Tables 1 and 2 indicate that share of urban demand (compared to rural demand of that region) in each region has increased over time, except in the case of northern region (marginal decline). It also indicates that share of rural demand has increased only in northern region. Owing to lack of reliability in power supply, significant latent demand is present in rural areas of the northern region. However, with improvement in power supply over time, it can be expected that there will be significant increase in rural demand in that region. On the other hand, out of total urban demand in India, share of northern region is highest, followed by southern and western regions. Moreover, share of each region in the total urban demand in India has not changed notably over time. On the contrary, regional share in the total rural demand in India has varied significantly. Share of northern region in the total rural demand in India was about one-third which has increased to almost 45% in 2056. On the other hand, share of southern region in the total rural demand in India has declined from about 23% to 11% within the same period. Rural areas in southern region has relatively better (compared to northern region especially) power supply position along with better appliance penetration. Thus, potential of increase of rural demand in southern region is low compared to northern region rural area which is characterized by poor power supply as well as lower appliance penetration.

However, share of lighting demand (in total residential demand in each region) has declined in each region over time. This has been indicated in Table 3.

Clearly, in every region, the share of electricity demand for lighting has declined at the cost of other electricity demands. This is quite obvious because, lighting demand is the most basic demand and once this is met, households increase their other demands with increasing levels of affordability. Moreover, adopting/shifting to efficient lighting technologies is relatively easier in case of lighting than in other end-uses (for example, AC), which may be relatively more expensive. So, households tend to settle for relatively less efficient technologies in case of many other end-use demands. Similarly, regional share in India's total AC demand is shown in Figure 3.

Figure 3 indicates that over time, share of southern and western regions, AC demand in India has marginally increased while share of eastern region has significantly increased (approx. 9% in 2016 to 14% in 2056). Northern region's share in the total AC demand in India has notably declined (42%–32% in same time span).

Over time, end-use wise/appliance-wise demand is changing. Figure 4 shows estimated temporal change (2011–51) in share of different end-use demands in India.

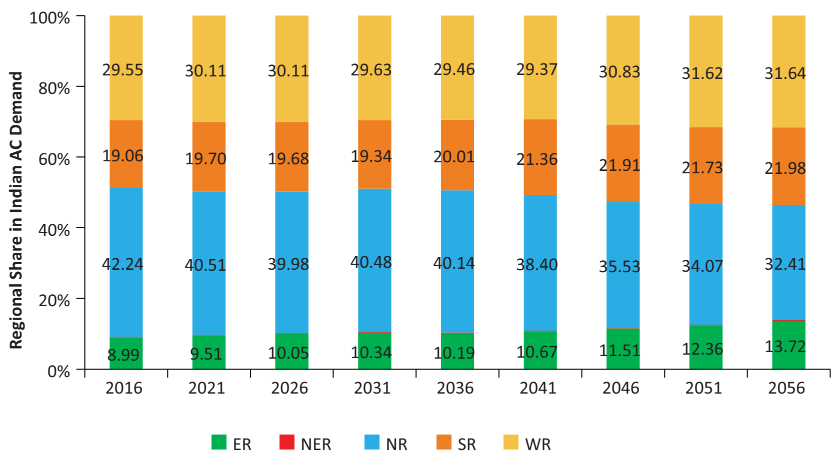


**Figure 3:** Regional share in AC demand

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

**Table 3:** Share of lighting demand in respective region

| Lighting | 2016 | 2021 | 2026 | 2031 | 2036 | 2041 | 2046 | 2051 | 2056 |
|---|---|---|---|---|---|---|---|---|---|
| ER | 44.31 | 41.32 | 38.80 | 37.17 | 35.30 | 33.40 | 31.49 | 29.72 | 27.76 |
| NER | 46.92 | 44.05 | 41.65 | 38.74 | 36.44 | 34.62 | 33.02 | 31.52 | 29.94 |
| NR | 33.00 | 31.30 | 28.63 | 26.77 | 24.92 | 23.63 | 22.68 | 21.80 | 20.96 |
| SR | 32.12 | 28.44 | 25.60 | 23.57 | 21.83 | 20.27 | 18.94 | 17.96 | 17.01 |
| WR | 33.51 | 29.41 | 26.64 | 24.33 | 22.34 | 20.74 | 19.26 | 18.15 | 17.31 |

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

*Note: The remaining demand in each cell represents the other (non-lighting) demand in the respective region.*

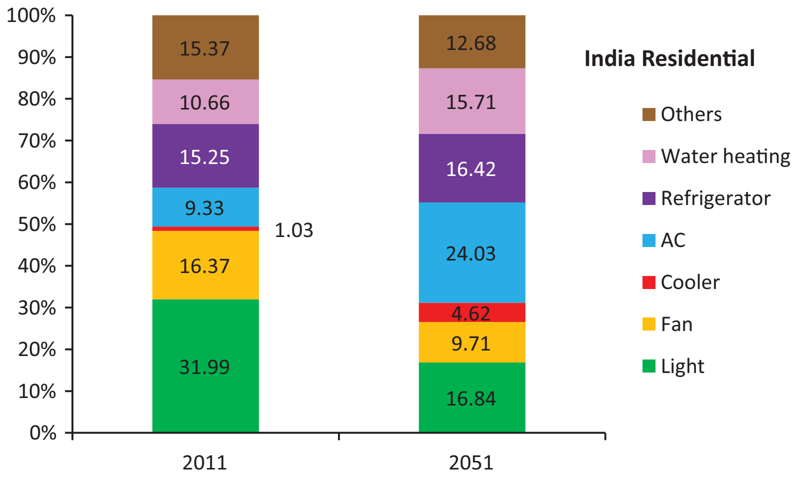


**Figure 4:** Appliance-wise share in residential demand, India

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

The appliance-wise demand estimation and forecast is based on NSS data for 68th (2011–12) and 63rd (2005–06) round and primary survey (more than 4000 households across 10 states) conducted in 2018–19 by TERI team. The study has assumed that usage pattern remains same over time while ownership pattern and technology penetration changes over time, based on past trend and future expectation (based on stakeholder interaction).

Our analysis and estimates indicate that the share of electricity for AC would increase significantly while share of lighting is expected to decline. According to NSS 63rd and 68th rounds data,[1] AC penetration increased from 7.7% to 11.5% between 2006 and 2011 in urban India and 1.9% to 3.4% in rural India. Past trend indicates that AC penetration will increase over time and hence overall usage in the society will increase many fold. On the other hand, since lighting demand is a basic demand, with increasing penetration of LED and CFL to replace ICL, it is likely that share of electricity for lighting will decline. Based on the survey and NSSO data, we expect that water-heating demand is expected to increase significantly due to increase of ownership of water heaters in rural households and shift from use of other fuels to electricity for water heating. Moreover, because of extreme weather conditions and increasing affordability, residential cooling demand through fan has been replaced with cooling demand through AC and cooler.

The study has estimated, residential electricity demand disaggregated at both rural and urban areas. Figures 5 and 6 show the temporal change in appliance-wise rural and urban residential demand.

Figures 5 and 6 indicate that both rural and urban households spent a sizeable share of electricity on lighting in 2011. However, decline in share of lighting in rural areas is starker between 2011 and 2051. Moreover, water-heating share has shown a growing trend in rural areas but is expected to be uniform in the urban areas between 2011 and 2051. Share of refrigeration is expected to increase in rural areas while this share will decline in urban areas between 2011 and 2051.

Estimated temporal change in regional demand shares of different end-use services are shown in Figures 7–11.

Figures 7–11 indicate that electricity usage pattern varies across regions mainly due to variation in income, appliance penetration, climatic condition, etc. Irrespective of regions, share of lighting and cooling through fan demand has declined while water heating and AC demand has increased over time.

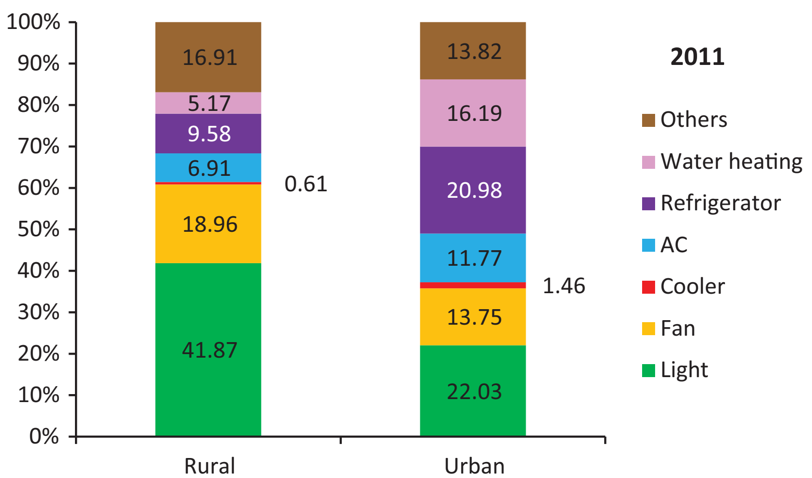


**Figure 5:** Appliance-wise rural and urban residential demand segregation in 2011

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

[1] NSS reports AC and cooler combined data. TERI team has segregated it to AC and cooler separately based on information available from stakeholder interaction.

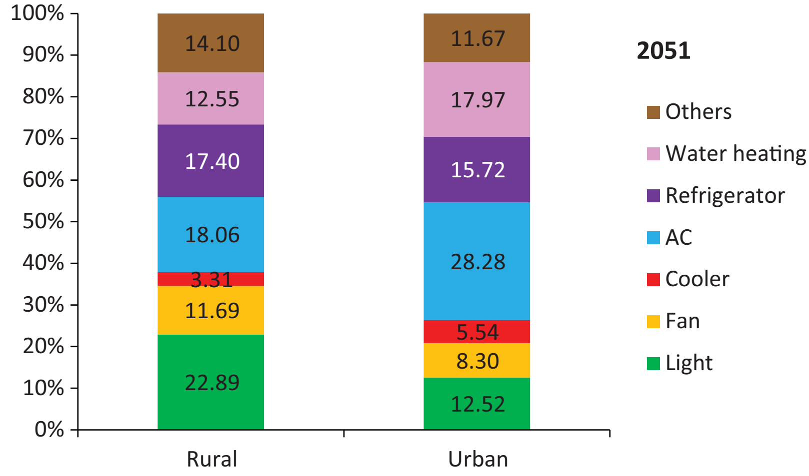


**Figure 6:** Appliance-wise rural–urban residential demand segregation in 2051

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

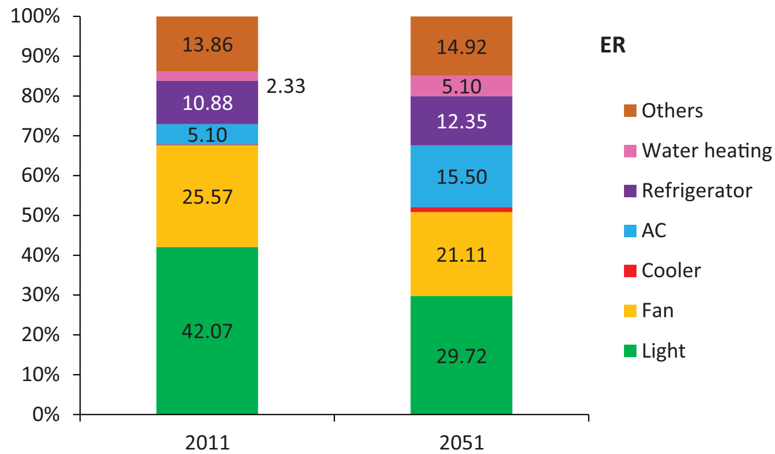


**Figure 7:** Appliance-wise demand in eastern region

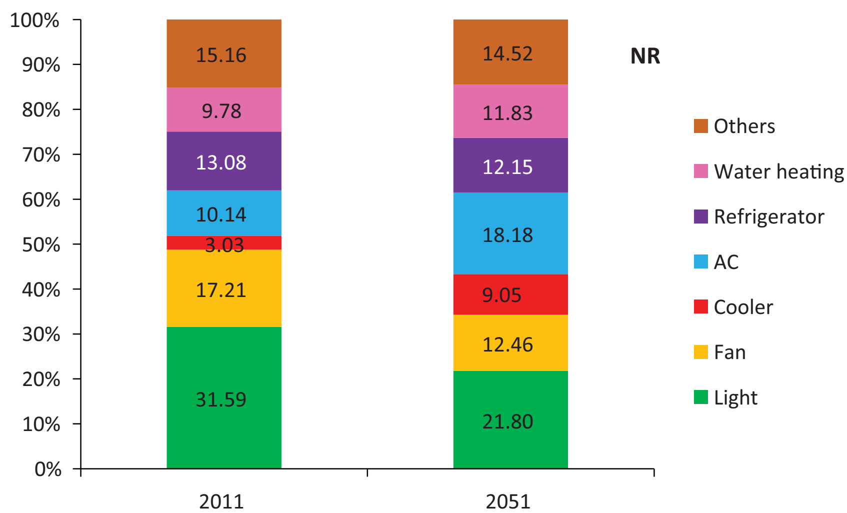


**Figure 8:** Appliance-wise demand in northern region

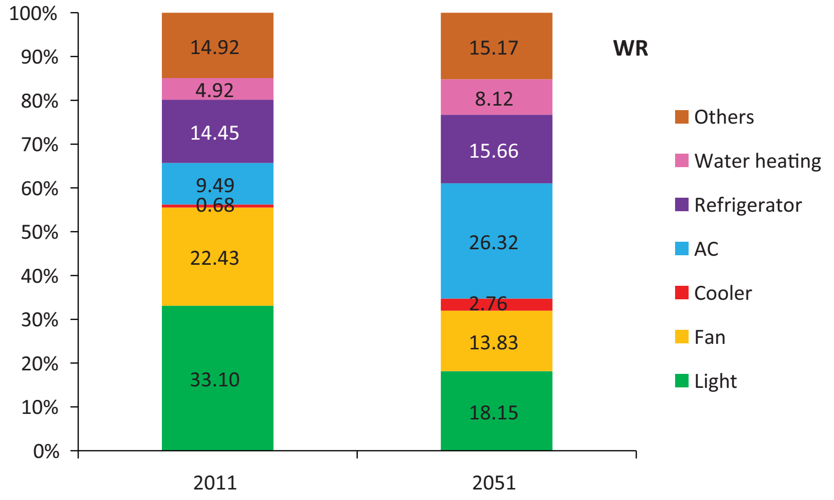


**Figure 9:** Appliance-wise demand in western region

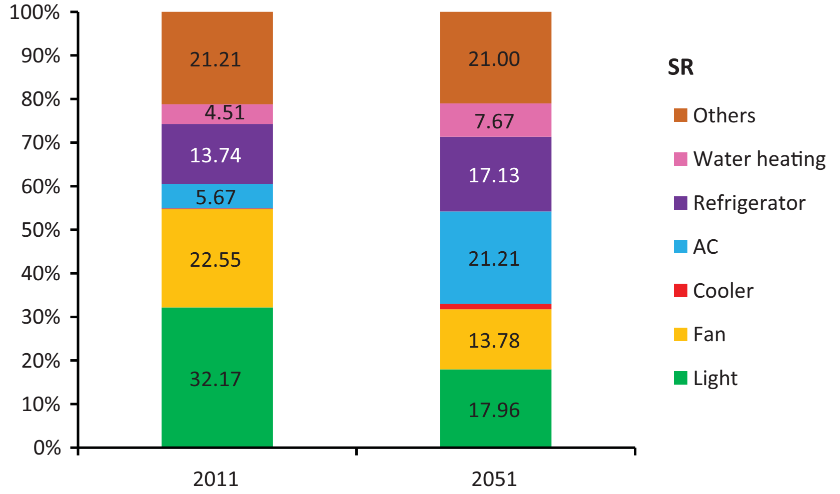


**Figure 10:** Appliance-wise demand in southern region

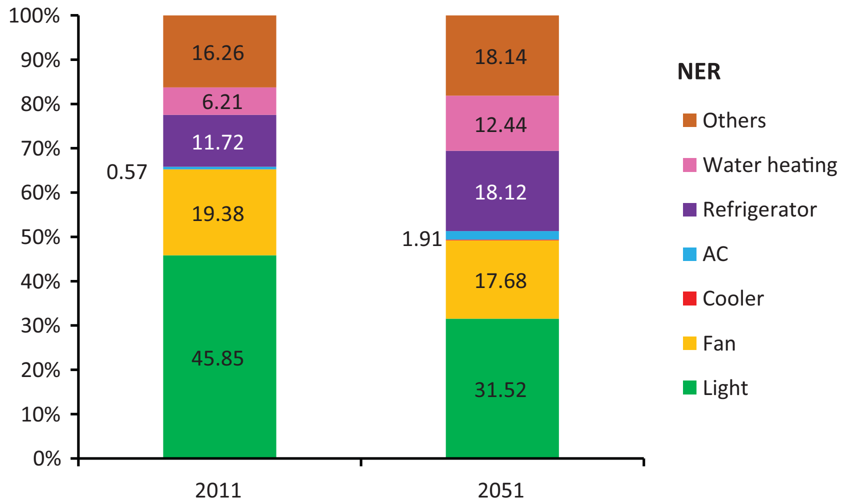


**Figure 11:** Appliance-wise demand in north eastern region

## Conclusion

The variation in appliance ownership and usage pattern across rural–urban and five grid regions (eastern, western, northern, southern, and northeastern) is expected to lead to significantly different power demand pattern across regions. In sum, the residential sector, appliance ownership and usage survey analysis indicates that, over time space cooling, water heating and other end-use services (including cooking, entertainment and communication) demand will contribute to an increasingly higher share of electricity consumption in the residential sector.

