the ones running for the next 20–30 years. Most underground mines and rest of mines will likely be shut down within this decade. Preparing a timeline of mine closure will be most effective using the reserve estimates.
- **Analyse the trend of contract workers** in every mine over a five-year period. This will help identify the actual employment provided by the mine in the district/area. A mine-wise estimate will help quantify and codify contract workers as formal coal transition workers. Job contractors are mandated by law to register their workers with the labour commission.
- **Identifying socio-economic characteristics** like age, education, technical qualification of workers in underground mines since they will most likely be shut down earlier. This will help prepare a plan to retire/transition workers. This should be followed by an assessment of workers in rest of the mines since they will be the next ones to be shut down. Here as well, it will be prudent to begin with the mines, which are almost exhausted or producing the least amount of coal.
- **Based on the socio-economic characteristics, delineate the extent of financial aid that will be required in every mine area for retrenchment, early retirement and retraining the existing workforce.** This can be useful if India decides to follow South Africa's strategy and seek global aid. At COP26, South Africa sought and will receive an initial amount of USD 8.5 billion from the US, UK, Germany amongst other countries to end its reliance on coal (Mkhize, 2021).
- **Prepare and implement environment remediation:** While a 2012 guideline (Ministry of Coal, 2012) document on mine closures has been notified by the Ministry of Coal, there is no evidence that this has actually been implemented in practice. Between 2008 and 2018, 123 collieries owned by CIL and SCCL have been shut down. However, there is little evidence of a robust transition in these areas.

## Coal Transport

- For the truck segment, the next steps are more or less covered under the coal mining category. Perhaps, it might be useful to identify the extent of debt amongst households in the district on HEMMs (trucks, etc.). This will have to be added to the financial cost of transition, since eventually it may lead to a payoff.
- For Indian Railways, there is a need to diversify its revenue sources. It is also imperative that they be a part of the mine closure roadmap, since closures will have a direct impact on the railway staff in coal bearing divisions.

## Power Sector

- The first step towards a smoother transition should be to identify plants, which are likely to be shut down in this decade. Germany, for example, is holding auctions whereby plant owners are incentivized to shut down a plant earlier. This has to be coordinated with mine closures timetable, a closure of both assets in the same or nearby districts is likely to impact economic parameters for the district and households within the district.

- Workers, unions need to be a part of this conversation. Without their inputs, it is unlikely that the transition will be smooth, and their involvement will also mitigate fears of job loss.
- Thereafter, it is necessary to categorize the age, skill level, and other socio-economic parameters of workers within these plants. This will help identify workers who can be provided with early retirement packages, those who will need to be transitioned to other local power plants and those who may be retrenched.
- This assessment will need to include contract workers since they are about 70 per cent or more of the workforce in the plant. If there is no external mandate, then it is likely that job contractors will move on, leaving contract labour stranded in the district.
- The sites of these plants will need investments for environment remediation and land rehabilitation, especially at the CHP and AHP sites (ash ponds, coal storage areas, etc.) before they can be utilized for other economic activities. It is necessary to assess these individual areas, analyse the necessary investment, demarcate finances, and identify appropriate funding sources. While the NGT order and the resultant draft guidelines provide a framework, these are yet to be approved. Moreover, these guidelines do not include impact on livelihood.
- At a minimum just these few steps are likely to take a decade to materialize. Therefore, even if India and the power sector does not expect early retirements, it will be imperative to begin the process of transition planning today.

## Iron and Steel Sector

- It is imperative for the Government of India to begin the conversation on moving towards natural gas or alternate fuels for the coal-based DRI industry. This will help reduce emissions from the sector and prepare them for the eventual transition.
- Supplementing this exercise, it is necessary to identify if the labour force can be transitioned in its existing form or if training programmes have to be conducted.
- Irrespective of the technology, it is clear that coal usage is expected to

decrease in the next two decades. This will impact workers on the coal supply chain in this sector and they should be considered as coal transition workers under the broader transition programme.

» Districts with smaller-sized units that are expected to see consolidation should be mapped alongside power plant and coal mine districts. This will help identify districts most vulnerable, i.e., if all three assets are in the same district.

## Bricks Sector

» Geotag kilns across the country to help fix the location of the kilns. This exercise has to be updated on an annual/bi-annual basis and will help provide information on the number of kilns.

» Incentivize kiln owners financially to adopt efficient electricity-based technology.

» Enforce environment pollution norms that will make it easier to incentivize transition and identify unregistered kilns.

» Make it mandatory for job contractors to submit labour data to the local labour commissioner's office every year. Once this has been done for a few years, it will help create a labour database for the brick sector. This information will also help identify socio-economic characteristics of the labour.

» Create a cadre of workers who will be able to train new labour every year ahead of the brick making season.

» Enforce minimum wage rules to improve socio-economic conditions of the labourers. EF

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# ELECTRIC VEHICLES AND SMART CHARGING

## Charging Forward

In this article, **Shweta Kalia** and co-authors say that to enable a smooth transition to accommodate India's projected increase in e-mobility and electricity demand, adoption of smart charging is a necessity. Smart charging is crucial to ensure that EV uptake is not constrained by grid capacity. A number of interventions can be adopted and implemented to enable a smarter, efficient, and sustainable way of scaling up the adoption of EVs in India. Keep reading to know more…

Electric vehicles (EVs) have seen a rapid growth with the global electric car stock hitting the 10 million mark in 2020 (IEA, 2021). This rapid adoption comes as a response to growing environmental concerns and to decarbonizing the transport sector. The transition to e-mobility is projected to increase continually with more than 20 countries announcing the full phase-out of internal combustion engine (ICE) car sales over the next 10–30 years. The same report also states that electricity demand from the global EV fleet will reach 525 TWh in the Stated Policies Scenario (STEPS) and 860 TWh in the Sustainable Development Scenario (SDS), which will account for at least 2% of global total electricity consumption by 2030.

This projected increase in electricity demand for EVs will have an adverse impact on the existing grid structure, more so with uncontrolled charging. The uncontrolled charging, also known as dumb charging, will result in the increased peak demand and upgradation of the grid infrastructure. Network overloading condition, which includes overloading of equipment, faster aging of devices may lead to frequent occurrence of faults and in extreme cases can even lead to system instability. Equipment stressing and faster aging due to network overloading will further give rise to requirement of major upgradation and reconfiguration of the grid, which is both time-consuming and expensive. Smart charging, thus, becomes a key determinant in mitigating the challenges of dumb charging without sacrificing the transition to electrified mobility.

## What is Smart Charging?

The definition of smart charging is rather broad with different sources having different definitions of smart charging. According to International Renewable Energy Agency (International Renewable Energy Agency (IRENA), 2019), "Smart charging means adapting the charging cycle of EVs to both the conditions of the power system and the needs of vehicle users. This facilitates the integration of EVs while meeting mobility needs." As per ElaadNL (ElaadNL, 2020), "Smart Charging is essentially a control signal that indicates when and at what speed an electric car is charged. Smart technology ensures that it is charged at the best time and at an optimum speed."

Generally, smart charging is a means of managing the EV load to reduce the impact of EV integration on the distribution network and may also incorporate grid support services. It can be achieved by customers responding to price signals, EVSE responding to control signals from the Distribution Company (DISCOM) or a Central Management System (CMS) while at the same time retaining enough charge in the battery to fulfil the EV users travel requirements.

The different types of smart charging (from basic to advanced level of charging) are listed here.

Smart charging essentially involves a control signal that controls the time of charging and the rate of charging power. The control strategies in smart charging introduce flexibility in the charging process such that EV users can incentivize by deferring their charging time to reduce stress on the grid. Consequently, instead of immediately charging when an EV is plugged to the charger, smart charging technology ensures that the EV is charged at the best time and at an optimum speed. Therefore, by controlling the time and rate of charging, smart charging ensures a better distribution of the power demand. This helps avoid peak demand stress and reduces cost associated with reinforcing electricity infrastructure. It, therefore, plays a vital role in achieving different objectives, such as cost minimization, loss minimization, congestion management, grid support and grid stability depending on the type, preferences, and required infrastructural and computational capabilities of consumers.

**Table 1:** Levels and types of smart charging

| Type of Application | Control over Charging Power | Possible Uses | Maturity |
|---|---|---|---|
| Uncontrolled but with ToU tariffs | None | Peak-shaving | High |
| Basic Control | On/off | Grid congestion management | Partial market deployment |
| Unidirectional controlled (V1G) | Increase and decrease in real time the rate of charging | Grid congestion management, RE integration, Ancillary service | Partial market deployment |
| Bidirectional V2G and G2V | Instant reaction to grid conditions | Grid congestion management, Ancillary services, RE integration | Advanced testing |
| Bidirectional V2X | Integration of V2G and home/building management systems | Micro-grid optimization, RE integration | Partial market deployment |
| Dynamic Pricing | EVSE embedded meter and close to real time communication between vehicle, EVSE and grid | Load following, RE integration | Partial market deployment |

## Smart Charging Control Strategies

The classification of the smart charging strategies is based on topology/architecture, location, ownership, methodology/approach, price structure, and objective(s). Based on the control architecture of smart charging, EV charging strategies can be categorized into five categories: centralized control, decentralized control, distributed control, hierarchical control, and local control. The network operator, aggregator, and EV owners are involved in the exchange of information or control signal according to the strategy.

Centralized control strategy facilitates direct control on global network constraints. In this strategy, the aggregator decides the pattern for EV charging within its contract considering the system operator's constraints and the charging energy requested by the EV owner. Further, the aggregator's role in the strategy is to maintain the system while fulfilling the energy demand of the EVs. However, the controlling unit in the centralized control does not permit the plug-and-play mechanism, which might discourage the owners due to the lack of assurance on immediate starting of EV charging.

In decentralized control architecture, the EV owners decide EV charging. Simultaneously, the aggregator/system operator indirectly tries to influence the decision of the EV owners by offering incentives, varying electricity prices, potential revenue, etc. This control architecture provides a plug-and-charge facility to the users, and it is relatively popular among EV customers. However, unlike the centralized control architecture, the decentralized charging approach does not guarantee the global optimum solution for the system.

Distributed control is the advanced version of decentralized control as the EV owners take the decisions in it. In contrast, the aggregators communicate among themselves to find the optimal operating point considering the maintenance of system stability (Nanduni I. Nimalsiri, Nov. 2020). This control benefits the system reliability as it continues charging operations if any fault occurs in the central unit.

The hierarchical control strategy is divided into several layers as per the nature of problem space and types of participants. The architecture is divided into a central aggregator, subordinate layers of sub-aggregators, followed by EV owner layer (Nanduni I. Nimalsiri, Nov. 2020). The control can again be sub-divided into several control strategies based on the decision-making authority, information signal flow, and required computation.

In local control strategy, only the EV owner is involved in maintaining local parameters and EV charging decisions. Local control only considers the local parameters, constraints, and pricing signals for making charging decisions (Kevin Mets, April 2010). This control only deals with the limited local constraints and linear single objective function, so the computation power required is significantly less than other

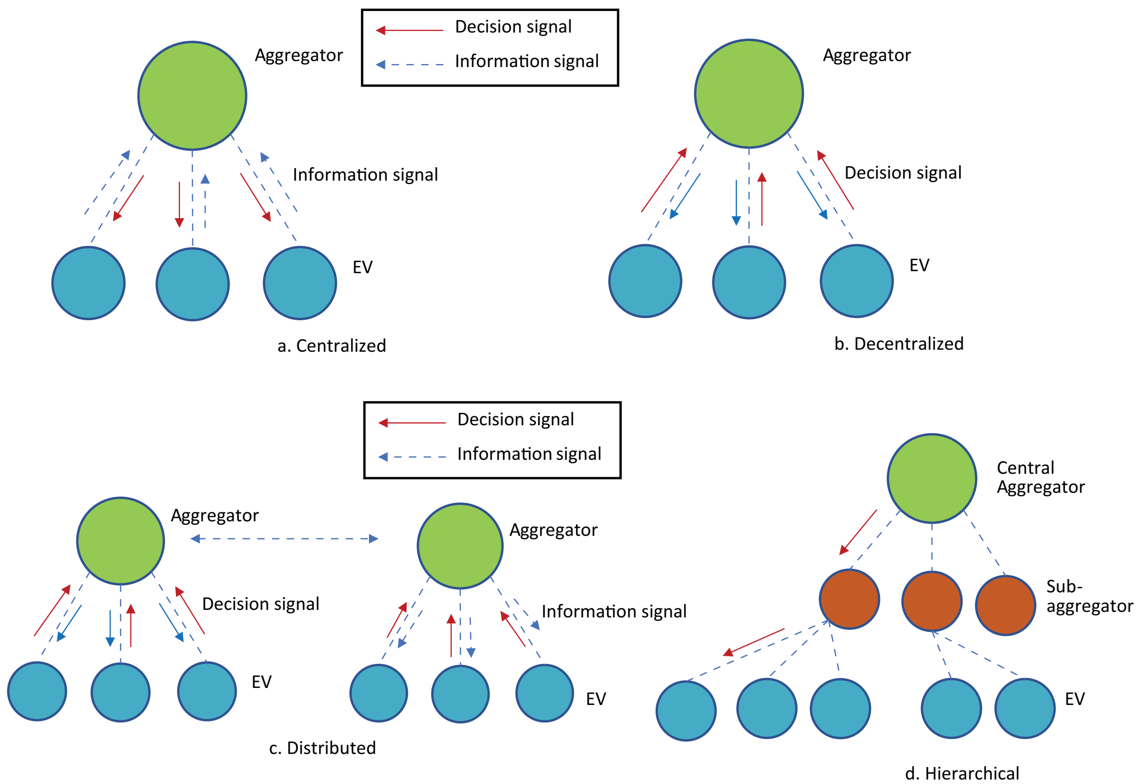


**Figure 1:** Key smart charging control strategies

smart charging control strategies. Figure 1 illustrates key smart charging control strategies.

**Smart Charging using pricing mechanism:** Smart charging strategy can also be implemented using price mechanism, that is, charging of EV in response to electricity price. The price may be set in advance (static) or determined in real time based on the system conditions (dynamic). Some of the price-based mechanism are real time price, time-of-use, critical peak price, and peak time rebate (Figure 2).

In **real-time pricing**, the electricity cost is updated every time step as per the network's requirement. Charging requests or charging demand, availability of energy, maximum allowable power limits, and available RE supply are the major reasons behind price variation. Some other constraints like feeder capacity line loading and transformer burden also indirectly affect the electricity prices. This real-time price variation allows the charging cost minimization objective to be performed in a real charging scenario. Decentralized and distributed control strategies majorly adopt real-time pricing mechanisms.

The **time-of-use (ToU) tariff** can perform smart charging without actually controlling the charging rates. In this method, a fixed price is allotted to time slots. These prices are published so that the customer can schedule the operation of appliances to reduce the electricity cost by shifting the flexible loads to a low price period. Using time-of-use tariff, the grid operator tries to influence the EV owners to shift their EV charging to an off-peak period such that the load is levelled, thereby, mitigating the increase is peak demand. TOU tariff is used in centralized charging where the aggregator considers this tariff to optimize the charging to reach the desired objective.

**Critical peak pricing (CPP)** works under the same TOU principle. The difference is that it is applied for a period of high demand. It is not decided on historical data, but rather forecasted data is used to apply and publish quickly. The electricity price is very high in CPP compared to TOU, so it is more effective than TOU for peak load reduction.

In the **peak time rebate tariff** structure, the utility provides a rebate to the customer to limit consumption within a predefined limit. Customer views it as a gain. However, shifting load to off-peak time is considered a loss. The economic effectiveness of the scheme is dependent on the predefined critical baseline load as it requires development of precise baseline load.

## Communication Standards, Interfaces, Connectors in Smart Charging

As smart charging involves control of time and charging rate of EVs, communication between the EV, the charging operator, and the utility company is essential. Thus, communication standards, interfaces,

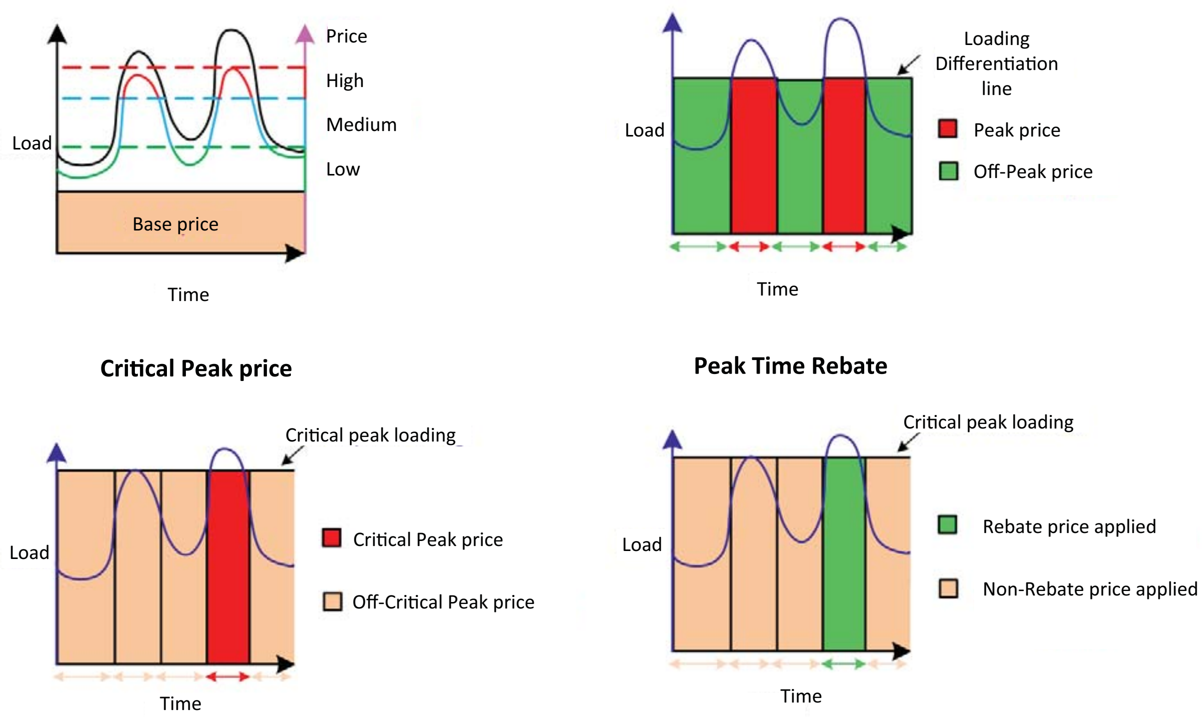


**Figure 2:** Smart charging using pricing mechanism

connectors are an integral part to realize smart charging functions.

### *Charging standards*

Indian charging standards for AC and DC conductive charging given by Automotive Industry Standards (AIS) are named as AIS 138 part-1 and part-2. These standards cover all the aspects of conductive charging ranging from general requirements for charging, rating, charging modes, connectors, the safety of EV Supply Equipment (EVSE), and protection against electric shocks. The Bureau of Indian standards (BIS) has issued the IS 17017 series of standards for EVSE connectors, socket plugs, outlets, its design, compatibility, and interoperability. These standards majorly follow the IEC standards.