Accordingly, if growth in electricity requirement is to be contained, efficiency improvements in these appliances are important to address. Moreover ways to encourage adoption of the more efficient appliances can further help to reduce the growth in residential energy consumption. Since air conditioners are likely to account for the largest energy consumption, special focus is required for adoption of energy-efficient ACs. EF

*Disclaimer: This article is an outcome of a study supported by the Royal Norwegian Embassy in India under Phase 2 of the Norwegian Framework Agreement with The Energy and Resources Institute and the Norwegian Ministry of Foreign Affairs.*

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# ENERGY–FOOD–WATER NEXUS

## An Approachable Solution

Highly subsidized or free power has driven farmers to use energy and groundwater inefficiently, leading to substantial depletion of the groundwater and unprecedented consumption of electricity. In this regard, enhancing water use efficiency has become a prerequisite for uniform distribution of the developmental benefits. Improving access to irrigation services for the farmers is essential for achieving sustained growth in agriculture. This article by **Prajnasish Swain, Apoorva Bamal, Sonia Grover, Niyati Seth**, and **Vidhu Kapur** talks about some of the most viable solutions that can be employed for improving irrigation services so that sustainability in agriculture can be realised.

To achieve food security and make agriculture the primary source of livelihood for approximately 58% of India's population, accessible and affordable for farmers, state governments have been providing various subsidies in various domains such as credit, power, water, and seeds, among others. Over a period of time, these interventions without relevant checks and balances have resulted in adverse impacts like soil degradation, groundwater depletion, and rising fiscal burden on governments. Further, free or highly subsidised electricity tariffs caused a rapid increase in the use of electrified pump-sets and a resultant proportionate surge in electricity consumption by agriculture consumers, leading to over extraction of groundwater. The surge in electricity consumption by agriculture consumers also leads to a rise in subsidy payments from state to distribution company (DISCOM). In addition to these, the guaranteed procurement of specific crops and minimum support price (MSP) has coincidently led to a shift from traditional to water-intensive crops such as paddy in many states.

## Nexus Reflection of the Problem

Agriculture contributed nearly 20.19% to the Indian GDP[1] in 2020–21, and with its allied sectors, it is a significant source of livelihood for about 70% of rural households.[2] During the Green Revolution in the 1960s, the state of Punjab was encouraged to increase the area under agriculture, especially in paddy and wheat cultivation, to meet the urgent food demands of the country. Since then, a large percentage of farmers in India have shifted to paddy and wheat cultivation due to assured procurement and the MSP with minimum or no risk involved. The MSP with guaranteed procurement had also proved to be of benefit to the farmers and the associated economy. However, in the current scenario wherein despite the surplus stock, the area under crop cultivation is increasing, and these crops being water intensive, have 30%–35% more water requirement than other crops. This has subsequently led to the overutilization of water resources in the already existing water scarcity situations.

Policies of subsidised, often free power to agriculture soon deteriorated into unmetered power, eroding the power sector's capacity and systems for efficient, accountable, and financially viable operations. As per the 15th Finance Commission report on agricultural subsidies, the total agricultural subsidies in FY 2017–18 was approximately INR235,500 crore (Ramaswami 2019).

## Electricity Consumption in the Agriculture Sector

In 2019–20 (P), electricity consumption in India was nearly 12.91 lakh GWh (gigawatt hour), 17.7% of which was consumed in the agriculture sector (MoSPI 2021). In terms of sector-wise consumption, agriculture sector is the third-largest consumer after the industrial and the domestic sectors. India's agricultural electricity consumption had increased from 125 GWh in 1947 to 2.28 lakh in 2019–20.[3] Energy consumption in the agriculture sector boomed with the commencement of the Green Revolution in India in 1968 and increased at 8.73% CAGR (compound annual growth rate) till 2019–20 (Figure 1).

Energy consumption in agriculture is mainly used for pumping groundwater for irrigation purposes. While 85% of the requisite energy comes from electricity, the rest comes from diesel generators. Moreover, the increase in tube-well irrigation in agriculture also corresponds to the rise in power consumption.[4]

Most states in peninsular India have extended electricity supply to agriculture pump-sets for irrigation. This electricity supply to these tube wells is either highly subsidised or free and, in most cases, unmetered. The unmetered power supply resulted in non-

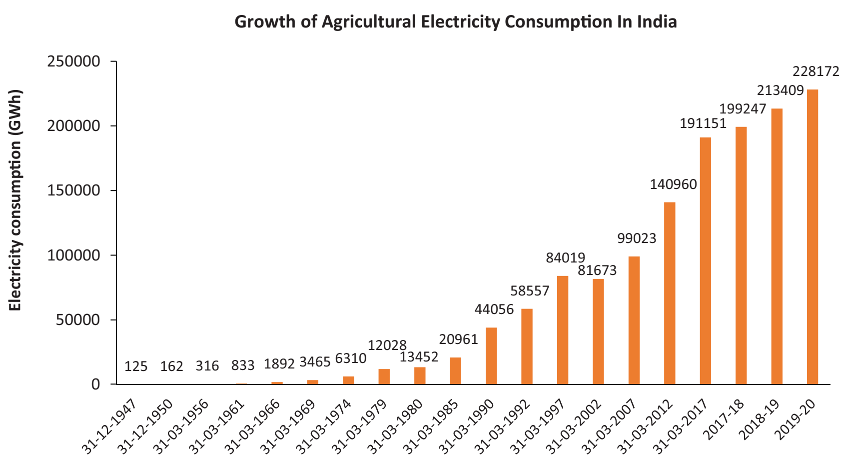


**Figure 1:** Electricity consumption in agriculture in India

*Source: Growth of Electricity Sector in India 1947–2020, Ministry of Power*

[1] Details available at <https://mospi.gov.in/documents/213904/416359//Press%20Note_31-05-2021_m1622547951213.pdf/7140019f-69b7-974b-2d2d-7630c3b0768d>

[2] Details available at <http://www.fao.org/india/fao-in-india/india-at-a-glance/en/>

[3] Details available at <https://cea.nic.in/wp-content/uploads/pdm/2020/12/growth_2020.pdf>

[4] Details available at <https://mpp.nls.ac.in/blog/probing-power-subsidies-in-agriculture/>

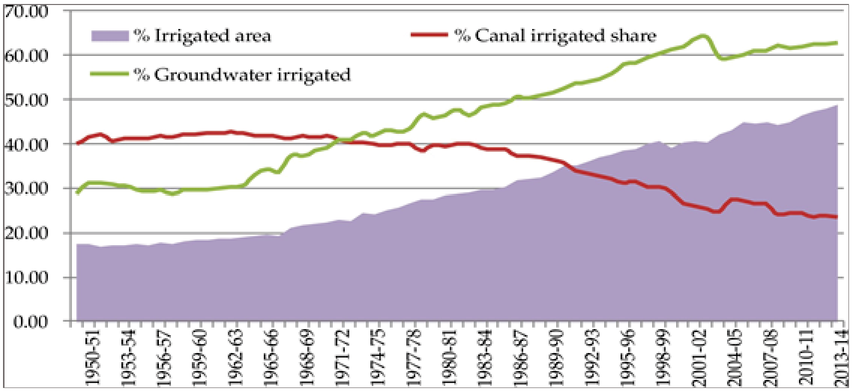


**Figure 2:** Percentage area under irrigation

*Source: Irrigation trends since 1950–51 (data from DES, 2017–18)*

reflection of true levels of consumption and considerable electricity going unaccounted.

## Power Subsidy: a boon or bane

Electricity subsidies are the single largest drain on state spending in India[5] and, as such, are widely discussed in policy circles.[6] As per the 15th Finance Commission's report, power subsidy was accounted for INR90,000 crore in 2015–16.[7] Anecdotal evidence has linked India's growth in groundwater irrigation, largely fuelled by electricity subsidies, to increased agricultural yields and low food prices.[8] However, it has also been argued that these subsidies have substantial environmental costs, including groundwater overexploitation.[9] While currently, the agricultural practices in India are mainly driven by MSP, and guaranteed procurement of crops, free/highly subsidised power supply also plays the role of catalyst.

5 Details available at <https://economics.ucdavis.edu/events/papers/Jessoe51.pdf>
6 Badiani, Jessoe, and Plant. 2012. An overview of agricultural electricity subsidies in India
7 Details available at <https://fincomindia.nic.in/writereaddata/html_en_files/fincom15/StudyReports/Agricultural%20subsidies.pdf>
8 Details available at <https://economics.ucdavis.edu/events/papers/Jessoe51.pdf>
9 Details available at <https://economics.ucdavis.edu/events/papers/Jessoe51.pdf>

In reality, highly subsidised or free power has driven farmers to use energy and groundwater inefficiently. This leads to a vicious cycle of over extraction of groundwater, a consequent increase in irrigation pump-set capacity (as the water levels go down) and increased electricity consumption. Groundwater overexploitation has reached a crisis level in many Indian states, amongst which Andhra Pradesh, Gujarat, Haryana, Karnataka, Punjab, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu together account for 85% of India's groundwater blocks that are in critical condition. Incidentally, these states also account for the largest power subsidy volumes. If current trends of declining groundwater tables continue, 60% of all aquifers in India will reach critical condition by 2025.[10]

## Impact of Power Subsidies on Distributing Companies

Power subsidies have an adverse impact on the finances of the utilities. As the pricing is not cost-reflective of electricity generation, the DISCOMs suffer from financial viabilities for their operations. As a result, DISCOMs pay the least attention to the agriculture sector and hence do not invest in the electricity network capacity improvement. Further, in most Indian states, the agriculture power supply is unreliable and is often provided during the night. Owing to this, most farmers install autostarters, which automatically start the pump-sets on electricity availability, leading to wastage of both water and electricity. Further, the concerns of DISCOMs associated with issues of energy efficiency, aggregate, technical, and commercial (AT&C) losses, unreliable supply, and supply of poor-quality electricity to agriculture are also crucial elements to consider for overall enhancement in the desired outcome on the power subsidies.

10 Pahuja, S. 2010. *Deep Wells and Prudence: towards pragmatic action for addressing groundwater exploitation in India*. World Bank

## Need for Solutions

Various independent unsuccessful attempts have been made, such as increasing tariffs, metered connections or financial bailout packages for DISCOMs. This is mainly due to passing over the nexus vision of the problem and visualising 'energy, water, and agriculture' in isolation. Therefore, to have a large-scale and long-lasting solution, it is essential to consider the nexus vision of the problem and look for integrated solutions. Further, to develop new solutions, it is also crucial to analyse the rationality and reasons for the unsuccessful implementation attempts in the past.

## Barriers in Implementing Corrective Actions

Electricity is placed in the Concurrent List in the Indian constitution, and the regulation is distributed between both the Centre and the states for operational convenience. While the Centre manages power generation, electricity distribution is operated at the state levels, and the State Electricity Regulatory Commissions are the nodal agencies for deciding the electricity tariff. Though tariffs must reflect the cost of serving electricity, they are considerably prompted by the agendas

and priorities of the state governments due to the rising populism.

**Unreliable power supply:** For better demand-side management, DISCOMs have been providing power supply for agriculture during the off-peak hours, mostly during night-time. Daytime power supply has been a long-standing demand of farmers.

**Unsuccessful metering:** A very relevant requirement is the metering of agricultural connections. It is well anticipated that farmers in states with free agricultural electricity are apprehensive towards metering due to fear of billing in the future. However, in the current scenario, all the stakeholders must understand that the purpose of metering is not limited to billing but in reflecting the actual network losses and their condition so that network expansion is planned. Also, metering will help in better demand-side management of agricultural power supply by DISCOMs. Moreover, due to human resources shortage, the manual meter reading is not feasible for DISCOMs.

## Potential Solutions

**Smart metering**: Upon analysis of the barriers, smart meters/AMI, which can be managed without deploying human resources, can be a potential solution. Smart Meter National Programme by EESL (Energy Efficiency Services Limited), an Energy Services Company (ESCO) of the Government of India, is being implemented under the BOOT model on cost–plus approach where no initial investment is made from Utilities. However, to implement these for agricultural consumers in free power supply states, extensive communication and outreach to address the apprehensions of farmers is a prerequisite.

**Feeder separation:** Over the last decade, separation of feeders for different consumers like domestic, commercial, and agriculture have proven to be better solutions for demand management and resulted in increased power supply. Under the Deen Dayal Upadhya Gram Jyoti Yojana (DDUGJY) project, Central Government has been implementing feeder separation projects all over the country. As per the impact evaluation, feeder separation has reduced the hours of supply and reportedly improved the quality of power supply.

**Solar irrigation:** Due to the reduction in the price of solar equipment and installation, solar Irrigation has emerged as a viable solution. It has the potential to solve many problems associated with both farmers and DISCOMs. The most significant benefit is the power supply during the daytime. Also, DISCOMs can clear the pending agricultural connection without any network expansion or improvement. Further, if connected to the grid, it will help improve power quality while ensuring a secondary source of income for farmers. Several pilot projects have been implemented in various states in the last decade. Considering the learnings from all those programmes, the Central government had launched PMKUSUM (Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan) in March 2019. The scheme plans to set up 30.8 GW of solar capacity by 31 December 2022, through the financial assistance of INR340.35 billion (USD 4.65 billion).

**Technological interventions:** The current age is termed the digital age, as an outcome of unprecedented technological developments. The growth of AI (Artificial Intelligence) and IOT (Internet of Things) technologies have shown the potential and benefit of resource efficiency. Therefore, using Internet of Things (IOT) devices and leveraging mobile app-based pump switching devices will play a responsible role in increasing water and electricity use efficiency.