Bharat AC 001 and Bharat DC 001 are the two chargers introduced by the Department of Heavy Industries (DHI) for the Indian EV market. Bharat AC 001 uses IEC 60309 pin, however, without communication protocols between EVSE and EV. For communication and authentication between EVSE and the CMS, Open Charge Point Protocol (OCPP) is used. On the other hand, Bharat DC 001 is developed considering IEC 61851-1 and it is recommended to use GB/T 20234.3 connector. It uses CAN bus communication based on IEC 61851-24.

### *Communication protocols and interfaces*

Communication between an EV and a charging station uses the IEC 61851 and ISO 15118 standard. IEC 61851 allows basic information on the charging process to be exchanged based on analog communication between the vehicle and the charging station. The ISO 15118 standard is based on IEC 61851 and supplements it with digital communication via Powerline. This makes it possible to exchange more complex information such as the vehicle's charging status and battery capacity, tariffs, and charging schedules.

Communication between charging station and IT backend uses protocols such as Open Charge Point Protocol (OCPP), Open Smart Charging Protocol (OSCP), IEEE 2030.5, Open Automated Demand Response (OpenADR), and EEBUS. The OCPP protocol handles the exchange of charging data and can trade information between EVs and the electricity grid. OSCP is an open communication protocol between a charge point management system and an energy management system. This protocol imparts a 24-hour forecast of the accessible capacity of an electricity grid. IEEE 2030.5 is designed to use the modern internet for transport of its messages between devices. The OpenADR standard available in version 2.0 allows the exchange of price signals, setpoints, and metered values between loads, electric storage, distributed generators, and EVs on the one hand, and energy providers and aggregators on the other.

For communication between charging station and e-mobility service Provider (eMSP), Open InterCharge Protocol (OICP), Open Charge Point Interface (OCPI), eMobility Inter-Operation Protocol (eMIP) are used. OCPI is an open protocol used for connections between charge station operators and service providers. Simply put, this protocol facilitates automated roaming for EV drivers across several EV charging networks.

Several EV smart charging products are already available in the market (Figure 3). These products can be categorized based on their applicability. The scope of applicability of products is network tools, optimization solutions, charging stations or charging boxes. Network tools can again be classified into interactive communication tools or mobile applications for communication platforms.

A network tool is used to connect to the communication network for indicating the charging request and other information on charging specifications, vehicle specification, and authentication. Mobile applications and cloud-based platforms are ways of connecting and communicating with responsible charging entities. Platform products such as Snapcharge, Juicenet, and ChargePoint have both mobile and cloud-based platform that provides real-time charging station's status and EV charging status.

## Indian Situation in EV Policies, Regulations, and Incentives

In India, although the e-mobility plan is developed at the central level, the onus largely lies on the state and union territory governments, who must develop and implement relevant policies, schemes and regulatory frameworks to enable the adoption of EVs and deployment of charging infrastructure in their respective states. Thus, considering India's federal structure as well as the wide variance in the social-geographic and economic variances between states, a one-size fits all approach cannot be applied. Nineteen states/UTs have notified their final EV policies and 3 states/UTs have released draft EV policies as of November

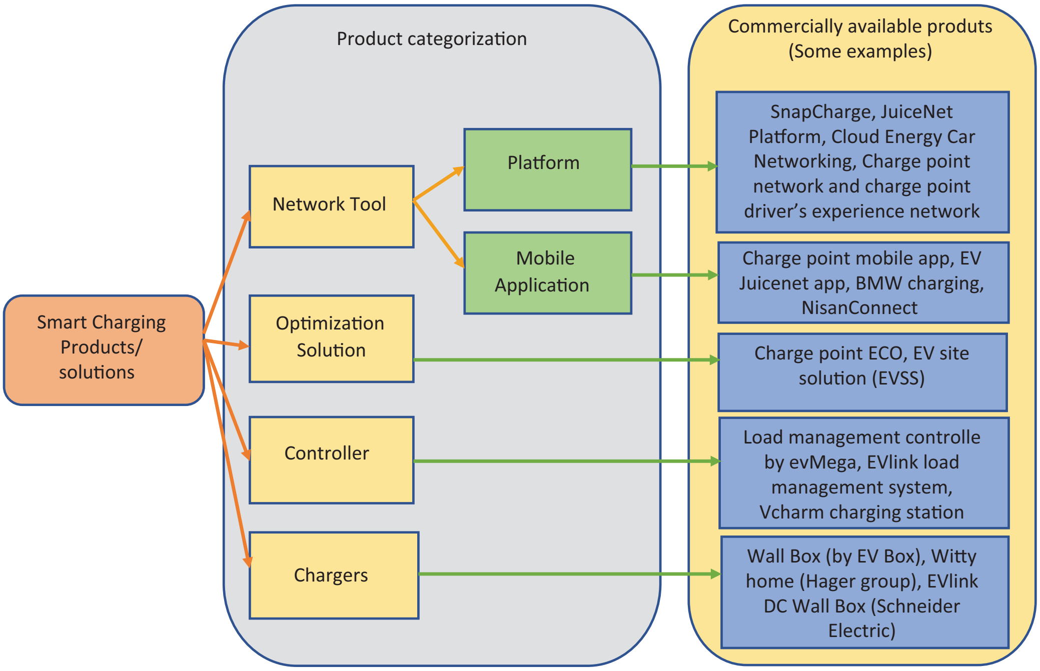


**Figure 3:** Globally available commercial EV smart charging products

2021. Some provisions in various policies from the viewpoint of smart charging, including communication and ICT technology have been made. Provisions such as Time-of-use special EV tariff for controlled charging, charging stations to be linked to mobile applications to track, monitor, and record historical and real-time data, separate EV tariff based on peak and off-peak loading time have been introduced. Figure 4 illustrates the roadmap of India's E-mobility journey. The figure below provides an overview of certain provisions and gaps in Indian State EV policies (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2021) Analysis of the provisions related to smart charging in different state policies and the evaluation of charging infrastructure shows that the underdeveloped and incipient communication infrastructure, inadequate CMS infrastructure, immature regulation framework forms the major disparity between existing charging points and smart charging-enabled charging points. To enable smart charging infrastructure,

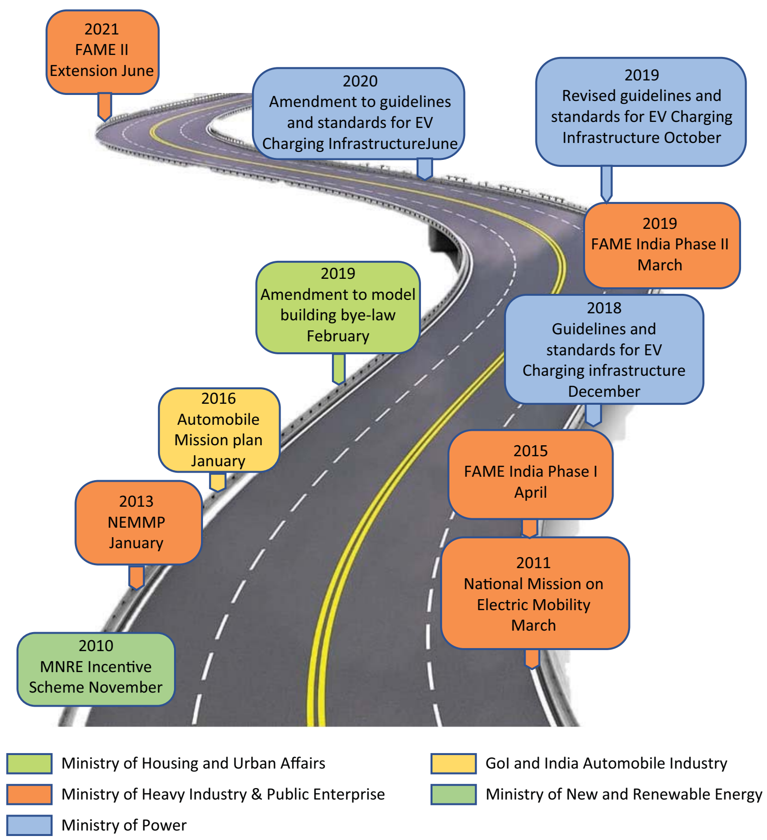


**Figure 4:** Roadmap of India's E-mobility journey

| | Key Point | DL | WB | KA | OR | MH | AS | AP | KL | BR | UP | GJ | TN | CH | MP | PB | TL | ML | UK | RJ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Incentives for public charging infrastructure | # | × | ✓ | # | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × | × | × |
| 2 | Mandate on DISCOMs for establishing charging infrastructure | × | ~ | ~ | ~ | × | ~ | ✓ | ~ | × | ✓ | ~ | ✓ | × | ✓ | × | ~ | × | × | ~ |
| 3 | Incentives for residential/ workplace charging infrastructure | ✓ | × | × | ✓ | ✓ | × | ✓ | × | × | × | × | × | ✓ | × | × | × | × | × | × |
| 4 | Incentives for retrofitting of vehicles | ✓ | × | ✓ | ✓ | × | ✓ | × | × | × | × | × | × | × | × | ✓ | ✓ | × | × | × |
| 5 | Purchase incentive for EVs | ✓ | × | × | ✓ | ✓ | ✓ | × | * | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| 6 | Public awareness programme | ✓ | ✓ | × | ✓ | ✓ | × | ✓ | ✓ | ✓ | × | × | ✓ | × | ✓ | ✓ | × | × | × | × |
| 7 | Information on reimbursement of financial incentives | ✓ | × | × | ✓ | × | × | × | ✓ | × | ✓ | ✓ | ✓ | × | × | ✓ | × | × | × | × |
| 8 | EV-specific tariff | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ |
| 9 | Land allocation/ concession for setting up the charging station | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | × |
| 10 | Focus on transitioning of government and public vehicles | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | × |
| 11 | Provision of R&D | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | ✓ | × | × | × |

× : Key attribute is not addressed in respective state EV policy, ~ : DISCOM is not mandated but encouraged to invest in charging infrastructure, # : Provision for a capital subsidy for the cost of charger installation expenses to the selected Energy Operators; * Incentives only for 3-wheelers
DL: Delhi, WB: West Bengal, KA: Karnataka, OR: Orissa, MH: Maharashtra, AS: Assam, AP: Andhra Pradesh, KL: Kerala, BR: Bihar, UP: Uttar Pradesh, GJ: Gujarat, TN: Tamil Nadu, CH: Chandigarh, MP: Madhya Pradesh, PB: Punjab, TL: Telangana, ML: Meghalaya, UK: Uttarakhand, RJ: Rajasthan (Policy draft under final stage, and concept paper)

interventions can be made in the state-wise policies through financial incentives, non-financial incentives, and creating awareness programmes. Some futuristic broad-level suggestions are mentioned in the subsequent section, which would require further investigation in detail. Figure 5 illustrates smart charging in Indian EV policies/ schemes/regulations.

Financial incentives can be provided for establishing a smart charging station and in purchasing smart charging software and services to attract the charging station operator. Special incentives may also be provided for retrofitting older charging stations and fuelling stations with smart charging stations.

Smart charging and ToU incentive may be provided for eligible residential EV customers. Private players can be allowed to provide EV owners and fleet operators' special offers for buying and participating in their smart charging using ToU or any other strategy. Local strategies can be encouraged such as using the locally controlled smart charging station by providing a small rebate on the monthly charging bills. Further, subsidies on procurement of metering equipment, required software, and communication networks required for smart charging may be introduced by the government.

DISCOMs can play a significant role in supporting smart charging by providing an initial logistic support (viz., network information, access to required data, historical data of load, etc.) required to implement a smart charging station. Government offices/PSUs can be

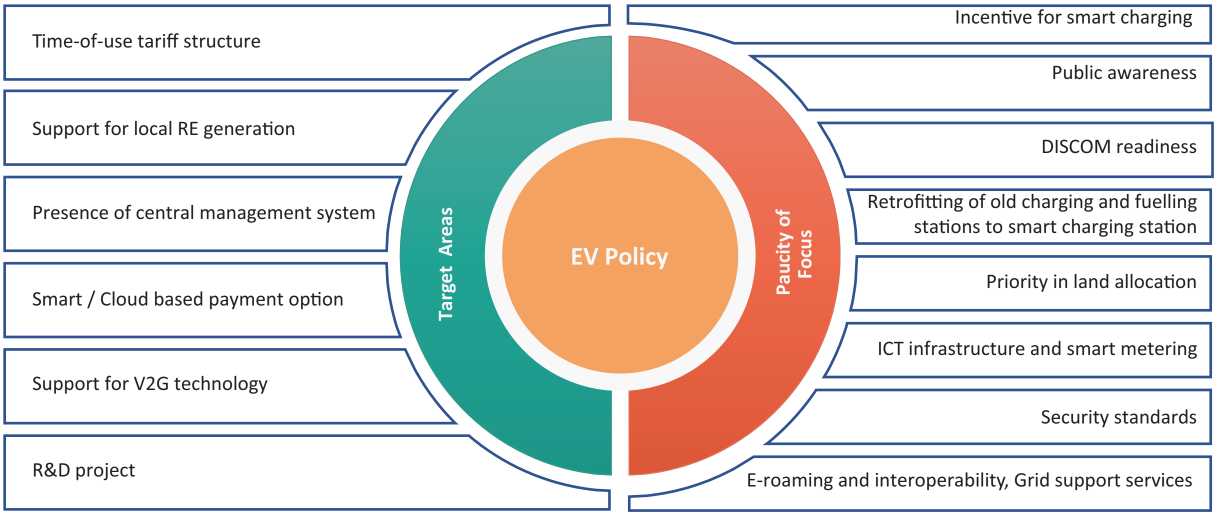


**Figure 5:** Smart charging in Indian EV policies/schemes/regulations

mandated to establish smart charging stations in the respective region and offices. Also, relevant agencies may be mandated to create a complete package of required logistics, software, network service providers, and training material. If a charging station owner/ service provider wishes to opt smart charging strategy, he could directly avail of this complete package and establish a smart charging station.

Reward points or green certificates can be issued to EV owners for using the smart charging option and charging their vehicles for more than pre-set aggregated charging energy (kWh). Free parking at government parking spaces against green certificate and concession in electricity bill against reward points could be provided.

Awareness programmes can be launched to spread the benefits of EV, state's EV policy, and smart charging in reducing electricity bills and promoting environmental welfare. R&D projects can be given grants to investigate and develop modern ICT-based integration and smart charging techniques for EV ecosystem in the presence of EV loads, smart grid, renewable generation, and digital billing.

Security standards can be structured or adopted from any standard organization to safeguard the users, charging stations, metering, and sensing equipment's data to maintain users' privacy and charging stations to avoid cyber threats on users or charging stations. Investigation of vulnerable nodes in the system can be done on a regular basis.

## Conclusion

To enable a smooth transition to accommodate India's projected increase in e-mobility and electricity demand, adoption of smart charging is a necessity. Smart charging is crucial to ensure that EV uptake is not constrained by grid capacity. Smart charging is necessary to manage the charging demand with the available grid infrastructure and generation capabilities. As mentioned in the above section, a number of interventions can be adopted and implemented to enable a smarter, efficient, and sustainable way of scaling up the adoption of EVs in India. Let's hope that India, both at central and at state level, supports policies, regulations, and schemes that complement smart charging adoption for EVs at large.

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# RECYCLING BATTERIES

## Old is Gold


In this article, **Sushovan Bej** and **Toni Zhimomi** say that with the envisaged increase in electric vehicle adoption in the coming years, the increase in battery demand is imminent. This increase in battery demand would lead to faster exhaustion of minerals required to produce batteries. Hence, battery recycling undoubtedly holds an important role in the efficient use and re-extraction of the resources ensuring a stable supply chain and thereby contributing to the circular economy.

Electric vehicles (EVs) have seen a rapid growth with the global electric car stock hitting the 10 million mark in 2020 (IEA, 2021). Delhi, the capital state of India, experienced around 9% of the total vehicle sales in the last quarter of 2021 of that of EVs. This increasing shift to EVs would also mean an increase in battery demand. Lithium-ion batteries (LIBs), which currently power the EVs reached global manufacturing capacity of roughly 300 GWh per year and the production was around 160 GWh in 2020. Battery demand is set to increase significantly over the coming decade, reaching 1.6 TWh in the Stated Policies Scenario and 3.2 TWh in the Sustainable Development Scenario (IEA, 2021).

The envisaged projections in EVs and the subsequent battery demand raises important questions with regards to catering to the demand for the materials that will arise for manufacturing batteries, end-of-life (EoL), and waste management.

## Battery Recycling and Technologies

The increasing demand for battery materials necessitates the need for increased extraction of raw materials. However, reserves are limited in nature and the emissions that result from extraction, processing and transport would defeat its decarbonization goals. This, therefore, necessitates the need to have a robust and efficient recycling infrastructure. It is important to note that recycling is crucial not only for securing the supply of key raw materials for the future but also for reducing the need for new mineral extraction, thereby, lowering the environmental footprint manifold.

The life of an EV battery generally ranges between 6 and 8 years and needs replacement when its capacity starts falling below 80%. There are three options post utilization of batteries for EV/traction purposes:

1. Re-use/repurpose the battery for secondary applications, e.g., stationary batteries for grid storage systems or standby use.
2. Recycle - Recover the materials in the battery such as cobalt, nickel, iron, copper, etc.
3. Landfill disposal

The sheer volume of used battery packs piled up in landfills is not an environmentally-conscious solution. Repurposing the battery is preferable to recycling as per the waste management hierarchy (Directive, E.C., 2008). Studies show that second life battery lifespan depends on its use, going from about 30 years in fast electric vehicle charge support applications to around 6 years in area regulation grid services (Lluc Canals Casals, 2019). Second life batteries start at 80% SOH and its common EoL is 60% SOH. Once the second life battery reaches its end of life (EoL), the appropriate option would be to recycle the battery. Recycling process reintroduces the recovered materials back into use, which reduces the consumption and mining of primary raw materials. This contributes to the economic cycle and forms a fundamental aspect to the circular economy. It also helps to avoid disposal of batteries in landfill. Recycling, thus, contributes to sustainability and circular economy (Kezi Cheng, 2021) and represents a viable option in managing the EV battery at its end stage. Figure 1 illustrates waste management hierarchy.

The battery chemistry with the maximum shares for EV application currently are lithium-ion battery (LIB), nickel metal hydride battery and lead acid battery, with LIBs forming the maximum share. The materials that can be recovered depends on the battery chemistry. However, currently there is a stark gap between the rate of production and rate of recycling. The gap between recycling and production currently represents an untapped source of valuable materials. Figure 2 presents battery recycling overview.