**Efficient water-saving interventions:** By adopting a simple on-farm package of practices, significant water could be saved in agriculture. Interventions such as efficient agronomic practices, including alternate wetting and drying (AWD), plotting, laser levelling, and underground pipeline system, can improve the water use efficiency in the agriculture sector. Besides these, micro irrigation could be effectively utilised for enhancing water use efficiency in the agriculture sector. The Government of India has been endorsing these technologies through National Mission on Micro-irrigation, which is presently subsumed under Pradhan Mantri Krishi Sinchayee Yojana (PMKSY). It also intends to expand irrigation coverage and improve water use efficiency in a focused manner with end-to-end solutions on source creation, distribution, management, field application, and extension activities.

The potential water saving by these systems is in the range of 40%–70%. Reduced water consumption also reduces the load on electricity for

operating the pump sets. The National Mission on Micro-irrigation study highlighted that drip irrigation increases productivity by 42%–53% in fruit and vegetable crops; it reduces irrigation cost by 20%–50%; lowers electricity consumption by around 30% and fertiliser consumption by about 28%.

## *Paani Bachao Paisa Kamao* Scheme in Punjab: nexus approach, an experience by doing pilot

Over the years, free agricultural electricity in Punjab has also led to unchecked use of pumps and inefficient use of water in the state. Past research has shown an undersupply of 12.7 billion cubic metres of water for agriculture in Punjab. Consequently, even as the groundwater tables decline, free electricity for agriculture results in an increase in pump-set capacity to draw water from greater depths, creating a cyclic situation. Moreover, as per the Central Ground Water Board, the categorisation of 105 administrative blocks in the overexploitation of groundwater category in Punjab is evident of more water consumption than that of potential supply and increasing groundwater depletion. Therefore, it is indicative that there is a need for newer and advanced strategies to control this exploitation of water resources as it has resulted in a crisis where despite agriculture production being plateaued (Punjab contributes 12% to the country's total paddy production), the state is reeling under huge economic and water depletion pressure due to free electricity supply to agriculture.

An innovative approach was the need of the hour to address this electricity–water–agriculture nexus problem in Punjab that has long confined the farmers, power utilities, consumers, and governments. Therefore, based on the research conducted by SE4ALL and the World Bank in 2010 on Direct Delivery of Power Subsidy to Agriculture in India, the Government of Punjab in 2018 launched the *Paani Bachao, Paisa Kamao* (PBPK) scheme [Direct Benefit Transfer for Electricity (DBTE) to agriculture] on a pilot basis on six feeders in three districts—Fatehgarh Sahib, Hoshiarpur, and Jalandhar.

The scheme in the state offers a choice to the farmers to increase their income while using groundwater and electricity more efficiently. The scheme design considers two prerequisites—the current policy of free power to agriculture cannot be discontinued, and crop diversification will not occur in the near future. The conceptual framework of the PBPK scheme was developed in 2012–13 with the support of the World Bank.[11] The design was based on consultations with multiple stakeholders, recommendations from fieldwork with farmers, a review of global experiences, and a critical analysis of multi-sectoral data and policies. It is aimed to develop a strategy that addresses the electricity–water–agriculture cross-sectoral issues and meets the requirements of agriculture and farmers.

The PBPK is a voluntary scheme that does not change the present policy of free electricity supply to agriculture pump (AP) consumers in Punjab. Instead, it has a provision to pay farmers for saving electricity with no charge for the excess consumption. Broadly, the scheme has three steps: enrolment (voluntary), automated meter reading (AMR) meter installation, and direct incentive transfer. The AP consumers are given a fixed electricity allocation every month (kilowatt hour (kWh)/brake horsepower (BHP)/month) linked to their sanctioned loads. This fixed allocation was calculated for each scheme feeder by Punjab State Power Corporation Limited (PSPCL) based on average electricity consumption (last 5 years) in the feeder. The allocation is different for Rabi and Kharif seasons as electricity consumption is higher for paddy cultivation in Kharif season than wheat in Rabi season. A smart meter that can be read remotely (through a SIM card) is installed on the AP connection enrolled

[11] Gulati, M. and Pahuja, S. 2015. Direct Delivery of Power Subsidy to Manage Energy–Groundwater–Agriculture Nexus. Aquatic Procedia, 5 (September 2014), 22–30

in the scheme, while no metering is done for non-PBPK consumers. If the electricity consumption is less than the allocation, the units of electricity saved are paid at the rate of INR4.00 per kWh, and the amount is transferred into the bank account of the respective enrolled AP consumer. Neither the consumption above the fixed allocation is charged, nor are any electricity bills issued to the enrolled AP consumers. The enrolled AP consumers receive one-time information from PSPCL through an SMS about their enrolment status, and periodic SMS updates are also provided about their electricity consumption with respect to their allocation.

Though the PBPK scheme was offered to AP consumers in the state, its implementation faced certain challenges at the initial stages. These were majorly due to a lack of consumers' knowledge or understanding of the scheme's benefits and processes, procedural delays related to the scheme's design, and lack of motivation amongst consumers to adopt new technologies and practices. In addition to these, while the agricultural consumers were apprehensive that enrolling under the scheme would expose them to the danger of being billed in future, they also feared that someone might fraudulently withdraw money from their accounts on the pretext of taking account details for enrolment under the DBTE scheme. To overcome these barriers, effective engagement with the community had played a significant role.

## Community Engagement in *Paani Bachao, Paisa Kamao* Scheme

Implementation of PBPK scheme, Phase-I showed that monetary incentive might not be sufficient to mitigate the nexus challenge. It requires extensive on-field engagement with farmers and other stakeholders for smooth implementation of the scheme. The subsequent section discusses key learnings attained in due course of implementation.

**Need for inter-departmental convergence**: Though monetary gains can incentivise farmers to join the scheme, it is insufficient to achieve the scheme objective. To save groundwater, farmers will either need to shift their cropping patterns or find alternate and efficient irrigation methods. But farmers lack overall awareness, skills, and support for adopting water and energy-efficient farming methods. DISCOM in Punjab is the flagbearer of the scheme; however, the objective requires inter-departmental coordination and on-ground convergence of the department of agriculture and water resources.

**Communicating effectively:** The PBPK implementation in the three feeders illustrated that carefully designed communication with primary stakeholders can clear out apprehension and help build support and acceptance. It can also increase trust and understanding of the political decisions that underpin the scheme. Experience shows that communicating before and during a scheme rollout is necessary for its smooth implementation.

**Establishing two-way communication**: Bridging the widening information gap between the government, DISCOM, and farmers required building a two-way communication channel. Foremost in this regard was conducting one-on-one farmer visits, with a primary mandate of mobilising farmers' enrolment and supporting scheme implementation. With the growing number of visits, the feeder representatives were successful in garnering the farmers' trust for the scheme.

**Communication messaging*:*** Messages around the scheme were carefully crafted and delivered through an interpersonal, group, or print medium. The communication intentionally highlighted the objective of the scheme— 'saving groundwater'—a challenge well understood by the farmers, while addressing stakeholders' commonly held doubts around metering and building awareness of the subsidy's scope.

**Farmer-to-farmer persuasion:** The enrolled farmers, who had benefited from the scheme, soon became the flagbearer of the scheme within their village, encouraging their peers to join. Peer influence was amongst the most effective strategies in mobilising farmer enrolment.

**Demonstration farms**: To bridge the knowledge gap regarding energy and water-saving practices, 15 demonstration farms, five at each feeder, were set up on farmers' fields with their consent. Supported by the inter-departmental schemes, farmers on a farm section experimented with new seed variety and irrigation techniques to minimise water losses during paddy and wheat cultivation. These plots soon became farmer field schools for other farmers popularising the adoption of the water- and energy-efficient technology.

## Reduction in Water Withdrawal and Efficient Agronomic Practices in *Paani Bachao, Paisa Kamao* Scheme

In the 15 demo farms, efficient water and agricultural practices were demonstrated. Some of these activities were common for the crops and some were specific for the seasonal crops (presented in Table 1.1).

Apart from these interventions, the state of Punjab offers up to 80% subsidy for MIS and approximately 50% for UGPS. Appropriate instrumentation and methodology for monitoring was undertaken to estimate the water withdrawals for the demo and the control farm. This analysis helped establish the amount of reduction in water withdrawal in demo farms due to the adopted efficient water and agricultural practices. By adopting these interventions, significant water savings were achieved in both Kharif and Rabi seasons. Further, the reduction in water withdrawal also led to increased total water productivity, that is, farmers were able to produce more yield per unit (kL) of water in the demo farm than in the control farm in both seasons.

The agronomic practices adopted in demo farms proved to be feasible for the farmers in terms of ease of application as well as cost-effectiveness. Apart from

**Table 1:** Efficient water and agricultural practices

| Common agricultural practices | Paddy specific practices in Kharif season | Wheat specific practices in Rabi season |
|---|---|---|
| Laser levelling | Short and medium duration paddy varieties (potential water saving: 10%–15%[12]) | Rust-resistant variety and happy seeder (potential water saving: 30%[13]) |
| Optimum pipe height and bend | Alternate wetting and drying (AWD) (potential water saving: 10%[14]) | |
| Mobile-based app for remote operation of the pumps | Plotting (potential water saving: 5%) | |

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[14] Daniela R. Carrijo, Nadeem Akbar, André F.B. Reis, Chongyang Li, Amélie C.M. Gaudin, Sanjai J. Parikh, Peter G. Green, and Bruce A. Linquist. 2018. Impacts of variable soil drying in alternate wetting and drying rice systems on yields, grain arsenic concentration and soil moisture dynamics, Field Crops Research 222: 101–10. ISSN 0378-4290. DOI: https://doi.org/10.1016/j.fcr.2018.02.026

showcasing a significant reduction in water withdrawal for their cultivation, it also resolved farmers' worry about yield penalty and farm economics, which led to their opinion into adopting efficient interventions for upcoming cropping seasons.

In sum, more extensive-scale adoption of the aforementioned efficient resource conservation technologies and practices will lead to evidently significant outcomes. Factors such as ease of applicability and cost-effectiveness of these interventions also support their feasible adoptability by the farmers. In addition to these, individual and community-level activities such as pond rejuvenation, rainwater harvesting, re-utilising abandoned wells, etc., will further aid in water conservation. This, in turn, will positively impact the prolonged problem of groundwater depletion in the area. Moreover, when carried on for the long term, these interventions will improve the groundwater development stage in Punjab and help achieve the ultimate goal of the scheme, that is, water-saving in Punjab's agriculture domain.

## Need of the Hour

The nexus situation in India highlights the interconnectedness of water and electricity in agriculture, and challenges thereof can be addressed only if the departments work in tandem. Additionally, the PBPK case study shows the importance of community engagement and ownership in achieving resource management schemes/policies objectives. Therefore, the schemes should include inbuilt aspects that strengthen community governance.

Improving access to irrigation services for farmers is essential for sustained growth in agriculture. Enhancing water use efficiency is a prerequisite for the equitable and just distribution of the developmental benefits. While the solar pumps are being promoted extensively under the ambitious PMKUSUM Scheme, incorporating features such as promotion of micro irrigation along with solar pumps is necessary to ensure that 'no one is left behind'. EF

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# ENERGY TRANSITIONS

## Current Trends and Future Directions

Human-induced climate change activities have reached to the point of such climate emergency and no one—be it developed or developing—poor or rich will be immune to it. The negative impacts of this can be easily noticed nowadays from changing weather patterns to extreme heat or cold becoming much more common than previous decades. These impacts would eventually be much more severe unless necessary, rectifying steps are not taken. This article by **Mohit Acharya** and **Sarvesh Devraj** discusses how India can formulate a long-term vision plan to reduce its reliance on fossil fuels, at the same time, increasing the share of renewables in its energy mix.

According to Intergovernmental Panel on Climate Change (IPCC) report, *Climate Change: the physical science basis*, released in August 2021, average rise in the global temperature could reach or exceed the 1.5°C target by 2040 and it could climb to 2.4°C by mid-century in a business-as-usual scenario.[1] Things will be much more alarming for developing countries like India. Glacial retreat in the Hindu Kush Himalayas and its effect on sea-level rising, flooding due to intense tropical cyclones, an erratic monsoon, and extreme heat stress are some of the few most likely effects that will be faced by the countries around the globe. Many of these impacts will be irreversible as highlighted by the IPCC report. Energy will be a crucial element in the battle against climate change and will play a major role in keeping the global average temperature in the range of 1.5–2°C by curbing the $CO_2$ emissions. In fact, in terms of overall total greenhouse gas (GHG) emissions energy contribution is about 73%, reaching 33 billion tonnes in 2021, increasing further in the business-as-usual scenario.[2] The prime contributor to this increase is the rapid economic growth, leading to high-energy demand and an increasing share of coal in the global energy mix. In order to curb down the emissions at lower level, a fundamental transformation in the energy sector as a whole is required. There do exist many solutions which can be tapped into to reduce the sector's emissions. A few of them are fossil fuel switching, increasing renewable energy (RE)-based generation, storage [pumped hydro, battery, carbon capture and storage (CCS)], green hydrogen, improving energy efficiency, etc. The energy transition is already underway globally; as many of these solutions are now being implemented, for example, massive growth of RE capacity addition in the past decade has suppressed the growth of fossil fuel-based capacity additions. As per the recent report by the International Energy Agency (IEA), about 270 GW capacity will be becoming operational by the end of the year 2021, reaching 280 GW mark by 2022.[3]

With RE capacity surpassing 100 GW mark[4] (solar: 44.9 GW and wind: 39.8 GW) from 13 GW (solar: 0.2 GW, wind:12.7 GW) in 2010 (increasing by more than 7 times in the past one decade), India has done a commendable job in increase the share of RE in its electricity mix. In fact, country stands at the fourth place in the world in terms of installed RE capacity The country also has made remarkable progress in achieving 100% electrification target, with more than 100 million people gaining connection in 2018 alone.[5] The demand for electricity had also increased, growing at 6.9 % compound annual growth rate (CAGR).[6] This was made possible with the Government of India's aggressive target setting and support in forming conducive policy and regulatory frameworks. This can further be noted from the GoI's headlining announcements[7] of the following five commitments in the recent COP 26 Summit in Glasgow:

1. Increasing the non-fossil fuel-based energy capacity of the country to 500 GW by 2030.
2. Aiming to meet 50% of its energy requirements from RE sources by 2030.
3. Reduction in the total projected carbon emission by one billion tonnes between now and the year 2030.
4. Reducing the carbon intensity of the economy to less than 45% by 2030.
5. Becoming carbon neutral and achieving net zero emissions by the year 2070.

At present, the country is majorly dependent on conventional resources for meeting its energy demands, making it third-largest country, with reference to carbon emissions, yet the country's per capita consumption of electricity is still around one-third of the world average. This would increase as the country's economy improves, despite GoI's efforts in bringing energy efficiency and plugging the leakages to reduce the overall energy intensity. The following challenges are in front of India:–

» Expanding energy access while maintaining the affordability for consumers and financial stability for the DISCOMs
» Integrating increasing shares of RE while maintaining the system resiliency
» Reducing emissions to achieve social and climate objectives while meeting economic goals.

The commitments made in COP 26 at Glasgow will further increase the complexity of the above challenges, thus needing immediate attention in filling up the gaps to accelerate the technology deployment. In the regard, the following directions could be taken forward:

**1. Developing regulatory framework for energy storage (pumped hydro and batteries) for catering the RE curtailment and system safety**

Achieving the 2030 target would leave with a high share of variable RE in the overall energy mix. This will need system flexibility to cater to the variability. Presently, RE's share in the overall electricity mix is about 9%–10%[8] which will increase in the near future. However, looking at the state-level share is as

[1] Details available at <https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Full_Report.pdf>

[2] Details available at <https://www.iea.org/news/global-carbon-dioxide-emissions-are-set-for-their-second-biggest-increase-in-history>

[3] Details available at <https://www.iea.org/reports/renewable-energy-market-update-2021>

[4] Details available at <https://mnre.gov.in/the-ministry/physical-progress?>

[5] Details available at <https://saubhagya.gov.in/>

[6] Details available at <https://www.brookings.edu/wp-content/uploads/2018/10/The-future-of-Indian-electricity-demand.pdf>

[7] Details available at <https://www.bbc.com/news/world-asia-india-59125143>

[8] Details available at <https://www.iea.org/reports/renewables-integration-in-india>


high particularly in RE-rich states like Karnataka (29%). At present, none of the states have a supporting regulatory framework for energy storage. Therefore, states should come up with a conducive policy with long-term plan (at least 5 years) which can help in creating a favourable regulatory framework for energy storage.

**2. Need of supportive power market which gives equal weightage to all the sources and visibility**

At the moment majority of transaction in the country is done through long-term power purchase agreements (PPAs) and only about 6% of the transactions are done through power exchange. These need to change and would require a lot of attention and need immediate market correction. The recent release of a framework for implementing the Market-Based Economic Dispatch (MBED), Phase I by the Ministry of Power (MoP) is a welcome move and will play a vital role in reforming the way the electricity market operates in the country. However, it would need a lot of deliberations as many states lack the capability and technical strength to participate in such a way.

**3. Segregating agriculture feeders for balancing the power systems and decreasing the curtailment levels**

Separation of electricity feeders by shifting agriculture load to day time to utilize solar energy can play a vital role in balancing the grid as well as reducing the curtailment. States such as Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Punjab, and Andhra Pradesh have already 100% dedicated feeders; however, more work is needed in the states like Rajasthan and others. Achieving targets of KUSUM scheme will further enhance the benefit.

**4. Increasing the interstate transmission connectivity to flow the power between the states**

Meeting the 2030 goal would need to increase connectivity within and between the states. Unlike RE projects transmission capacity takes longer time to come online, which makes it critical. At present majority of installations of solar and wind came in the 10 states, famously known as the 'RE-Rich' states. The share of RE in the annual electricity mix in these states are already well above the national average of 8%. States like Karnataka with the highest share of about 29% (fourth highest globally), Rajasthan – 20%, Tamil Nadu – 18%, and Gujarat – 14% have already started seeing the pinch of high VRE in the overall electricity mix leading to system integration challenges. GoI's plan to meet 50% of the country's energy requirement from RE sources by 2030 would further make things more complex for the utility operator to evacuate the power at the time of high solar and wind generation. Therefore, better transmission connectivity between the regions of high RE generation to the regions of low/none RE generation would help not only in reducing the challenges in system integration but also provide flexibility to the overall system.

**5. In order to reach the target of 2030, the country would need to look beyond the traditional ground-mounted solar PV and wind-based projects; floating solar PV could be one of such alternative**

TERI published a report which estimated a potential of about 280 GW that could be accrued from this technology.[9] Among many advantages of this technology, the possibility of integration with already existing hydro capacity and utilization of existing power infrastructure could be much more beneficial to the country like India. Recent auctions and price discovered indicate a level of confidence shown to this technology. However, it is still in its nascent stage and there are many things like long-term performance, etc. that are not known fully. Also, there is a lot of uncertainty regarding the various clearances among the stakeholder. Hence to reach the benefit of this technology GoI must come up with a set of guidelines for developing such projects.

**6. Transition from coal economy to clean economy**

With 202 GW[10] of install capacity, coal is still a dominant player in country's energy

[9] Details available at <https://www.teriin.org/sites/default/files/2020-01/floating-solar-PV-report.pdf>

[10] Details available at <https://cea.nic.in/wp-content/uploads/installed/2021/10/installed_capacity.pdf>

share. Moreover, projects worth 39 GW are under construction and another 25 GW in various stages of approval. The demand of coal has also doubled in the past decade and will continue to rise in the business-as-usual scenario. The country is also planning new sites for coal explorations to meet this rise in demand. This dependence on coal needs to change drastically within 10 to 15 years, if India wants to even attempt towards achieving net-zero target by 2070. However, the issue is not as simple as it looks like, and there are many facets which need to tackle. Over the past decades, coal sector has position itself centrally and even contribute significantly in the overall revenue of central and state governments as they rely heavily on energy sector for taxation revenues. Transitioning away from coal would be more challenging to coal-bearing states like Chhattisgarh, Odisha, Jharkhand, Bengal, Madhya Pradesh, and Uttar Pradesh, as in these states, for example, in Chhattisgarh and Jharkhand close to 15% revenue comes directly or indirectly from the coal-mining sector. In addition to this, these states would also lose out on employment of the large workforce associated with sector either directly or indirectly. Therefore, a long-term vision plan addressing such challenges must be developed by the policy makers and regulators.

**7. Green hydrogen could be vital in the decarbonizing transport, agriculture, and industrial sector**

India has set a target of deduction of 1 billion tonnes carbon emission by 2030, green hydrogen is going be instrumental in achieving this.[11] India is developing its own National Green Hydrogen Energy Mission to scale-up annual green hydrogen production by 1 million tonnes by 2030 to decarbonize sectors such as transport, agriculture,

and steel industry.[12] However, there are several challenges related to developing infrastructures and supply chain management, etc. in bringing down the cost of electrolyzers. As per India Hydrogen Alliance estimation, the country needs $15 billion funding for setting up 15 GW green hydrogen electrolyzer capacity by 2030.[13] This capacity can produce 3 million metric tonnes (MMT) of green hydrogen and for this, 30 GW of RE would be required. Therefore, to leverage the opportunity of green hydrogen utilization in the mentioned sectors there is an urgent need for developing a hydrogen value chain-based economy and extensive research and development to scale-up hydrogen production.

## Conclusion

Recent IPCC report clearly highlights that human-induced climate change activities have reached to the point of such climate emergency and no one, be it developed or developing, poor or rich will be immune to it. The negative impacts of this can be easily be noticed nowadays from changing weather patterns to extreme heat or cold becoming much more common than previous decades. These impacts would eventually be much more severe if necessary, rectifying steps are not taken. Recent COP 26 at Glasgow was an attempt to bring in all the stakeholders to reach an agreement on how to tackle climate change while keeping global temperature rise below 1.5 °C level. The Summit has ended with a climate agreement knows as The Glasgow Climate Pact.[14] The Pact was a clear recognition towards the role of energy in climate change and urgent need to transition away from fossil fuels, especially coal.

India has done a commendable job in increasing the RE-based capacity in its energy mix in the past decade, guided by GoI's aggressive push for RE and favourable policy. Announcements made in COP 26 are yet another example of GoI's willingness and support in transitioning towards clean energy. However, India still relies heavily on coal and will need support from the developed countries for financial assistance to achieve its targets. Additionally, country must formulate a long-term vision plan focusing more on implantation. EF

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[11] Details available at <https://indianexpress.com/article/explained/climate-change-carbon-emissions-cut-narendra-modi-7603315/>

[12] Details available at <https://swarajyamag.com/news-brief/india-to-target-one-million-tonnes-green-hydrogen-production-per-annum-by-2030>

[13] Details available at <https://energy.economictimes.indiatimes.com/news/renewable/india-needs-15-bn-funding-to-set-up-15-gw-green-hydrogen-electrolyser-capacity-by-2030/87577407>

[14] Details available at <https://unfccc.int/sites/default/files/resource/cma2021_L16_adv.pdf>

# FOSTERING DER INTEGRATION IN DISTRIBUTION GRID

## Challenges and Measures

Distributive energy resources (DER) have revolutionized the operation of the power system. Therefore, it is the need of the hour to implement measures at device and system levels to boost integration and promote the adoption of DER. In this article, **Aravindakshan Ramanan**, not only discusses DER but also answers why is it important to have effective mitigation strategies so that large quantities of DER could be integrated with the power system.

The Prime Minister of India, Shri Narendra Modi presented a five-point agenda—Panchamrit—in COP 26 climate conference in Glasgow, Scotland. Under this framework, it is expected that by the year 2030, the non-fossil fuel-based energy capacity of the country would increase to 500 GW (gigawatt), 50% of the country's energy requirements would be met by renewable energy sources, the total projected carbon emission would be reduced by one billion tonnes. Consequently, the carbon intensity of the economy would be reduced to less than 45% and net-zero emissions are to be achieved until 2070.

The distributed energy sources (e.g., solar PV rooftop and EVs) are expected to play a key role in this energy transition, contributing to the agenda set out by Panchamrit. The Government of India has been promoting the adoption of distributive energy resources (DER) through various policies. Around 20 states have come out with either draft/finalized EV policies.[1] Provision is there towards centralized financial assistance for the installation of rooftop PV solar for residential consumers. KUSUM scheme encourages the installation of rooftop PVs together with agricultural lands.

The Solar Atlas developed by the National Institute of Wind Energy (NIWE) based on historical measurements of radiation data from the network of Solar Radiation Resource Assessment stations and satellite-derived values indicate a considerable pan-India availability of Global Horizontal Irradiance. Therefore, this augurs well for good power generation from solar rooftop PV plants across India.

Installation of large quantities of DER is expected to pose great challenges to the operation of the power system. Hence, it is important to have effective mitigation strategies so that large quantities of DER could be integrated with the power system.

## Technical Challenges for DER Integration

Solar PV rooftop power plants have a lot of inherent variability associated with them. The solar resource variability occurs mainly due to continuous change in position of the location with respect to the sun, occurrence of clouds, and change in the composition of atmospheric constituents in that location. When the quantum of solar PV rooftop installation increases, large variability in power generation could lead to a lot of challenges in the operation of the power system.

The electric mobility fleets and rooftop solar PV plants are not generally visible to the distribution grid operator in India. At present, the penetration levels are so low and hence these are not posing major challenges. However, in the future when the penetration levels would sufficiently increase, it would be important for the distribution grid operator to have visibility of the same. The variable nature of power demand from EVs and supply of solar rooftop PVs, if not handled efficiently, could lead to interruptions in power supply, affecting the system reliability indices (SAIFI, SAIDI, and CAIDI). The distribution network has a higher R/X ratio compared to the transmission grid. Hence, higher power supplied by the solar PV rooftop or higher power drawn by the EV load could severely affect the voltage levels of the distribution grid.

When the power supplied by solar PV exceeds the power absorbed by the loads, there is a possibility of reverse power flow from low-voltage grid to high-voltage grid. This is a huge challenge to the traditional operations of the power system. Therefore, a conventional protection system may fail with the occurrence of this phenomenon leading to tripping. Both EV chargers and solar PV power plants have power electronic components, which are non-linear devices and would introduce harmonic distortions to the power system.

The solar rooftop PV could introduce significant changes to the load curve of the utilities. In systems with high RE penetration, it was observed that there was an imbalance between the occurrence of peak load and distributed generation. This resulted in a different shape of load curve, which was termed as 'Duck Curve'. Therefore, power generation which is to be arranged by the utilities should match this load curve.

## Measures for Fostering DER Integration

Demand response measures are one of the effective means to combat the variability encountered on account of DER. For EV users there is time of use (ToU) and dynamic pricing strategies. Under ToU tariffs, for EV users' participation, different price slabs are provided for various time slots in a day by DISCOMs. In this way, it is expected, EV users are benefitted from cheaper tariffs and DISCOMs are benefitted by levelling the load curve. Dynamic pricing is a method by which the different units respond to real-time price signals from distribution utilities. This requires features of bidirectional communication between the loads and the distribution grid operator.

The 'State Estimation' technique would help a great deal to improve the observability of DER to the grid operators in the distribution grid. This would provide the operator information about the voltage and phase angles in the various nodes of the power system. Consequently, active, and reactive power flows in various parts of the network could be estimated.

The technical standards and grid codes should be upgraded so that the power system's stability could be maintained, considering the DER penetration scenarios in the future. It is also worth mentioning that RE generators are able to mimic the properties of conventional generators,

for example, inertial response so as to support the power system in different operating conditions. The capability of DER to ride through system faults is also pertinent. For instance, ability to ride-through undervoltage and overvoltage events, rate of change of frequency (ROCOF), and voltage phase angle changes in order to support power system stability would be some of the important features of DER, which would greatly help in system operation. The power electronics components in the solar PV rooftop systems would be the key to providing many of the advanced features related to grid support. In addition to well-elaborated grid code requirements for DER technologies, it is also important to establish and apply clear procedures for grid code-compliance assessment based on type tests, DER plant simulations, or DER plant on-site compliance tests and monitoring.

Netload forecasting is a key requirement for distribution utilities to manage the situation for the supply of power in its control area. Very few distribution utilities in India perform forecasting of rooftop solar PV as the penetration levels are quite less. However, all the utilities recognize the fact that once the penetration levels increase, ignoring this requirement could lead to catastrophic effects. Depending on the intended time horizon for forecast, various methods, such as numerical weather prediction (NWP), satellite images, sky imagers could be utilized. Contrary to large-sized solar farms, static data sets related to plant configurations are not known regarding rooftop solar PV power plants. Hence reasonable assumptions are required to be made regarding the characteristics of the solar plants. The irradiance forecast is then combined with the solar PV power plant model to arrive at a power forecast for the region. On the basis of the availability of historical measurement data from the region, the accuracy of the forecasted power output could be improved by using statistical methods.

## Conclusion

DER have revolutionized the operation of the power system. Therefore, it is the need of the hour to implement measures at device and system levels to boost integration and promote the adoption of DER. As seen from experiences throughout the world, provisions for advanced features would play a key role in minimizing the integration costs by reducing the need for retrofitting/upgradation of different equipment in the future.

DER could play a key role in the provision of reliability of supply in case of disconnection of the main grid. Large penetration of DER would go a long way in decarbonization and improving air quality. It feeds into the objectives laid out by the National Clean Air Programme and action and micro-plans set out by various state pollution control boards.

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# ABLEST FAECAL SLUDGE MANAGEMENT

## Challenging a Dormant Opportunity

Faecal sludge (FS) and septage is an assimilation of excreted night soil and black water. Primarily being a human waste, FS constitutes enormous genera of microbes, opportunistic pathogens, and parasitic cysts. The World Bank data revealed it has a potency to cause about a lakh of diarrhoeal diseases every annum in India within the age group of 0–5 years. With the catastrophic consequences, mismanagement of faecal sludge is undoubtedly a hazard to wholesome sanitation. Since all 28 states and 8 union territories of India have been declared open defaecation free (ODF) in October 2019, presently the nation is keen to augment the individual components attributed to the sanitation value chain. Initiating from decanting to scientific management, and final disposal/reuse on each stage noteworthy contributions were recorded either in terms of technical interventions or engaging stakeholders. As per the depository of the Ministry of Housing and Urban Affairs (MoHUA), presently 819 cities in the country are already compliant and certified under ODF+ protocol of which total 312 cities are further accredited with ODF++ tag for ensuring zero discharge of untreated sludge. Hitherto, different ranges of conventional and mechanized treatments have been explored for pertinent handling and management of FS with the primary agenda of eased solid-liquid separation. It is highly difficult to opt for a single mechanism that is ample to cater to all the requisites and economic factors; rather the management of FS is more case specific. The review of several FS management technologies has ultimately aided in developing an affirmative understanding that geotextile-based technologies genuinely have an upper hand within limited capacities, while mechanization is a mandate for large-scale centralized management. Keep reading this article by **Atun Roy Choudhury**, **Neha Singh**, **Namita Banka**, **LK Mahalakshmi**, and **Manoj Mavuduru** to know more…

Faecal sludge management (FSM) is a settlement, where the faecal sludge collection, transport, and treatment from pit latrines, septic tanks or other onsite sanitation systems (OSS) are followed. Faecal sludge (FS) is a mixture of human excreta, water and solid wastes (e.g., toilet paper or other anal cleansing materials, menstrual hygiene materials) that are disposed of in pits, tanks or vaults of the onsite sanitation systems.[1] It is an unpleasant material containing pathogens, generating odours and causing surface water and groundwater pollution as well. Septage/faecal sludge is basically, raw or partially digested slurry or semisolid form of excreta. It is the collection (of excreta, black water, grey water), storage or treatment combinations that constitute FSM. Such FS are generally a few times more concentrated in suspended and dissolved solids when compared to domestic wastewater.[2]

The developing countries are experiencing a runaway urban population growth, with a major chunk living in slums without access to any basic sanitation amenities, only making the problem further rampant, severe, and challenging.[3] Although with rapid population growth due to modernization, the density of rural population also imposes a similar challenge.