## Methods of Recycling

The battery pack in an EV is usually made up of modules and each module has several cells. Each cell has an external casing, usually made from metal or plastic, which has two terminals affixed to it—a positive and a negative terminal. The positive terminal is connected to the 'cathode' and the negative terminal is connected to the 'anode'. The electrons flow in an electrolyte medium. The type of materials that make up the cathode and anode for batteries vary depending on the different chemistry types. Figure 3 shows the cutaway view of a cell.

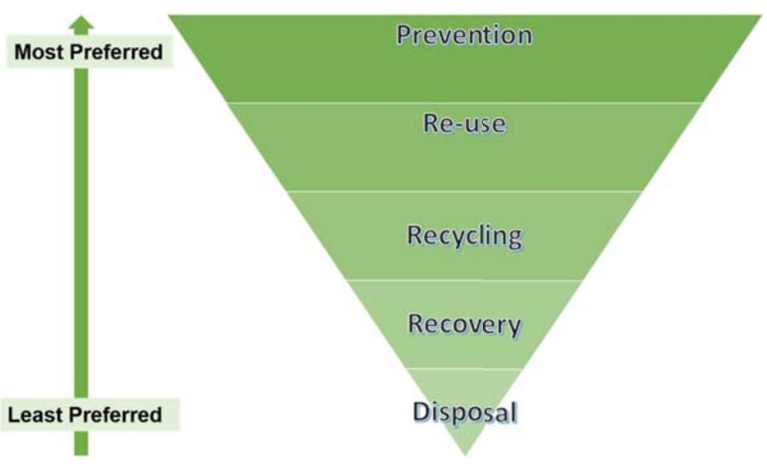


**Figure 1:** Waste management hierarchy

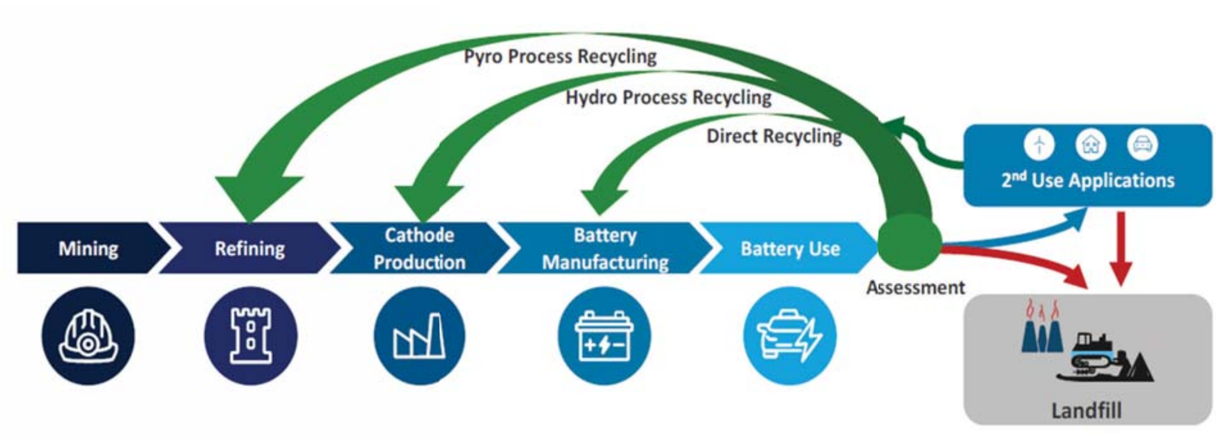


**Figure 2:** Battery recycling overview[1]

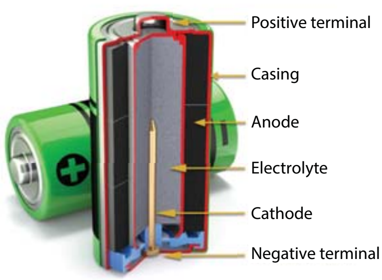


**Figure 3:** Cutaway view of a cell

Primarily, there are three recycling methodologies as described below:

1. **Pyrometallurgical recycling** involves the use of heat to recover metallic battery components.
2. **Hydrometallurgical recycling** consists of a series of chemical steps with aqueous solutions for the recovery of metals from the battery powder.
3. **Mechanical or physical recycling** relies on the mechanical and physical separation of battery components.

## Pyrometallurgy Recycling

Pyrometallurgical recycling (smelting) uses high-temperature furnaces to burn large quantities of battery packs and combustible battery materials (e.g., graphite anode, aluminium wires, paper, and plastic casing). The process reduces the chemical components (e.g., copper, cobalt, nickel, iron) into molten metals, which are collected as alloys to be sent to metal refineries for further processing and recycling.

It recovers valuable transition metals but leaves behind a furnace slag, consisting of ashes of the burnt components and primarily containing lithium, aluminium, silicon, calcium, and some iron compounds. The key advantage of pyrometallurgical recycling is that all battery chemistries can be recycled simultaneously.

## Hydrometallurgy

Hydrometallurgical recycling (leaching) uses acids to dissolve the metal components of batteries, primarily found in the cathode of LIBs, rather than using high temperatures as done in pyrometallurgy. To facilitate dissolution, battery packs are dismantled, and cells are usually further fragmented by crushing and shredding. Once the metals are brought into solution, depending on the recycling facility, several solvent extractions, chemical precipitation, and electrolysis steps may be required to separate the constituent elements as inorganic salts. This process is especially attractive for LFP and LMO cathodes, being the only method devised so far to recover any significant value from them. It can also recover electrolyte and anode materials.

This route requires certain mechanical and/or thermal pre-treatment to separate the cathode and organic materials in the batteries, which can be put through chemical processes such as leaching, precipitation, solvent extraction, etc. The hydrometallurgical route has significant lower carbon emissions and energy usage in comparison to pyrometallurgy (see Figures 4 and 5).

## Direct Recycling

Physical or mechanical recycling consists of manual or automated dismantling and crushing of the battery packs to recover key components in their original state (e.g., electrodes, wiring, casing). Some recovered components (e.g., electrodes) could be used directly in the manufacturing of new batteries, whilst other components (e.g., wiring) need recycling using usual pyro or hydro schemes (as metals). In principle, the mixed metal oxide cathode materials can be reincorporated into a new cathode electrode with minimal changes to the crystal morphology of the active material. These materials can be then reused as fresh cathode material in new battery manufacturing. Figure 6 shows direct recycling of LIB.

Table 1 captures the various technologies being used to recycle EV traction batteries across the world and gives a brief overview of the processes.