Since the most conventionally approached solution for urban sanitation is piped sewerage with centralized wastewater treatment; likewise, many of the engineers, city managers and politicians regard it as the only authorized solution. Networked sewerage system is accessible to mostly the better-off, while the poor people are the ones left to fend for themselves. They improvise on-site systems, which are also shared with other families, which might be illegal under the local by-laws.[3] So, they basically use non-networked sanitation that includes the excreta and wastewater discharged into a septic tank or pit, or directly discharged into the environment. Those with further affordability issues are left to defaecate in the open or into a plastic bag. Once the pits and tanks are filled up, they are often emptied by informal, unhygienic and undignified methods (manual), with the faecal sludge being buried or dumped openly. The result in such cases is chronic outbreaks of cholera and other enteric infections, which affect the whole residence.[4]

Thus, FSM is mostly necessary in the densely populated areas where a segment of the population is not connected to a sewerage network, and where the overlaying and remodelling of the pit latrines is not possible.[2] This primarily prevails in the developing countries, mostly in the urban areas; but the developed countries also use such services, specifically where sewerage systems are unavailable. In Uganda, around 46% of excreta, in Tanzania 57% of excreta, in Kenya 64% and in Indonesia more than 80% of excreta are left untreated.[5] In Sub-Saharan Africa, 65%–100% of access to sanitation in the urban areas is provided through onsite technologies.[6] These services are mostly endowed by the local governments, water authorities, formal and informal service providers in the private sector, etc. However, in many of the developing countries FSM services are often unavailable, or even if they are available, are often informal, unregulated, unhygienic or unsafe; which can lead to the pollution of surface water and groundwater along with spreading of pathogens into the environment, which creates adverse impacts on public health.[2]

## Faecal Sludge Management in India

One of the major challenges in urban sanitation sector is the collection, treatment and disposal or reuse of faecal sludge. Adequate amenities and services for collection, transportation, treatment and disposal of faecal sludge do not exist in most Indian cities and towns. In the absence of such facilities, most of the on-site sanitation systems are emptied manually. As per the Central Public Health and Environmental Engineering Organization (CPHEEO) guidelines, preferably, a septic tank system should be cleaned in every 1.5–3 years.[7] However, ignorance of maintenance and operational conditions usually results in accumulation of organic sludge, reduction in effective volume and hydraulic overloading, which ultimately causes system failure and the release of partially treated or untreated septage from the septic tank.

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Private operators often do not transport and dispose of septage far away from human settlements; instead, they dump it in drains, waterways, open lands, and agricultural fields.[8]

India has witnessed revolutionary changes in its voyage of becoming an open defaecation free (ODF) country since the Swachh Bharat Mission (SBM) materialized, bringing several corporates, NGOs, and government working for the cause of a clean India together. Also, various other such initiatives have come into the forefront to hold the reign of sanitation and make India a safe and healthy country.[9] Swachh Bharat Abhiyan/Swachh Bharat Mission (SBM) or Clean India Mission is a country-wide campaign established by the Government of India in 2014 to eliminate open defaecation and improve Solid Waste Management (SWM). The Ministry of Housing and Urban Affairs (MoHUA), Government of India, is working towards ensuring sustainability of the ODF status to ensure proper maintenance of toilet facilities, hereby referred to as SBM ODF+, and safe collection, conveyance, treatment and disposal of all faecal sludge and sewage, hereby referred to as SBM ODF++, to the cities and towns that have already achieved ODF status as per the ODF protocol, in order to achieve safe sustainable sanitation for all. The SBM ODF+ and SBM ODF++ protocols are incremental in nature, and reflect on-ground realities present in India.[10]

Under the SBM, it is predicted that nearly 80% of the 7.90 million households (HHs) (or nearly 6.3 million HHs) will meet their sanitation needs through newly-built individual household toilet (IHHT) and the remaining 20% (or nearly 1.6 million HHs) will rely on existing or newly-built community toilets. India's bigger cities have large, centralized sewerage systems with vast underground pipelines, pumping stations and huge treatment plants, that are expensive to be built and even more expensive to be operated effectively, as they require continuous power, a large amount of water, skilled operators and extensive electro-mechanical maintenance. This is the reason why India's 7000+ small towns do not have such systems and are unlikely to be covered by centralized sewerage systems in the near future.[11]

The Ministry of Urban Development (MoUD), Government of India, recognizes the end objectives and that the corresponding benefits of SBM cannot be achieved without proper management of faecal sludge and septage across the sanitation service chain.[12] Further, it is well acknowledged that sewerage handling will not meet the complete sanitation needs in all areas, and a strategy which is a combination of OSS and off-site (decentralized and centralized) must co-exist in all cities and must be given equal attention. So, to address the gaps and provide necessary directions to diverse stakeholders engaged in provision of FSSM services, the MoUD and a host of research and civil society organizations jointly drafted and signed a National Declaration on Faecal Sludge and Septage Management (FSSM) on September 9, 2016. This policy addresses the efficiency of systems in place for onsite sanitation whereof the faecal sludge output is supposed to be managed in an environmentally safe manner including the proper engineering design, construction and maintenance of septic tank systems, pit latrines and such other systems generating faecal sludge for further treatment.[11]

[8] An Assessment of Faecal Sludge Management Policies and Programmes at The National and Select States Level. Report by WaterAid.

[9] India Sanitation Conclave Report (April 26–27, 2018).

[10] Declaring your City/Town SBM ODF+ and SBM ODF++ Toolkit for Urban Local Bodies. Ministry of Housing and Urban Affairs (MoHUA), Government of India.

[11] National Policy on Faecal Sludge and Septage Management (FSSM) (February 2017). Government of India, Ministry of Urban Development.

[12] Guidelines for septage management in Maharashtra (2015). Swachh Maharashtra Mission, Urban Development Department, Government of Maharashtra

## Overview of Treatment Technologies

The report of the Census of India, 2011 states that only 32.7% of urban households are connected to a piped sewer system whereas 38.2% dispose of their wastes into septic tanks and about 7% into pit latrines, emphasizing the predominance of onsite arrangements—and it is not clear how the waste is further disposed of by the majority of these installations.[8] It also showed that in 4041 statutory towns, 7.90 million HHs do not have access to toilets and defaecate in the open.[11] Currently, septic tanks and pit latrines along with open defaecation are major contributors to groundwater and surface water pollution in many cities in the country.[14] 2.7 billion people worldwide are served by sanitation methods that need faecal sludge management.

The key objective of the urban FSSM Policy is the nationwide implementation of FSSM services in all the urban local bodies (ULBs) such that safe and sustainable sanitation becomes a reality for all in each and every household, street, town, and city.[11] With the increased coverage of toilets across the country under the SBM, it is of utmost importance that the technological interventions for the management of faecal waste–septage and sludge are strategically implemented.

The post-2015 Sustainable Development Goals (SDGs) include the whole sanitation services chain, from toilet, to excreta containment at the household—in a pit or tank or flushed into a sewer—to transport, treatment, and disposal.[2] The value chain of excreta: containment, emptying, transport, treatment, reuse or disposal, is designed to recover resources and improve sanitation in areas with no centralized sewerage systems in order to contribute to sustainable sanitation services. Figure 1 shows component-wise alternatives for sanitation value chain.

### *Faecal sludge treatment technologies*

Since Indians are predominantly washers, so the septage coming for the treatment processes typically contains 96% of water and only 4.0% of solid, often biologically stabilized or not stabilized. The faecal sludge coming

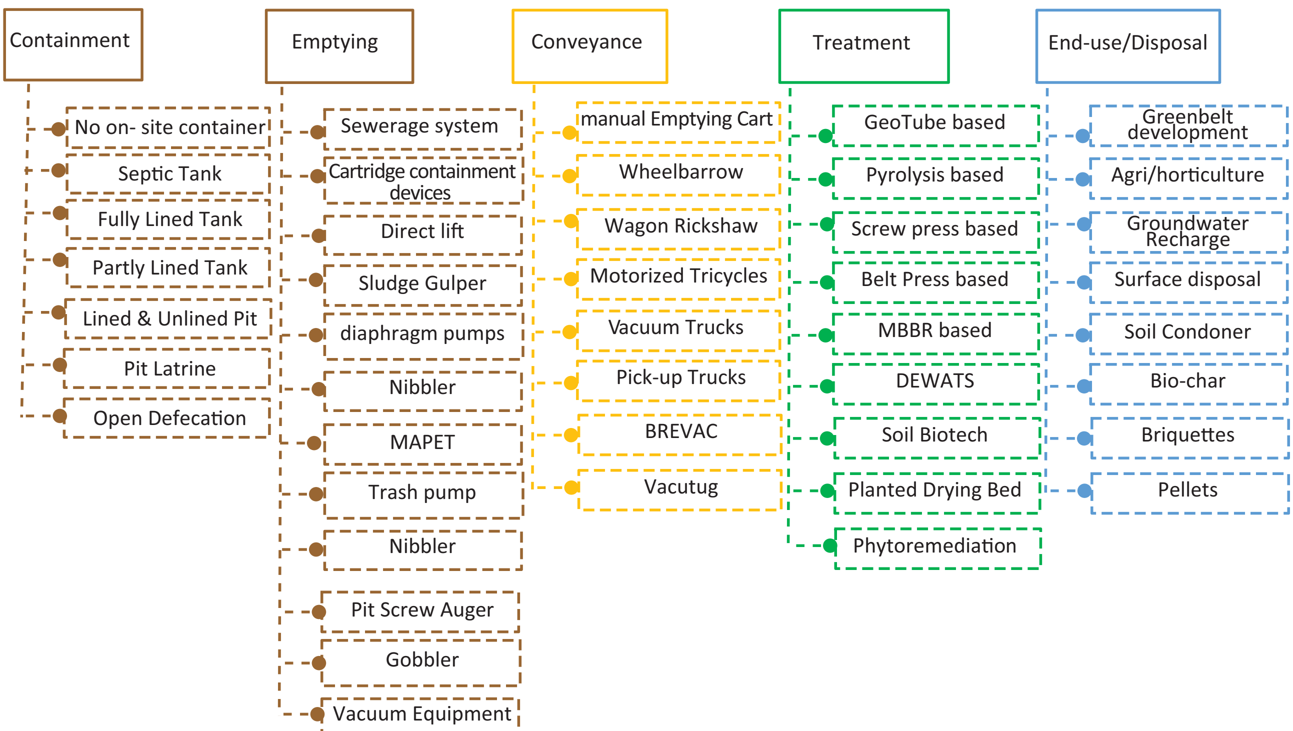


**Figure 1:** Component-wise alternatives for sanitation value chain

[13] Ingallinella, A.M., Sanguinetti, G., Koottatep, T., Montangero, A., Strauss, M., (2002). The challenge of faecal sludge management in urban areas - strategies, regulations and treatment options. Water Science and Technology 46: 285–294.

from the OSS sectors is basically stable, while the sludge coming from holding septic tanks is unstable. After the extraction of debris and sand, grit, rocks, glass, and metal from the incoming sludge, rendering those materials safe for human contact and disposal, the major challenge is achieving optimal solid-liquid separation by dewatering and treating the effluent so that it is safe for disposal or re-use.[14]

Thus, the technologies being compared here, mainly focusing on efficacy in segregating water and solid; purifying the water to an extent for reusing or surface disposal; and ensuring that the bio-solid hence acquired, undergoes disinfection and removal of pathogens for re-use.

The pros and cons of the most prominent available technologies have been delineated in Figure 2.

## Operational Advantages and Disadvantages of the Faecal Sludge Treatment Technologies

Every technology has some pros and cons. For instance, some consume more energy for the process to run (automated electro-mechanical), whereas, the others (biological) require less energy to operate. Similarly, some

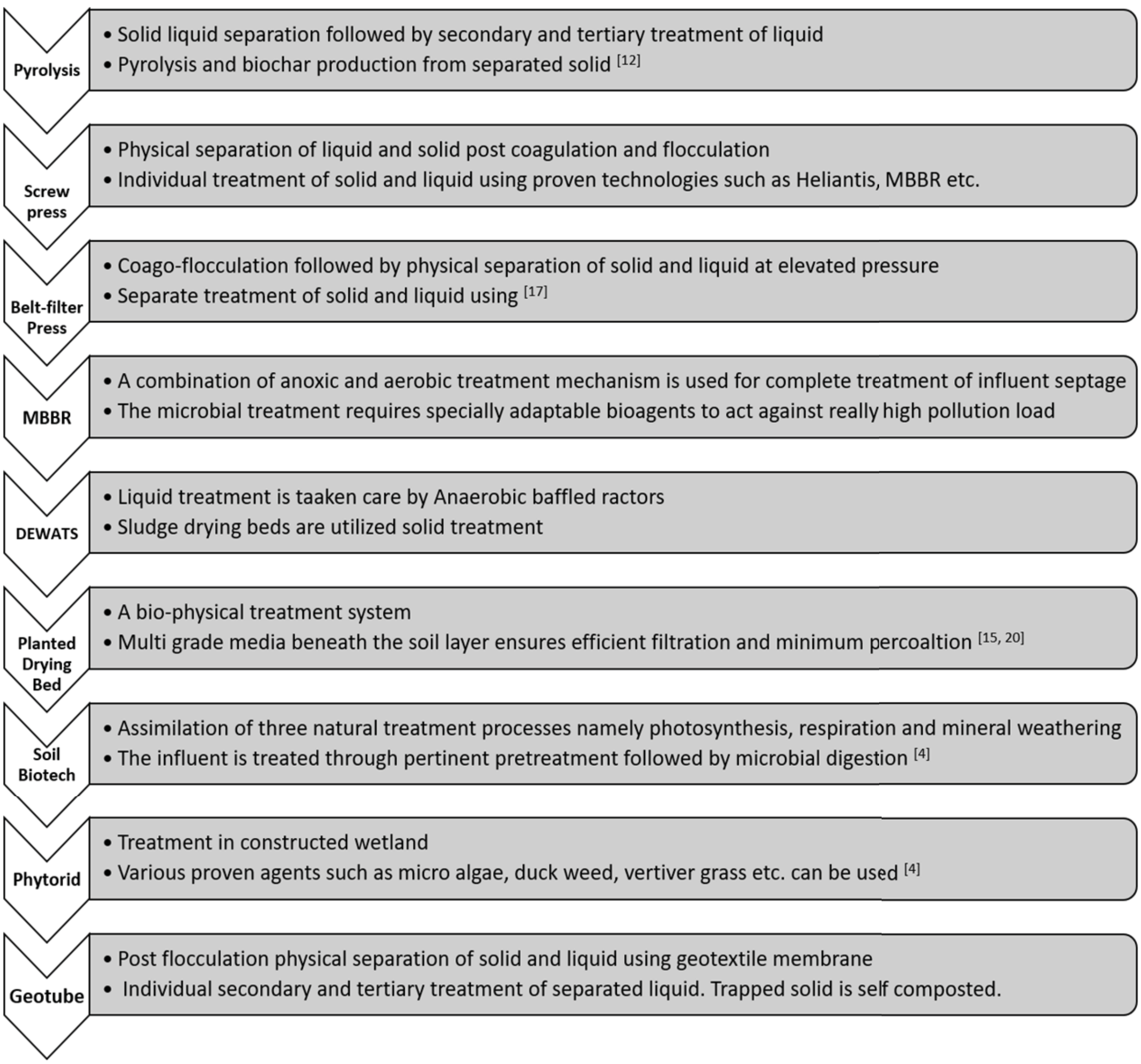


**Figure 2:** Overview of various treatment technologies

[14] Faecal Sludge Dewatering (December 02, 2015). Xinova.

need more manpower and some require fewer administrative interventions. While, some have lower operation and maintenance cost, some have higher cost in this sector. In some technologies, pasteurization is easier, and in some cases, further treatment is needed for higher degree of pathogen removal.

The advantages and challenges faced in the above-mentioned faecal sludge treatment technologies are detailed in Table 1.[15,16]

**Table 1:** Operational pros and cons of the treatment technologies

| Type | Technology | Advantages | Disadvantages |
|---|---|---|---|
| Electro-mechanical | Pyrolysis-based Operation | Automated system having no direct contact with faecal sludge | Requires Electricity (Grid/ DG) and skilled manpower |
| | | Energy consumption is monitored | External thermal energy needs depend on varied septage characteristics |
| | | Suitable for all weather conditions | |
| | | Bio-safe treatment process for solids and liquids | |
| | | Modular and scalable | |
| | | Fast deployment, with very low footprint | |
| | Screw-press-based Operation | Simple design and continuous operation | Capture rate varies per sludge quality |
| | | Excellent capture rate | Maintenance is hectic |
| | | Designed to feed material that has a 40%–60% water make up | |
| | Belt Filter Technology | Continuous operation | Relatively higher energy requirement |
| | | Easy maintenance | |
| | Hydraulic Piston Press and MBBR | The process outputs are completely bio-safe for use | Require highly skilled staff for operations |
| | | Treatment technology is simple | No end to end solution |
| | | | Mostly liquid fraction treated and solid part is not given attention |
| Biological | DEWATS | Low operation and maintenance cost | Sludge handling requires space |
| | | Allows for safe operations as there is no direct contact with faecal sludge | Further treatment of solids required for higher degree of pathogen removal |
| | | Operates without skilled human resource | |

*Contd...*

[15] Faecal Sludge Treatment Technologies in India –Compendium. National Institute of Urban Affairs (NIUA).

[16] Singha, S., Mohana, R. R., Rathi, S., Janardhana R. N., (February, 2017). Technology options for faecal sludge management in developing countries: Benefits and revenue from reuse. Environmental Technology & Innovation 7.

**Table 1 *contd...***

| Type | Technology | Advantages | Disadvantages |
|---|---|---|---|
| Biological | Planted Drying Beds | Technology is robust and flexible for extreme conditions | Rate of biological degradation during extreme cold weather takes longer treatment time |
| | | No direct human contact with faecal sludge | Bio-safe character of the process output needs to be determined |
| | | Minimal odour during the process and aesthetically designed to locate near habitation | Odour and flies may be noticeable |
| | | Gravity-based system with natural and biological treatment having no use of chemicals or electricity | High land requirement |
| | | Simple operations, can be handled with unskilled operators and labour | |
| | Soil Biotechnology | Process can be run on batch or continuous mode | Marginally higher capital requirement |
| | | Mechanical aeration is not required | Bigger land area requirement |
| | | No bio-sludge formation and complete water recycling resulting in reduced water intake | |
| | | Unskilled human resource required to operate | |
| | | Low power consumption | |
| | Phytorid Waste Water Treatment Technology | No mechanical/electrical machineries required, hence low maintenance | Clogging might occur |
| | | Space saving and scalable | Insufficient treatment |
| | | Skilled manpower not required | |
| | | Facilitates recycle and reuse of water | |
| | | No foul odour and no mosquitoes | |
| Other | Geo-tube Treatment Technology | This is a passive technique, does not need extensive and constant deployment of labour | Land requirement is moderately higher |
| | | Frequent maintenance of equipment is not needed | Dried sludge before disposal must be solar-dried to ensure pathogen/helminths eradication |
| | | Minimum energy required for daily operation | Reusability is a hindrance |
| | | Skilled labour requirement is very low | |
| | | Operates noise free and reduces odour problems | |
| | | Does not require any start-up or shut down time | |
| | | Permeate is filtered water of a quality that can be re-used/diluted, with or without additional treatment | |

*Contd...*

Table 1 *contd...*

| Type | Technology | Advantages | Disadvantages |
|---|---|---|---|
| Other | Geo-tube Treatment Technology | Semi-permeable fabric nature doesn't allow water inflow and thereby ensures zero atmospheric interference | |
| | | Grade V polypropylene make ensures recyclability | |
| | | Can easily handle any shock load or dry flow without compromising the efficacy | |

## Comparative Assessment Using Analytic Hierarchy Process (AHP)

Faecal sludge is a scarcely investigated waste stream and a very limited range of research has been pursued on best-suited handling and management techniques. But citing the heterogeneity of the substrate, the solution should be case-specific and robust. This provoked the idea of using the analytical hierarchy process for prioritizing the various available technologies (Figure 3). Figure 4 delineates a pair-wise comparison to arrive at the priority-based ranking.

The decision matrix was formulated based on resulting weight from principal eigenvalue of 7.649 against a consistency ratio of 8.1% (Figure 5). The comprehensive finding for the sequential ranking is summarized in Figure 6.

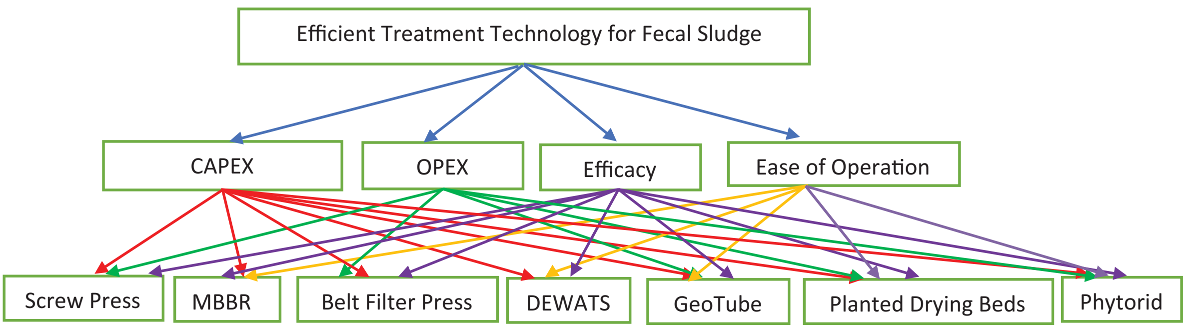


**Figure 3:** AHP hierarchies for prioritizing the efficient treatment process for faecal sludge

| Cat | | Priority | Rank | (+) | (-) |
|---|---|---|---|---|---|
| 1 | Geotube | 39.1% | 1 | 17.8% | 17.8% |
| 2 | Screwpress | 24.5% | 2 | 10.6% | 10.6% |
| 3 | MBBR | 15.2% | 3 | 6.5% | 6.5% |
| 4 | Belt filter press | 9.4% | 4 | 4.1% | 4.1% |
| 5 | DEWATS | 5.8% | 5 | 2.6% | 2.6% |
| 6 | Phytorid | 3.6% | 6 | 1.6% | 1.6% |
| 7 | Planted drying bed | 2.3% | 7 | 1.2% | 1.2% |

**Figure 4:** Pair-wise Comparison using AHP analysis

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 | 8.00 |
| 2 | 0.33 | 1 | 3.00 | 4.00 | 5.00 | 6.00 | 7.00 |
| 3 | 0.25 | 0.33 | 1 | 3.00 | 4.00 | 5.00 | 6.00 |
| 4 | 0.20 | 0.25 | 0.33 | 1 | 3.00 | 4.00 | 5.00 |
| 5 | 0.17 | 0.20 | 0.25 | 0.33 | 1 | 3.00 | 4.00 |
| 6 | 0.14 | 0.17 | 0.20 | 0.25 | 0.33 | 1 | 3.00 |
| 7 | 0.12 | 0.14 | 0.17 | 0.20 | 0.25 | 0.33 | 1 |

**Figure 5:** Decision matrix using AHP analysis

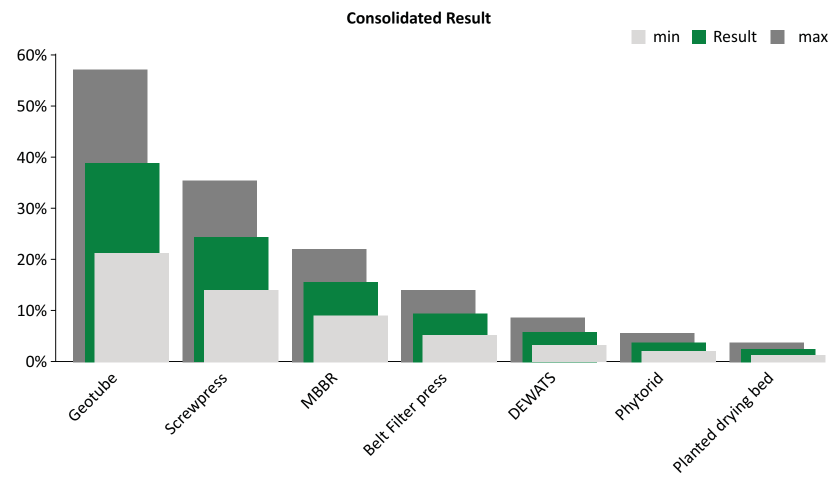


**Figure 6:** Consolidated AHP evaluation report for faecal sludge

## Cost Analysis of the Faecal Sludge Treatment Technologies

Selection of faecal sludge treatment plants (FSTPs) for rapid roll-out is possible with a costing standard across all the available technologies over time. This cost assessment here includes CapEx (Capital expenditures) and OpEx (Operational expenditures). Further, assessment of successfully developed models of STPs would strengthen in defining the suitable contracting model for FSTPs, with the cost implications of different technologies over time.[15,17]

The cost analysis in terms of CapEx and OpEx, for each of the mentioned technologies is provided in Table 2.[17,18]

These parameters strongly influence the decision-making about the selection of the appropriate faecal sludge treatment technology. The selection of a FS treatment technology for a city also depends on the local conditions and priorities of the region with respect to sanitation such as population coverage, environmental and health benefits, elimination of open defaecation, etc.[16] Extent of treatment has a significant influence on the cost of FSTPs.

**Table 2:** Cost analysis of the treatment technologies

| Technology | CapEx (in Rs./KLD) | OpEx (in Rs./KLD) |
|---|---|---|
| Pyrolysis-based Operation | 800,000 | 65,000–100,000 |
| Screw-press-based Operation | 1,000,000 | 110,000 |
| Belt Filter Press-based operation | 900,000–1,400,000 | 100,000–120,000 |
| Mechanized De-watering and MBBR | 413,000–8,83,000 | 183,000 |
| DEWATS | 400,000–1,420,000* | 43,000–60,000 |
| Planted Drying Beds | 450,000 | 83,000* |
| Soil Biotechnology | 101,000–1,000,000 | 25,000–100,000 |
| Phytorid Waste water Treatment Technology | 45,000 | 120,000 |
| GeoTube-based Technology | 50,000–100,000 | 17,000–38,000 |

**The cost varies as per site and location*

[17] Cost Analysis of Fecal Sludge Treatment Plants in India. National Institute of Urban Affairs (NIUA).

[18] Technology Options for the Sanitation Value Chain 1 (June, 2016). Center for Study of Science, Technology and Policy (CSTEP).

## Co-treatment of Faecal Sludge

Co-treatment is the treatment of the raw faecal sludge with sewage or treatment of the effluent from faecal sludge treatment technologies that typically requires further polishing before it is discharged into the water bodies or reused. Primarily, this is a treatment method of faecal sludge and septage in sewage treatment plants (STPs) with pre-treatment facilities for faecal sludge.[14,19,20]

Presently, co-treatment is a mandate for all the functional STPs to address the sanitation issues in non-sewered areas. Septic tanks are emptied using mechanical decanters and the digested septage is transported to the designated STP. Co-treatment unit includes two primary components namely, screening chamber and homogenization tank. Inert present in the influent stream is removed at the screening chamber. The screened sludge is stored and homogenized using a submersible-type cutter pump. Once filled, the homogenized septage is pumped alongside the screened sewage maintaining a minimum dilution ratio of 1:100. Since the faecal sludge is highly variable in its consistency; quantity and concentration, varying results are obtained from the co-treatment process. Thus, co-treatment plants are designed in such a way, that the existing STPs do not get any shock load.

## Challenges to Faecal Sludge Management

There is a plethora of technologies that are existing right now, and every other day, new technologies are emerging for the treatment of faecal sludge. Ultimately, whichever technology is taken up, the efficiency of the process depends on dewatering the sludge water and the solid; purifying the water to a level for reusing or surface disposal; ensuring the disinfection and removal of pathogens from them; and assuring their re-use.

So, considering waste as a valuable resource, proper technology implementation is required. Based on the geographical location, prevalent market for the recyclability of the bi-products from the treatment plant would empower the contribution to circular economy in sanitation. Attempts are in process to optimize and scale up resource recovery from such byproducts.

The major challenges faced mainly in the urban areas, while contemplating the installation of a FSTP are:

» Getting a suitable location for the plant.
» Selecting the ideal technology, post-construction of the FSTP.
» Gathering trained human power to run the plant. Because there are no standards for faecal sludge, so monitoring the evaluation poses a big challenge. Although it is quite understood by now that evaluation is not restricted, as FS has a diverse range in its consistency, quantity, and concentration.
» Running the plant is a challenge in itself, when it is highly power intensive; like in the case of electro-mechanical-based treatment mechanisms.
» Changing the habitat and mindset of the people residing nearby, as well as the people working in the FSTP is a tough job.
» Managing the de-sludgers, an unorganized sector of workers, to not flush out non-biodegradable waste from domestic OSS systems, is a huge obstacle in the way. Also, convincing them and properly monitoring them for the easy supply and usage of personal protective equipment (PPE), during their work is quite hectic.

So, overcoming these challenges to establish a Faecal Sludge Treatment Technology is not only about providing the best solution at the lowest price, but also about initiating sustainability, including social and environmental acceptance and institutional feasibility. EF

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[19] Bachmann, A., Beard, V. L., McCarty, P. L., (1985). Performance Characteristics of the Anaerobic Baffled Reactor. *Water Research* **19** (1): 99–106.

[20] Sperling, M.V., de Lemos Chernicharo, C.A., (2005). Biological Wastewater Treatment in Warm Climate Regions, Volume One. IWA Publishing, London, UK. pp. 728–804.

# ADOPTION OF TECHNOLOGY AMONG FARMERS

## Changes After the Pandemic

**Mr Rajesh Aggarwal**, Managing Director, Insecticides (India) Ltd, in conversation with us for *Energy Future.*

**How has COVID-19 accelerated the adoption of technology among farmers?**

For approximately 58% of India's population, agriculture is their primary source of income. It accounts for more than 20% of India's GDP, making it the backbone of the country's economy. Over the last two decades, India's rapid adoption of mobile phones has aided in closing the agricultural productivity gap and facilitating technology adoption. In terms of overcoming supply chain challenges and increasing yield, income, and sustainability, technology has proven to be a great enabler. Technology in agriculture aids farmers in gaining access to markets, inputs, data, advice, credit, and insurance, allowing them to make more profitable agricultural decisions.

As lockdown and COVID-19 posed challenges, farmers started adopting technology on a greater scale. COVID-19 paved the way for the advancement of digital technology in all sectors and farming was no exception, accelerating growth by ensuring higher crop yields and improving sustainability by reducing water consumption and promoting the judicious use of agrochemicals.