[1] Argonne National Laboratory

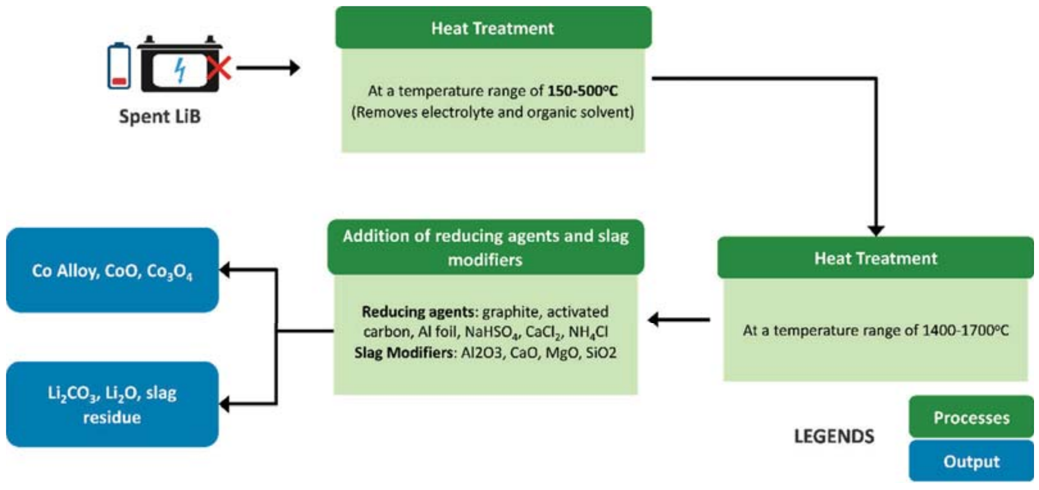


**Figure 4:** Generic process flow of pyrometallurgical recycling of LIB (Mohammad Assefi, 2020)

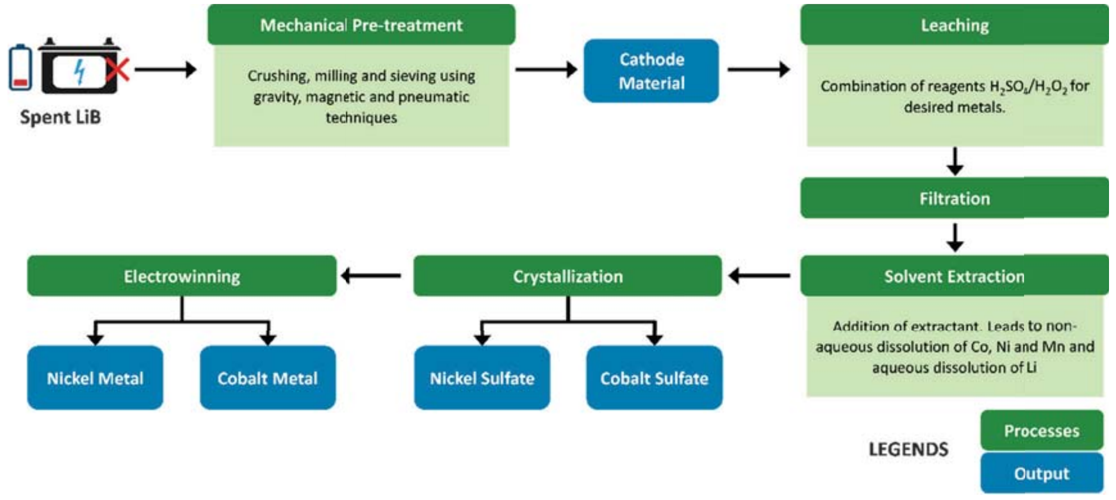


**Figure 5:** Generic process flow of hydrometallurgical recycling of LIB[2]

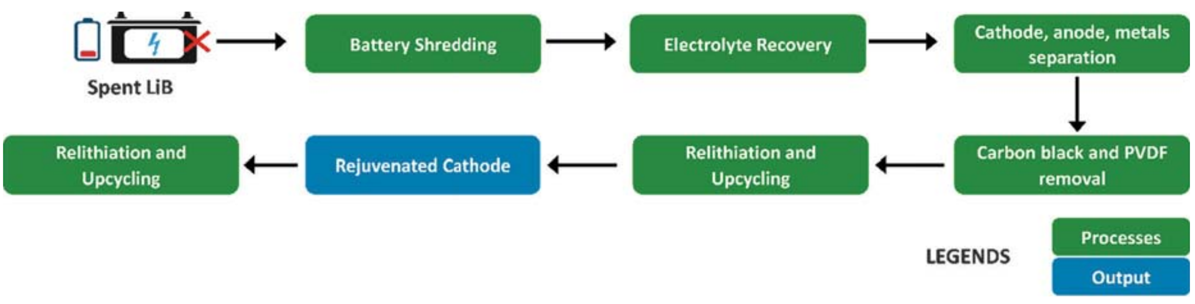


**Figure 6:** Direct recycling of LIB (Linda Gaines, 2021)

[2] UBS Analyst Report and GIZ compilation

**Table 1:** Battery recycling technologies and their uses for various chemistries

| Recycling Technology / Battery Chemistry | Pyrometallurgy | Hydrometallurgy | Direct Recycling |
|---|---|---|---|
| Lithium Ion | Matured technology for recovering metal alloys<br>» Further refinement is required to get the desired metal<br>» Requires high capital investment, energy usage, and results in more emissions<br>» Does not recover lithium, aluminium or inorganics<br>» 95%–99% of cobalt, nickel, and copper can be recovered | Has a high raw material recovery rates and yield<br>» Product purity suitable for cathode manufacturing<br>» Can accommodate multiple batteries and cathodes<br>» Matured technology with low basic investments and emissions<br>» Requires prior dismantling/ discharging/ crushing<br>» Recovery rate is generally between 85% and 90% | Avoids lengthy and expensive purification steps reducing costs.<br>» Advantageous for low value cathodes such as LMO, LFP – technology/cathode agnostic<br>» Most energy efficient compared to other recycling processes<br>» Can recover anode as well<br>» Complex process with the risk of obsolescence of technology when returned to market<br>» Almost 100% of cathode and anode material recovered |
| Nickel Metal Hydride | The process doesn't require prior discharging, conditioning<br>» Pure metal alloys are generated<br>» Matured technology<br>» The process is capital intensive<br>» Energy intensive with higher emissions<br>» Some companies have efficiency ~100% for iron, nickel and cobalt | Lower capital investment with options for recovery optimization<br>» Recovers rare earth elements with cathode metals (>95%) and metals with efficiency >90% with electrowinning<br>» Efficiency is highly driven by environmental conditions | Not employed for Nickel Metal Hydride batteries |
| Lead Acid Battery | Mainstay of both organized and unorganized lead acid battery recycling<br>» The lead alloy generated is of high purity and the process is highly matured with nearly 100% recycling efficiency | Not generally used for lead acid batteries as pyrometallurgy provides nearly all the lead content of batteries in cost-effective manner | Not used for lead acid batteries |

Figure 7 shows a simplified workflow of all battery recycling technologies on LIBs.

## Challenges of Battery Recycling

- **Carbon footprint**: One of the biggest supporting arguments for promoting battery recycling is that it helps in reducing an EV's carbon footprint. However, the recycling process itself involves a number of carbon-emitting activities, starting with the emissions resulting from collecting and transporting batteries to the recycling process, which itself requires a considerable amount of electricity and thermal energy. Therefore, recycling batteries is only effective from a carbon footprint reduction perspective when the entire closed loop of battery recycling has a lower carbon footprint.
- **Economic feasibility**: Battery recycling is a complex process and requires substantial capital investment. The recycled materials may also be more expensive than newly extracted materials. This poses a threat to its overall acceptability and hence will likely require government

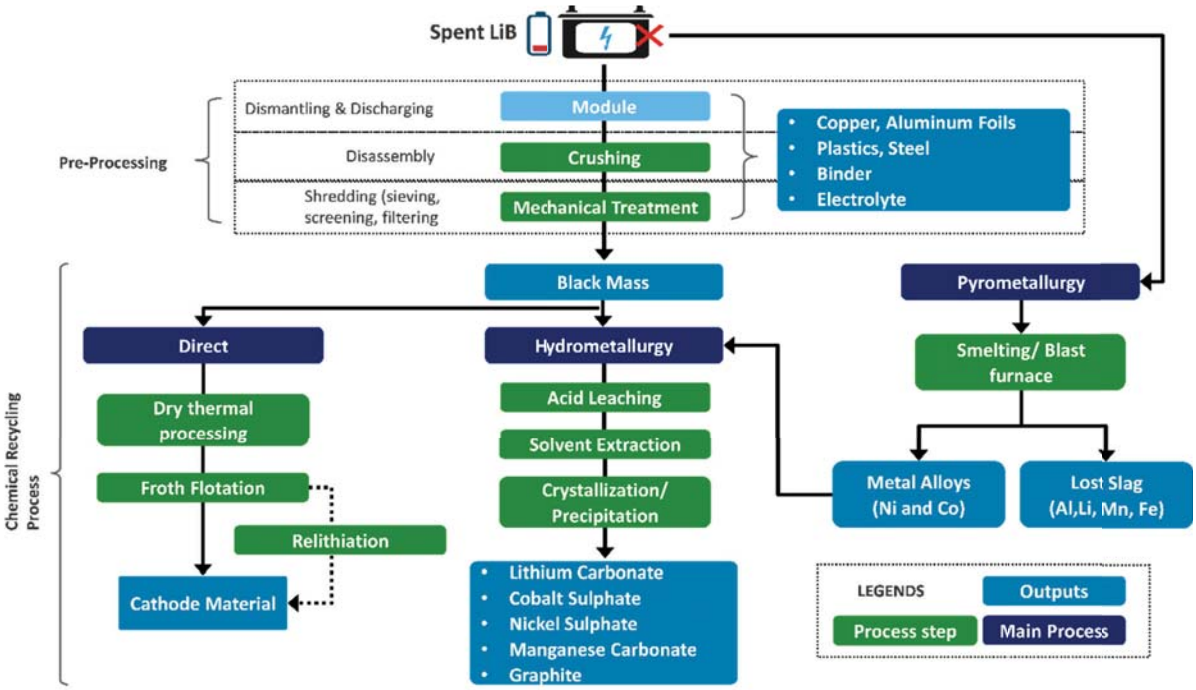


**Figure 7:** Simplified workflow of LIB recycling processes[3]

incentives (policies, guidelines, etc.) to promote the circular economy.

- **Evolving design and technology**: Batteries are subject to constant R&D to enhance their chemical composition. As a result, there is a question on the feasibility of using the materials recovered from 10–12-year-old batteries to meet the needs of new generation batteries.
- **Traceability of recycled materials**: LIBs can be used in less demanding applications once they are taken off from their first-life applications. The secondary usage may appear to be more feasible than recycling (due to the high cost of the latter) and thus batteries may ultimately end up in a landfill after their capacities gradually wear off. Thus, a monitoring or reporting system should be in place to enable traceability of recycled battery materials, which is challenging to implement.
- **Quality of recycling**: Materials from improper or substandard recycling could lead to battery explosion causing threat to life and property. Therefore, battery recyclers need to adhere to the highest quality standards to ensure the purity of the material recycled.

## Global Practices on Battery Recycling

### *Germany*

The European Battery Directive 2006/66/EC adopted in Europe from September 26, 2006 requires European countries to transpose the Directive into national law. The aim of the Battery Directive is to increase the percentage of batteries that are returned and recycled, because they contain not only valuable raw materials but also substances that are environmental and health hazards. It sets limits for the use of harmful substances such as lead, mercury, and cadmium. The Battery Directive requires manufacturers, distributors or importers of batteries to contribute to the cost of disposing of the batteries.

With reference to directives 2006/66/EC of European Union, Germany has her policy named Batteries Act 2015 in the same line. The Batteries Act differentiates between portable, industrial, and automotive batteries for the purpose of collection. The Batteries Act restricts the percentage of mercury and cadmium in batteries to not more than 0.0005% and 0.002% (by wt). The main amendments are:

- A notification of registration obligation to all manufacturers of batteries
- Establishment of minimum standards for containers used by the collection schemes for collection and pick up
- New responsibilities and framework for the approval of manufacturers' collection schemes
- Incorporation of the waste electrical and electronic equipment (WEEE) register foundation into manufacturer registration and the approval of collection schemes as well as enforcement in this area.

[3] Based on discussions by GIZ India team with the industry stakeholders.