Farmers have started to now realize the importance of adopting new technologies in order to increase their yield and reducing the input cost. Tech-savvy farmers are now earning more than they used to. As a result, after the initial hiccups caused by the pandemic, India's agriculture technology sector has emerged as one of the fastest-growing sectors in India.

**How can technology be leveraged to help farmers?**

Since the beginning of the pandemic, digital agriculture tools have enabled farmers to continue receiving advisory, obtain much-needed financing, receive farm inputs, and identify new markets for their products. Agritech companies are helping farmers to stay connected and thrive. They cut out the middlemen, allowing farmers to sell their produce directly to consumers online. Agritech start-ups in the country received $300 million in investments in 2020, and the industry is expected to grow at a CAGR of 32% from FY20 to FY25. Using technology in agriculture accelerates the process and ensures a positive impact on the environment as well as a long-term, profitable future that meets the demand for food.

This year, Insecticides (India) Limited (IIL) conducted a survey of farmers to identify specific information gaps. The company dispatched a crop advisor team to meet the farmers and assist them with their various crop protection needs, as well as to inform them about the latest technology and other important points that reduced their input costs. With a network of more than 60,000 retailers, the company was able to provide cutting-edge technology to even small and marginal farmers.

**How about the rise of the digital era in farming?**

Artificial Intelligence (AI), Machine Learning (ML), remote sensing, Big Data, Blockchain, and the Internet of Things (IoT) are transforming agricultural value chains and modernizing operations. While several countries, including the Netherlands, the United States, Australia, and Israel, have successfully adopted and exploited digital solutions to revolutionize agriculture, India is still in its early stages. The Public–Private Partnership (PPP) model will foster the adoption of digital agriculture in India. For example, a project led by the International Food Policy Research Institute (IFPRI) and supported by the Digital Credit Observatory (DCO) and the Consultative Group on International Agricultural Research (CGIAR), used satellite images and smartphone pictures collected from farmers to generate credit scores that could be used to extend loans to farmers without an on-site visit.[1]

During the pandemic, many agritech providers adapted their digital agriculture solutions to include e-commerce realizing that finding markets for their products had become a pressing concern for farmers. In some cases, these e-commerce capabilities are as simple as connecting buyers and sellers via messaging or social media platforms such as WhatsApp, Facebook, or Twitter. Agri companies have enhanced their digital initiatives providing help through apps and call centres.

The Ministry of Agriculture's app Kisan Rath came in handy in response to transportation restrictions and mandi (market) closures that impacted farmers across India. The app, which runs on Android, is similar to Uber in that it connects farmers and traders with transportation companies. Farmers upload information about the crop's volume and destination. Owners of trucks can then agree to transport that volume to the correct location. Despite some early glitches, the app registered over 80,000 farmers and 70,000 traders in the first week of operation, indicating that there is a demand for this type of service.

The National Agriculture Market (eNAM), a pan-India electronic trading portal that connects the existing APMC mandis to create a unified national market for agricultural commodities, is one of the many initiatives launched by the government. The Digital Agriculture Mission 2021–2025 is another initiative that aims to support and accelerate projects based on new technologies such as artificial intelligence, blockchain, remote sensing and GIS technology, and the use of drones and robots. The Jio Agri (JioKrishi) platform, which was launched in February 2020, digitizes the agricultural ecosystem throughout the value chain to empower farmers. The DBT Agri Portal, which was launched in January 2013, is a centralized portal for agricultural schemes across the country. Through government subsidies, the portal assists farmers in adopting modern farm machinery.

[1] https://www.gsma.com/mobilefordevelopment/wp-content/uploads/2021/04/COVID_19_Accelerating_the_use_of_digital_agriculture_updated.pdf


**Please throw some light on the future in this regard.**

The government has approved the spray of agrochemicals via drones, and trials are already underway by institutes and companies. Drones are currently being tested for use in the cotton-growing region along with other crops of the country to spray pesticides to control pests that would otherwise be treated by agricultural labourers, which takes a long time and does not always result in uniform spraying. They not only reduce the risk of unintentional fume inhalation, but also speed up the pest control process by covering larger areas in less time. The main advantage of using a drone is that it uses less water and pesticide and allows for more precision during the application process. Pesticide companies are required to submit phytotoxicity studies under the directives issued by the government. This will significantly contribute to research, leading to increased productivity in the coming years. Though commercialization will take some time, it is encouraging that the government is moving in this new direction.

Among other technologies, remote sensing, soil sensors, unmanned aerial surveying, and market insights enable farmers to gather, visualize, and assess crop and soil health conditions at various stages of production in a convenient and cost-effective manner. They can act as an early warning system, identifying potential issues and providing solutions to address them as soon as possible. AI/ML algorithms can generate real-time actionable insights to help farmers improve crop yield, control pests, assist in soil screening, provide farmers with actionable data, and reduce their workload. Blockchain technology enables tamper-proof and precise farm and inventory data, as well as quick and secure transactions for the farmers. Hence, they are no longer reliant on paperwork or files to record and store critical data. More such state-of-the-art technologies will continue to be valuable tools for connecting with farmers next year too. The year 2022 will be a year of innovations that will greatly benefit the agricultural sector.

Despite of all technological advancements taking place only a handful of farmers are being benefitted by the same, a large number of farmers are still far away from the same due to numerous reasons, again the role of the education and training becomes pivotal for the farmers, which requires a joint effort by the government agencies and the industry. EF


# 29TH CONVERGENCE INDIA

## & 7th Smart Cities India 2022 Expo

India Trade Promotion Organisation (ITPO) & Exhibitions India Group inaugurated the 29th Convergence India and 7th Smart Cities India 2022 Expo on March 23, 2022 at Pragati Maidan, New Delhi. Convergence India, now in its 29th edition, heralded the telecom revolution in India. It is the largest technology and infrastructure expo in the country. The expo provides a platform to showcase 'Brand India' and focuses on promoting the 'Make in India' & 'Digital India' campaigns and showcases the emerging technologies. It includes, Internet of Things, Mobile India, EmbeddedTech, Fintech, and Digital Gaming.

Smart Cities India expo aims to deliver better citizen services by showcasing the latest technologies. Integrating technology with the key pillars of urban development, that is, green buildings, energy, transport, clean environment, and water, for optimizing resources and making cities smart and sustainable. The expo is a unique meeting point for Union and State government officials, private sector representatives, foreign delegations, businesses, city leaders, etc.

India's largest tech & Infra expo concluded a successful first day, with a virtual address by Shri Nitin Gadkari, Hon'ble Union Minister for Road Transport & Highways, Government of India. The three-day expo hosted approximately 800+ brands and more than 100 start-ups, along with participation from various

government departments, public sector undertakings, and smart cities. The event was organized keeping in mind the COVID-19 protocol, ensuring a safe and seamless experience.

The inaugural session set the tone of an eventful day, with addresses from Shri Kaushal Kishore, Hon'ble Minister of State, Ministry of Housing & Urban Affairs, Government of India; Shri Vibhu Nayar, IAS – Executive Director ITPO; Mr Sandeep Narula, Chairman, Electronics & Computers Software Export Promotion Council (ESC) India; Mr Gurmeet Singh, Executive Director, ESC India; and Ms Chandrika Behl, Managing Director, Exhibitions India Group; and Dhruv Behl, Director – Exhibitions India Group.

The first day was packed with 12 high-powered conference sessions with over 30 thought leaders. Apart from hosting a plethora of technology-redefining brands under one umbrella, day 1 of the expo also organized a series of keynote sessions and panel discussions with notable dignitaries across sectors. The conversations covered pertinent topics such as the readiness versus the reality of 5G in India, surge of OTT industry in the pandemic and its impact on growth, the future of Indian cities, and accelerating the modal shift to public and shared transport systems.

Shri Nitin Gadkari, Hon'ble Union Minister for Road Transport & Highways, Government of India, addressed the gathering, "I'm really happy with the Smart Cities India and Convergence India 2022 exhibition and convention. It is going to qualitatively contribute to our vision for the development of a new India. I appreciate the expo's vision for Smart Cities in India, particularly the fact that we are working to bring India to the world standard. I appreciate the role of the industry and the organizers of the expo and extend my best wishes to all."

Speaking at the inauguration, Kaushal Kishore, Hon'ble Minister of State, Ministry of Housing and Urban Affairs, Government of India in the context of the #SCI2022, "A fragmented approach to building smart cities is not a visible approach; we must strive to make whole cities smart. The vision of Smart Cities is not limited to creating infrastructure but also incorporates the idea of making every individual self-reliant. Smart City does not only mean infrastructure, electricity, and housing, it means adding to the income levels of families. We're glad to see an event like this, providing a platform for such conversations."

Chandrika Behl, Managing Director, Exhibitions India Group, said "We are back with a physical event post a hiatus, and are glad to host industry stalwarts at the expo. The annual Convergence India and Smart Cities India Expo have provided an excellent platform for brands to showcase their work and network across technologies, innovation and everything that is smart and sustainable. We are glad to have been able to be back on ground and create an ecosystem of opportunities."

Day two had an equally powerful and exciting line-up of thought leaders and knowledge sessions as part of the Digital Transformation Conclave, the City Leaders Conclave, the Future of Start-ups in India and sessions viewing development from a gender lens with discussions on Women in Tech and Future for Female Founders in Start-ups. EF

*For further information, please contact: srishti@onpurposeconsulting.in; Visit: www.eiexpolive.com*

# 'INVESTING FOR IMPACT: FOOD, AGRI AND AGRITECH' REPORT

## Launched by Aspire Circle in New Delhi

- » Aspire Circle, Impact Leadership champion and advocate released a report titled 'Investing for Impact: Food, Agri and AgriTech'
- » Top 10 impact investment ideas in the sector can mobilize an investment of $272 billion by 2030, with a potential to create 152 million jobs impacting 1.1 billion lives
- » Agritech start-ups to dominate the sector with a 25% growth year-on-year and one in every 9 agritech start-ups in the world being an Indian company
- » Opportunities for investments in farm mechanization, which currently stands at only 40–45% in India as opposed to over 90% in developed economies
- » Adoption of cold storage and efficient logistics provide becomes imperative as India struggles with a gap of 3.2 million MT in cold storage capacity and the total harvest and post-harvest losses amount to USD 14 billion
- » While India's population is projected to grow at a CAGR of 2%, demand for key food grains is expected to grow at a CAGR of 3%

With an investment of $272 billion in agritech and allied segments by 2030, India stands to generate $813 billion in revenue, creating 152 million jobs and impacting 1.1 billion lives, says a report launched on December 23, 2021 in New Delhi by Aspire Impact, the foremost Impact Leadership champion and advocate in the country. The report titled '*Investing for Impact: Food, Agri and Agritech*' has been authored by leading agritech experts, industry leaders, academics, and thinkers. This comes at a time when the pressing need to make agricultural practices more sustainable and less polluting was emphasized at the COP26 by the United Nations held at Glasgow recently. With agriculture continuing to remain the mainstay of economy for the country, investment in agritech and allied segments can transform the face of Indian agriculture with far-reaching implications for food security and sustainable farming solutions.

Outlining ten disruptive investment ideas, the report offers a comprehensive roadmap on how new-age technologies, innovative practices, process reengineering, and refined business models can all combine to make Indian agri and food industry future-ready. The ten themes include Farm Mechanization and Farmgate Infrastructure; Water and Soil Management; Cold chain and logistics; Bio-inputs and Sustainable farming; Plant-based Proteins; Climate Risk Mitigations; Sustainable Forestry; Food Fortification; Protected Cultivation, Vertical Farming and Hydroponics; and Dairy Farming.

This was the fifth in a series of reports launched by Aspire Circle as part of an initiative to generate 100 Impact Ideas for India's Inclusive Growth through collaborative research involving over 200 experts, with the goal to shape India's Impact Economy. "In the last decade India attracted close to $9 billion in FDI investments in the agriculture sector. This decade brings an opportunity for India Inc to take advantage of the massive untapped potential this sector holds and transform it to be sustainable and future-ready. With smart innovations, infrastructure and policy support and newer business models the top 10 ideas researched by IFP community can attract $272 billion in investments and generate $813 billion in revenue, impacting 1.1 billion lives," said Mr Amit Bhatia, Founder of Aspire Circle & Creator - Impact Future Project.

India has its share of challenges when it comes to agricultural practices. Mechanization levels in India are at 40–45% unlike the developed economies' 90%. The country has been estimated to be at the biggest production risk with 68% of the cultivation area being directly dependent upon the monsoon accounting for 40–45% of total agriculture production. With a gap of 3.2 million MT in cold storage, the food processing industry incurred a loss worth $14 billion in 2018. At the same time, 55% of country's forests are prone to fire with 70% having no natural regeneration. The demand for key food grains is expected to grow at a CAGR of 3% against the projected population growth of 2% further underlines the challenge that the country faces today. To meet its dairy needs, India would require around 600 million tonnes of milk per year in 2060 and onwards. Significant investments in the sector along with a policy push are needed to ensure transformation in agriculture practices and ecosystem. With agritech start-ups and innovative models speculated to dominate the sector, India Inc. has already started paving this path to change.

"Only when we get ahead together do, we win as a nation. Agriculture must become a steady and profitable trade for India's 130 million farmers and their families. Agritech entrepreneurs will be part of that solution, leveraging innovation, technology, and persistence to reinvent agriculture and food systems. In the years to come, we hope to see more scalable, long-term solutions to help the agri-ecosystem move away from practices based on natural resources extraction and depletion to ones designed for regeneration," said Mr Jinesh Shah, Managing Partner, Omnivore.

"The world's oldest industry is also the newest sunrise sector. From massive movements towards plant-based proteins to protected cultivation to tech-driven farmer services and collectivization of small-hold farmers, man's ability to produce more with less in a socially- responsible and environment-friendly manner has grown by leaps and bounds. In a country like India, this is also politically sensitive sector impacting lives of extremely large section of society making reforms difficult. In this context, platform such as IFP is extremely valuable bringing various stakeholders together, ideating on solutions and identifying actionable initiatives," said Ms Purnima Khandelwal, Co-Founder, INI Farms.