## China

In 2018, the Ministry of Industry and Information technology (MIIT) issued "Interim Measures for the Administration of Recycling Traction Batteries of New Energy Vehicles", also called the "Interim Measures", to promote comprehensive utilization of resources, protect the environment and human health, ensure safety, and promote the sustainable and healthy development of the new energy automotive industry. The Interim Measures stipulate the design, production, and recovery responsibilities of traction batteries, the comprehensive utilization of traction batteries, and their supervision and administration. The key details from the interim measures are:

- Manufacturers of EVs are responsible for setting up facilities to collect and recycle spent batteries.
- The carmakers must also establish a maintenance service network allowing members of the public to repair or exchange their old batteries conveniently.
- Together with battery makers and their sales units, carmakers must also set up a "traceability" system enabling the identification of owners of discarded batteries.
- Battery makers are also encouraged to adopt standardized and easily dismantled product designs, to help automate the recycling process. They must also provide technical training for car makers to store and dismantle old batteries.
- The guidelines encourage battery-makers to strengthen cooperation with companies that can make a better and rational use of used batteries removed from new energy cars. Today, Guidelines are not subject to penalties or incentives.

A timeline of the various waste battery-related regulations that were notified in China[4] is shown here.

## United States (US)

In May 1995, the US Environmental Protection Agency (EPA) promulgated the Universal Waste Rules to reduce the amount of hazardous wastes entering the municipal solid waste stream, encourage the recycling and proper disposal of certain common hazardous wastes, and reduce the regulatory burden on businesses that generate these wastes by simplifying the applicable regulations and making them easier to comply with. The Universal Waste Rule, however, does not automatically apply in each state.

On May 13, 1996, the Mercury-Containing and Rechargeable Battery Management Act (the Battery Act) was signed into law. The Battery Act applies to Battery and Product Manufacturers, Battery Waste Handlers, and certain Battery and Product Importers and Retailers, not consumers. Specifically, the Act:

- Establishes national, uniform labelling requirements for Ni-Cd and certain SSLA rechargeable batteries.
- Mandates that Ni-Cd and certain SSLA rechargeable batteries be "easily removable" from consumer products. A battery can be easily removed if it is detachable or removable from the product with the use of common household tools.
- Makes the Universal Waste Rule effective immediately in all 50 states for the collection, storage, and transportation of batteries covered by the Battery Act.
- Requires EPA to establish a public education programme on battery recycling and the proper handling and disposal of used batteries. EPA is required to consult with manufacturers and retailers to carry out this initiative.
- Prohibits, or otherwise conditions, the sale of certain types of mercury-containing batteries (i.e., alkaline-manganese, zinc-carbon, button cell mercuric-oxide, and other mercuric oxide batteries) in the United States.

## Indian Scenario

On May 15, 2001, the Ministry of Environment and Forest (MoEF),

Legislations related to waste batteries in China.

| Laws and regulations | Year | Major regulations on battery recycling |
|---|---|---|
| Law of the People's Republic of China on the Prevention and Control of Solid Waste Pollution | 1995 | Waste batteries are dangerous solid wastes and need to be recycled separately |
| Technical Policy for the Prevention and Control of Hazardous Waste Pollution | 2001 | Phase-out batteries containing mercury and cadmium |
| Policy on Pollution Prevention Techniques from Waste Batteries | 2003 | Battery industries should take responsibility for collecting waste batteries and for proper labeling |
| National Hazardous Waste List | 2008 | Lead-acid batteries are dangerous solid wastes that need to be collected and treated separately |
| Administrative Measures on the Collection and Using of Waste Electrical and Electronic Product Treat Fund | 2012 | Manufacturers or importers are responsible for the fund collection |
| Directory of Waste Electrical and Electronic Equipment Treatment (2014) | 2015 | Waste LIBs were officially added to the scope of the Fund |
| Technology Policy for the Recycling of Power Battery (2015 edition) | 2016 | Provisions on the recycling and utilization of waste EV batteries |
| Policy on Pollution Prevention Techniques of Waste Batteries | 2016 | The pollution prevention and control technologies of waste LIBs |
| The Implementation Plan of the Extended Producer Responsibility System | 2016 | Implement the extended producer responsibility system for batteries |
| The Interim Measures for The Management of Power Battery Recovery and Utilization of New Energy Vehicles | 2018 | Automobile manufacturers should shoulder the primary responsibility for power battery recovery |
| The Interim Provisions on The Traceability Management of Power Battery Recovery and Utilization of New Energy Vehicles | 2018 | The comprehensive management platform for national monitoring and power battery recovery and utilization traceability of new energy vehicles must be established |
| The Notice on the Pilot Work of Power Battery Recycling of New Energy Vehicles | 2018 | Confirmed some pilot regions and pilot enterprises to carry out the pilot work of power battery recycling |
| The Law of the People's Republic of China on the Prevention and Control of Solid Waste Pollution (2020 edition) | 2020 | The establishment of a credit record system for the prevention and control of solid waste (including waste LIBs) pollution |
| The Notice on Matters Related to the Total Ban on Solid Waste Import | 2020 | The import of solid waste in any way is prohibited |

[4] GIZ compilation

Government of India, notified the Batteries (Management and Handling) Rules, 2001 to regulate the collection and recycling of all the used lead-acid batteries in India (Ministry of Environment and Forest (MoEF), 2001). The rules as mentioned limited the definition of a battery to a 'lead acid battery' and Li-ion batteries were not covered under. The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, published the Draft Battery Waste Management Rules, 2020 on February 20, 2020, which is to supersede Batteries (Management and Handling) Rules, 2001 (Ministry of Environment, Forest and Climate Change (MoEFCC), 2020). The Draft Rules brings under its ambit, all manufacturers, producers, collection centres, importers, re-conditioners, re-furbishers, dismantlers, assemblers, dealers, recyclers, auctioneers, vehicle service centres, consumer and bulk consumers involved in manufacture, processing, sale, purchase, collection, storage, re-processing and use of batteries or components thereof including their components, consumables and spare parts, which make the product operational.

As per our discussions with the industry recycling of lead-acid batteries is mostly informal (75%–80%) in nature, that is, by means of recycling through *kabadiwalas* and unregistered recyclers. The LIB recycling generally follows a mix of formal and informal recycling, given the fire safety aspects related to such type of batteries.

The following points should be considered while preparing the rules/guidelines for battery recycling in India:

- Need for a separate operational guideline for EV/automotive batteries, given their size (compared to other e-waste) and the envisaged scale.
- Identify the feasibility of battery recycling and the fund support required for sustenance of such businesses in India.
- Need to develop rules/operational guideline, where all the roles and responsibilities are to be undertaken by private sector, while a public institution is undertaking monitoring of the value chain.
- Need for compulsory implementation of battery recycling guidelines with stringent monitoring and appropriate penalization for non-adherence.
- Need to mandate submission of Extended Producer's Responsibility (EPR) plan by all the stakeholders in the EV value-chain such as, EV Manufacturers, EV Manufacturer's Dealerships, Battery manufacturers, Battery vendors & dealerships, Charging Infrastructure and Battery Swapping Operators for collection of batteries from consumers.
- Need to mandate tagging of batteries for data generation and tracking batteries along the value chain.
- The list of collection centres for submission of batteries by the consumers should be made publicly available by all the stakeholders in the EV value-chain.

The above considerations would enable development of a holistic EV battery recycling ecosystem for India.

## Conclusion

With the envisaged increase in EV adoption in the coming years, the increase in battery demand is imminent. This increase in battery demand would lead to faster exhaustion of minerals required to produce batteries. Hence, battery recycling undoubtedly holds an important role in the efficient use and re-extraction of the resources ensuring a stable supply chain and thereby contributing to the circular economy. However, the scale at which battery recycling can contribute significantly has not been achieved yet owing to many reasons. Efficient battery waste management policies and regulations are the need of the hour to encourage participation from the industry and the entire ecosystem, appropriate technological assistance to sort and recover materials. Although safe handling of batteries especially LIB, environmental impacts due to battery recycling and issues regarding standardization of batteries can enable automation of the recycling process in the future, a viable and thriving battery recycling industry can easily address this challenge.

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# END-USE POWER DEMAND ESTIMATION IN RESIDENTIAL SECTOR

## Regional Variation in India

Residential sector is one of the important and fast-growing sectors in terms of energy consumption. If growth in electricity requirement is to be contained, efficiency improvements in these appliances are important to address. This article by **Saswata Chaudhury** talks over about how adoption of efficient appliances can further help to reduce the growth in residential energy consumption.

On world level, India stands third in terms of both production and consumption of electricity. Per capita consumption of energy showed a compound annual growth rate (CAGR) of 2.54% for the 2011–12 to 2017–18 period. India is currently the third-largest greenhouse gas (GHG) emitter globally, with the energy sector accounting for 77% of its GHG emissions and electricity production accounting for 38% of GHG emissions. Moreover, nearly one-third of the total primary commercial electricity demand of India is import-dependent. As India develops, the demand for energy in the country will inevitably rise, both on account of a growing population, especially a growing middle class, and on account of economic growth and the changing structure of the economy. Technology improvement and fuel shifts also have a role to play, and these implications and interactions are complex and need to be well understood.

India is currently undergoing a transition of its energy system where it must meet the energy demands of a growing economy, with better lifestyles and a population that is both growing and urbanizing. The current energy policy and development environment of the country has inculcated an element of dynamism in the economy and in the electricity sector in particular. This, coupled with global progress in technology development and changes in patterns of production and consumption, are leading to significant variations in the way electricity demands have evolved in the past. Accordingly, it is important to understand the composition of electricity demand, its determinants and patterns at the regional and national levels. Simultaneously, it is important to study the factors that drive these demands including structural or behavioural factors, so as to be able to examine what measures may be used to influence these.

Residential sector is one of the important and fast-growing sectors in terms of energy consumption. In 2017–18 (provisional estimate), 24% of the total power consumption and 11% of the total energy consumption in India was contributed by residential sector alone. In case of energy sources for lighting, over time electricity has sharply replaced kerosene. In rural area, while 51.9% households were electrified in 2001/02, 71.24% households were electrified in 2011/12. In urban India, 96.3% households were electrified in 2011/12 compared to 91.4% in 2001/02. Recently, 100% of the villages were electrified in India and 99.99% households received electricity connection at their premises. Appliance-wise residential electricity demand in India is captured in few survey based studies like World Bank (2008) and

Boegle, *et al*. (2010). Figure 1 indicates the appliance-wise share in power demand as indicated by the World Bank (2008) and Boegle, *et al*. (2010).

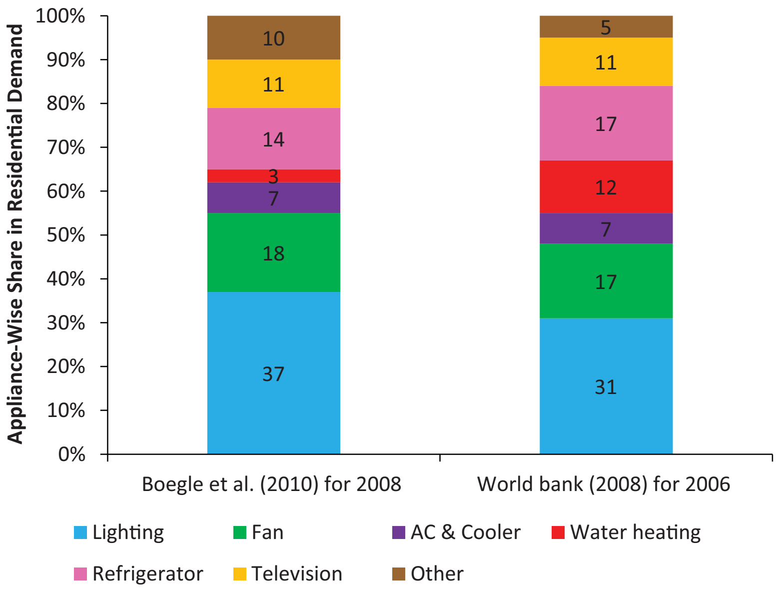


**Figure 1:** Appliance-wise power demand in residential sector

*Sources: World Bank (2008) and Boegle, et al. (2010)*

According to these studies, lighting demand in residential sector is approx. 31%–37% while demand for space cooling is around 24%–25% (17%–18% by fan and remaining by AC and cooler). On the other hand, electricity demand for refrigeration in residential sector is around 14%–17% while water heating demand is 3%–12%. Electricity demand for television is around 11% and remaining 5%–10% is due to other appliances. No study has attempted to capture regional, rural-urban or socio-economic class-wise variation in demand by end-use. Twenty per cent of the power demand in residential sector was consumed for lighting, followed by 16% for fan and AC (including cooler) each, 12% for water heating, 11% for refrigerator and television each, and remaining 13% on other appliances.

But, none of the studies has estimated regional variation in power demand pattern. Owing to variation in agro-climatic condition and behavioural and life-style pattern of the residents, the power demand and its composition is expected to vary across regions also. This study has addressed this unexplored dimension of Indian power sector. The study has segregated rural–urban and grid region-wise variation in power demand in residential sector.

## Approach

Residential electricity demand comprises broadly five major end-uses, namely, lighting, space conditioning, refrigeration, water heating, and other domestic uses (including communication, entertainment, etc.) for which different appliances (technologies) are used. In India, there are significant socio-economic, regional, and temporal variations in patterns of energy usage in the residential sector as also in the choice of technologies to fulfil the same.

Four technologies—incandescent light bulbs (ILB), tube light, CFL, and LED—are mainly used for residential lighting purpose, however, penetration of these technologies is different across socio-economic classes. Usage can also vary across household classes as well as across regions (as per agro-climatic zone). Similar variation exists for space-conditioning demand (met by fan, cooler, air conditioner, and heater) and other domestic uses (television, water heating appliances, laptop/computer/music system, etc.).

The variation has been captured/validated based on secondary data (NSS rounds 63rd and 68th) as well as primary survey. Primary survey was conducted to get information related to number of appliances per household, technology penetration, and usage of appliances. Our primary survey covered a sample of more than 4000 households across rural and urban areas across 10 states from five grid-zones and was used to arrive at and validate the norms.

The factors which determine the electricity demand in residential sector include percentage of households having access to a particular appliance, number of appliances in each household, technology variation of the appliances, and usage pattern (daily and seasonal) of the appliance.

For end-use demand estimation, households have primarily been divided based on location (rural and urban) and their economic status (poor, middle-income and rich households), which, in turn are defined by their monthly per capita expenditure. Within each category, percentage of households owning to different appliances (for example, AC/cooler/refrigerator/TV, etc.) and having different number of connections/appliances (number of light points, fan points, etc.) were considered. Average daily usage of each connection point/appliance in different seasons (summer, monsoon, winter, and normal days) was also considered for demand estimation. Technology variation under each end-use (for example, whether the lighting point is ILB/tube light/ CFL/LED) was given proper weightage for more realistic demand estimation.

TERI's primary survey data was utilized to complement (and validate) the norms derived from the secondary data available from NSS and other sources. Final electricity demands estimated by the normative end-use method were compared with final electricity demand estimates provided by other secondary sources for the past years. The energy forecast for the required time-period (up to 2051) was obtained by extending our assumptions regarding growth of household income, growth of appliance penetration, technology improvement, etc.

One of the important aspects in our estimation relates with the percentage of households in each expenditure category owning different appliances. For example, a newly electrified household usually starts with electricity consumption from a single light point and possibly a fan, thus generating lighting and cooling demand. However, over time, the suite of appliances owned is assumed to expand, based on household affordability and requirement.

## Analysis

As per CEA data, actual supply in India and five regions in 2001, 2006, and 2011 is given in Figure 2.

Northern and southern regions have almost equal share of 30%–32%, followed by western (25%) and eastern regions (11%).

Regional and rural–urban demand was separately estimated in this study using regional/rural–urban segregation of number of households, appliance penetration, technological variation, and usage pattern. This is a value addition of this study. This demand segregation across region and rural-urban areas will help to address demand–supply gap more effectively and implement demand control measures more efficiently. Tables 1 and 2 detail the forecasted regional urban and rural demands, respectively.

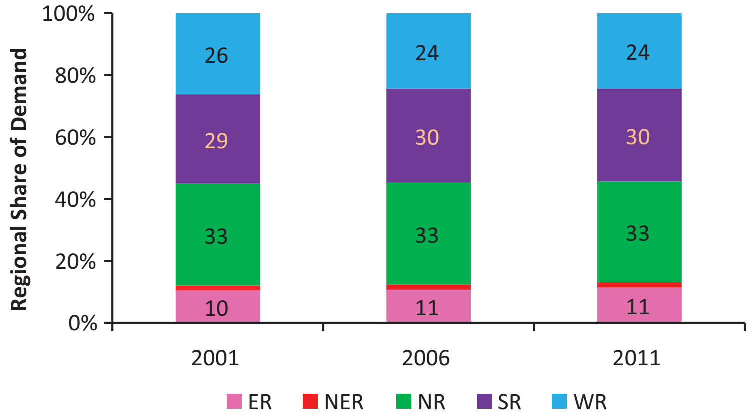


**Figure 2:** Regional power demand estimate for residential sector

*Source: TERI Analysis*

**Table 1:** Regional urban demand (in MU) forecast (2016–56)

| | 2016 | 2021 | 2026 | 2031 | 2036 | 2041 | 2046 | 2051 | 2056 |
|---|---|---|---|---|---|---|---|---|---|
| ER | 16,203 | 21,011 | 26,115 | 30,969 | 35,659 | 41,035 | 46,631 | 52,655 | 59,933 |
| NER | 2,296 | 2,984 | 3,713 | 4,409 | 5,063 | 5,756 | 6,332 | 6,953 | 7,659 |
| NR | 48,393 | 61,577 | 75,150 | 89,169 | 100,288 | 110,953 | 119,457 | 128,899 | 138,481 |
| SR | 43,243 | 56,091 | 67,875 | 78,559 | 87,855 | 98,382 | 106,845 | 114,163 | 122,350 |
| WR | 39,097 | 49,781 | 59,130 | 69,042 | 78,917 | 88,877 | 98,427 | 106,879 | 113,530 |

*Source: TERI calculation based on NSS data and primary survey*

**Table 2:** Regional rural demand (in MU) forecast (2016–56)

| | 2016 | 2021 | 2026 | 2031 | 2036 | 2041 | 2046 | 2051 | 2056 |
|---|---|---|---|---|---|---|---|---|---|
| ER | 26,726 | 34,275 | 41,630 | 48,398 | 52,828 | 56,720 | 60,494 | 64,779 | 70,336 |
| NER | 4,790 | 6,059 | 6,999 | 7,721 | 8,305 | 8,868 | 9,381 | 9,956 | 10,655 |
| NR | 52,228 | 68,688 | 82,304 | 96,389 | 109,967 | 123,315 | 134,882 | 146,984 | 161,181 |
| SR | 34,566 | 35,297 | 35,152 | 35,774 | 36,119 | 36,429 | 36,497 | 36,669 | 37,149 |
| WR | 35,107 | 39,932 | 44,286 | 49,430 | 54,245 | 59,318 | 64,515 | 69,986 | 76,363 |

*Source: TERI calculation based on NSS data and primary survey*