Aspire is the foremost Impact Leadership champion and advocate in the country which focuses on impact leadership and ecosystem development through three initiatives: Aspire Impact for ecosystems, Aspire Circle for social impact leadership, and Aspire Education for K-12 and university leadership education. Aspire, established in 2007, based in Gurugram (India) is committed to living Impact. EF

# CURRENT R&D

RENEWABLE

## Utilization of Poultry Waste as a Source of Biogas Production

Materials Today: Proceedings, **45**: 783–7871

*Arka Gohil, Sejal Budholiya, C G Mohan, R Prakash*

The present study aims to explore the use of poultry and domestic waste to produce biogas. The current rate of diesel consumption is quite high while taking into account the gas emissions and the fast depletion of non-renewable fuel sources. The study conducted is about adding a certain optimal amount of biogas from the poultry waste to the gas mixture from the carburettor to reduce the fuel consumption. The greatest biogas generation potential for the dairy animal's excrement and poultry dropping blend is in the request of 25% CD + 75% PL, >50% CD + 50% PL, >00% CD + 100% PL. The two-composition mixture of 20% and 30% biogas with air shows that the amount of diesel consumption is reduced. The highest reduction at 20% biogas and at zero load stands at 29% less diesel consumption and 30% biogas mixture and at zero load, 37.5% fuel reduction. EF

## A Study of Enhancing the Biogas Production in Anaerobic Digestion

Materials Today: Proceedings **45**: 7994–7999

*Vijin Prabhu, Sivaram AR, Prabhu N, Sundaramahalingam*

The present study provides a comprehensive overview on biogas production enhancement techniques in anaerobic digestion from various biomass wastes. Co-digestion, two phase digestion, recirculation of slurry, thermal pretreatment, alkaline pretreatment, acid pretreatment, ultrasound pretreatment, hydrothermal pretreatment and milling pretreatment are some of the techniques used to improve the biogas production. Pre-treatment before anaerobic digestion increases the biogas yield, especially hydrothermal pretreatment of rice straw increases the yield of biogas from 140 to 315.9 Lkg_1VS. In addition, thermal and mechanical pretreatment of barley straw increases the biogas production by 40.8% and 50.2%, respectively. Information on different biomass waste components is important for the efficient implementation of anaerobic digestion and maintaining the key parameters within the desired range will also boost the biogas production. EF

## A Systematic Framework for the Assessment of Sustainable Hydropower Potential in a River Basin—The Case of the Upper Indus

Science of the Total Environment, Volume 786, 147142
*Dhaubanjar S, Lutz A F, Gernaat D E H J, Nepal S, Smolenaars W, Pradhananga S. et al.*

The authors developed a systematic framework for the basin-scale assessment of the sustainable hydropower potential by integrating considerations of the water–energy–food nexus, disaster risk, climate change, environmental protection, and socio-economic preferences. Considering the case of the upper Indus, the framework is developed by combining advances in literature, insights from local hydropower practitioners and over 30 datasets to represent real-life challenges to sustainable hydropower development, while distinguishing between small and large plants for two run-of-river plant configurations. The framework first addresses theoretical potential and successively constrains this further by stepwise inclusion of technical, economical, and sustainability criteria to obtain the sustainable exploitable hydropower potential. It is concluded that sustainable hydropower potential in complex basins such as the Indus goes far beyond the hydrological boundary conditions. The framework enables the careful inclusion of factors beyond the status-quo technological and economic criterions to guide policymakers in hydropower development decisions in the Indus and beyond. Future work will implement the framework to quantify the different hydropower potential classes and explore adaptation pathways to balance SDG7 with the other interlinked SDGs in the Indus. EF

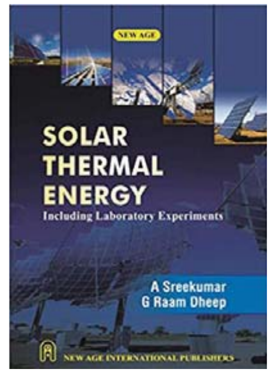
## Solar Technologies and Their Implementations: A Review

Materials Today: Proceedings **28**: 2137–2148
*Shivanshu Dixit*

This article highlights the revolution of solar energy and its application as a renewable energy source. It starts with the introduction, describing solar power, energy types, energy scenario, current status, solar energy with their advantages, solar technologies (traditional, present, and future) with the application of these technologies and its future scope. Currently, for countries like India, this solar power energy generation is a boon in terms of energy requirements and tackling environmental problems. The other benefits of reduction in energy dependency, energy security, job creation, and healthy economic growth in the country can also be seen with such technologies when implemented. EF

## Solar Thermal Energy

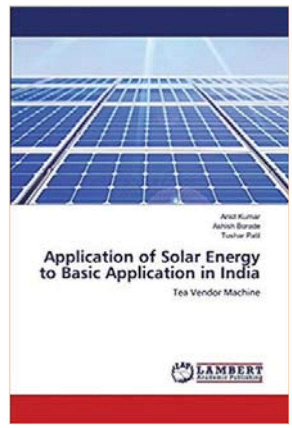
This book on solar thermal energy including laboratory experiments is articulated to serve as an unswerving textbook-cum-laboratory manual for undergraduate, postgraduate, and research students of science, engineering, and technology. This book gives coverage of fundamentals of heat and mass transfer, solar thermal energy devices, and all the important practical experiments in solar thermal energy engineering. Detailed descriptions are given in the beginning of the book to elucidate the theoretical aspects of practical experiments. Apposite tabular columns for recording the observations are given in all the experiments. Relevant equations for evaluating the performance of various solar thermal collectors are appended with appropriate experiments. This book will find its use as an authentic manual for solar thermal energy education as well as testing of different types of solar thermal collectors. EF




Authors: A Sreekumar and G Raam Dheep
Publisher: New Age International Private Limited
1st edition, 138p
Year: 2020

## Application of Solar Energy to Basic Application in India

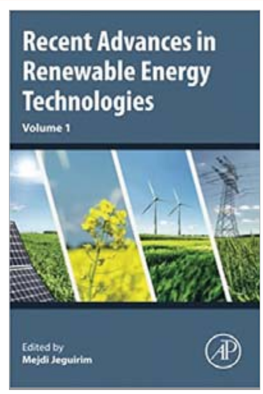
This book will help students to understand the basic principal of solar energy and how this energy is helpful for the basic need of humans. It will also help students to develop small applications based on the solar energy. EF




Authors: Ankit Kumar, Ashish Borade, and Tushar Patil
Publisher: LAP Lambert Academic Publishing, 80p
Year: 2021

## Recent Advances in Renewable Energy Technologies: Volume 1

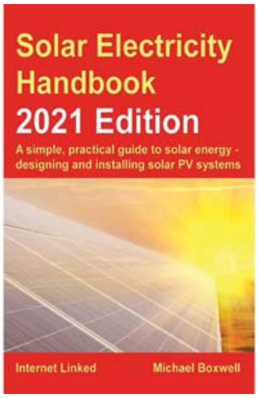
Recent Advances in Renewable Energy Technologies is a comprehensive reference based on the International Renewable Energy Congress (IREC) covering critical research and industry developments on renewable energy technological, production, conversion, storage, and management. It covers solar energy system (thermal and photovoltaic), wind energy, hydropower, geothermal energy, bioenergy production and hydrogen production, large-scale development of these renewable energy technologies, and their impact on global economy and power capacity. The technology advancements include resources assessment and deployment, materials performance improvement, system optimization and sizing, instrumentation and control, modelling and simulation, regulations and policies. Each modular chapter examines recent advances in specific renewable energy systems, providing theoretical and applied aspects of system optimization, control, and management and supporting them with global case studies demonstrating practical applications and economical and environmental aspects through life cycle analysis. EF




Editor: Mejdi Jeguirim
Publisher: Academic Press, 444p
Year: 2021

## Solar Electricity Handbook – 2021 Edition: A Simple, Practical Guide to Solar Energy – Designing and Installing Solar Photovoltaic Systems

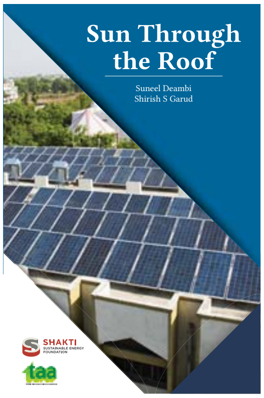
This book explains the advantages of solar energy and the drawbacks you need to consider. As well as explaining the underlying principles, it provides a step-by-step guide so that you can successfully design and install a solar energy system from scratch. This book includes online solar calculators and tools to simplify your solar installation, ensuring that building your system is as straightforward and successful as possible. Readers can also get in touch directly with the author to ask questions and get further support with their solar projects. EF




Author: Michael Boxwell
Publisher: Greenstream Publishing, 240p
Year: 2021

## Sun Through the Roof

*Sun Through the 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. EF



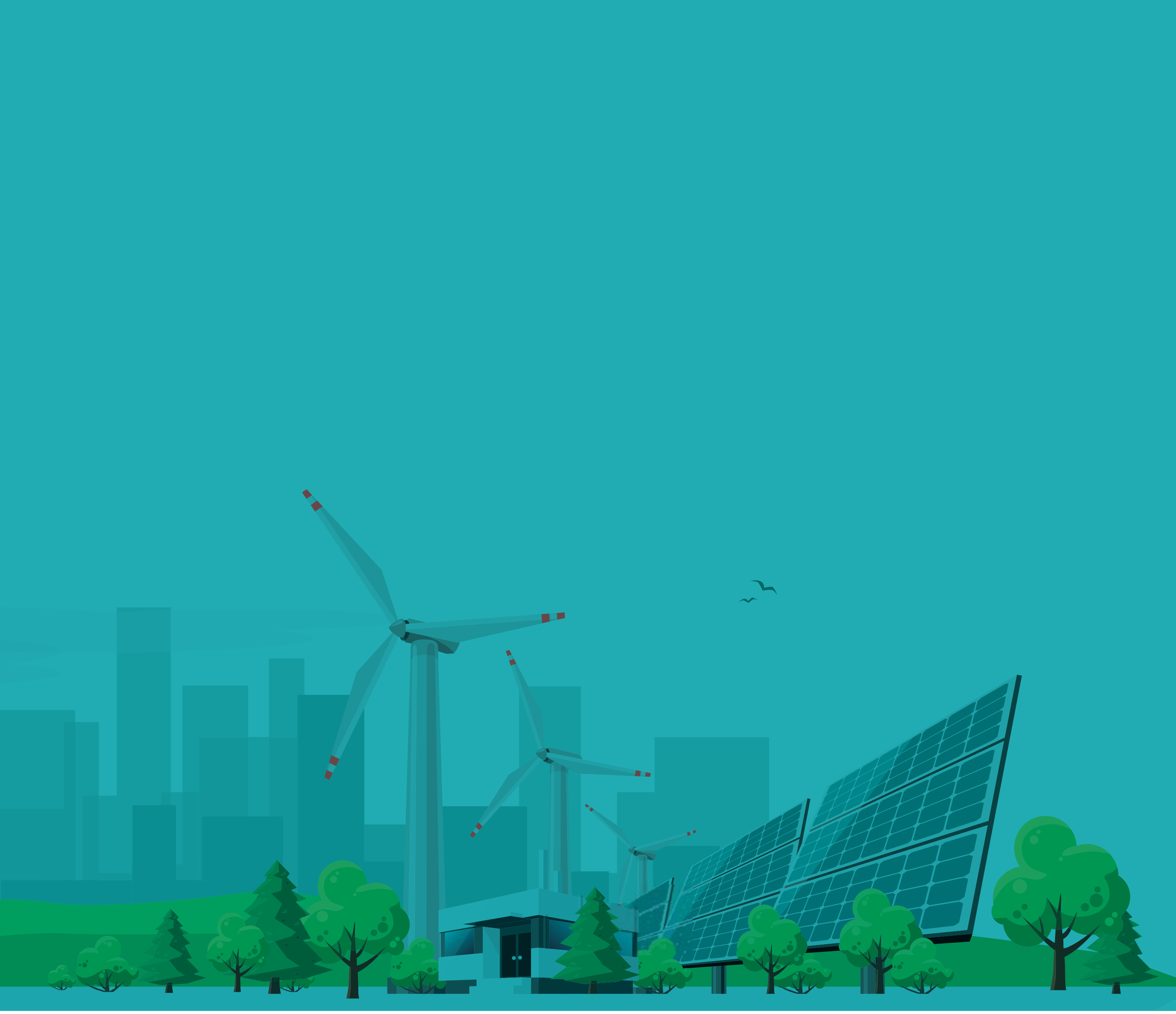

Authors: Suneel Deambi, Shirish S Garud
Publisher: TERI Alumni Association, 50p
Year: 2022

# RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

## A low-cost way to make efficient, stable perovskite solar cells

Researchers have identified a way to create nickel oxide (NiO) films of sufficient quality in solution and at relatively low temperatures of less than 150°C. The researchers used 4-hydroxybenzoic acid or trimethyloxonium tetrafluoroborate ligand-modified NiO nanoparticles and a microfluidic mixer, which promotes high-pressure mixing of low-volume liquids, to distribute the nanoparticles evenly prior to depositing them on the substrate. The chemical process could contribute to the scalable fabrication of inorganic and inexpensive, high-performance films able to be used in the commercial production of flexible solar panels. The researchers have recorded power conversion efficiencies of 17.9% and 17.5%, respectively, in prototype devices compared to 16% for a previous comparable approach, which lacked the advantages of the ligand exchange and also required a post-processing oxygen plasma treatment step. Significantly, the new devices exhibited just a 0.2% reduction in efficiency over an intensive 300 h testing period, providing a strong indication of their potential suitability for commercial applications. According to the researchers, their work showcases that high-temperature processing of functional materials for solar cells can be omitted using facile processing ways. It is a crucial step for commercialization of the perovskite technology.

*https://www.sciencedaily.com/releases/2021/06/210630115408.htm#:~:text=Nickel%20oxide%20(NiO)%20is%20used,properties%20and%20long%2Dterm%20stability*



# Polymer scientist helps develop new technique for large-scale energy storage

Electric vehicles require power to be available anywhere and anytime without delay to recharge, but solar and wind are intermittent energy sources that are not available on demand. And the electricity they do generate needs to be stored for later use and not go to waste. New research reveals a more stable way to store this important energy.

Just as the gas station today, electricity power stations need a storage system to keep the electricity for EV constantly charging. Low cost, scalable redox flow batteries (RFBs) are among the most suitable technology for such a system; however, current RFBs use high-cost and environmentally hazardous active materials (electrolytes). Recently, water-soluble organic materials have been proposed as future electrolytes in RFBs (namely, aqueous organic RFBs or AORFBs). Organic-based electrolytes can be obtained from renewable sources and manufactured with very low cost. However, the lack of stable water-soluble organic electrolyte materials, particularly the positive electrolyte (catholyte), is a major hurdle of AORFBs.

The researchers successfully developed the most stable catholyte (positive electrolyte) to date in AORFBs and demonstrated cells that kept more than 90% of capacity over 6000 cycles, projecting more than 16 years of uninterrupted service in a pace of one cycle per day. According to them, 'Development of high-performance

RFBs will enrich the category of electricity energy storage systems and complement the shortcoming of intermittent renewable energy sources, therefore largely improving the usability of electricity powered facilities such as vehicles'. To significantly improve the performance of aqueous organic RFBs, the urgency of developing new catholyte is crucial.

*https://www.sciencedaily.com/releases/2021/08/210819125243.htm*

## Turning thermal energy into electricity

With the addition of sensors and enhanced communication tools, providing lightweight, portable power has become even more challenging. Army-funded research demonstrated a new approach to turning thermal energy into electricity that could provide compact and efficient power for soldiers on future battlefields. This research demonstrates a new approach, where the separation between the emitter and the photovoltaic cell is reduced to the nanoscale, enabling much greater power output than what is possible with FF-TPVs for the same emitter temperature.

This approach, which enables capture of energy that is otherwise trapped in the near field of the emitter, is called near-field thermophotovoltaics or NF-TPV and uses custom-built photovoltaic cells and emitter designs ideal for near-field operating conditions. This technique exhibited a power density almost an order of magnitude higher than that for the best reported near-field TPV systems while also operating at six times higher efficiency, paving the way for future near-field TPV applications.

*https://www.sciencedaily.com/releases/2021/08/210830140229.htm*

# GREEN HYDROGEN FROM WASTE NOW A REALITY


Preliminary approval has been granted to H2-Industries by the General Authority for Suez Canal Economic Zone (SC° wZone) for the development of a 1 GW LOHC Hydrogen Hub at East Port-Said which will be the first project of its type in the world. The hydrogen plant will be fed with 4 million tonnes of organic waste and non-recyclable plastic per year secured at the Mediterranean entrance to the canal. Read on to know more…

Protecting our environment involves significant challenges. Reducing the carbon footprint of energy production and the amount of waste we produce as a society are two of them.

$H_2$-Industries has embarked on a revolutionary project to create green hydrogen using proprietary technologies by using organic wastes as feedstock for its energy production while capturing $CO_2$ and commercializing it, achieving carbon neutrality.

Countries and major industries are increasingly recognizing that one of the most promising routes to a zero-carbon future is the production and use of green hydrogen. However, creating green hydrogen has historically proven uneconomic. $H_2$-Industries, using its proprietary technology, has developed a process to create large amounts of green hydrogen from organic waste at competitive costs. The green hydrogen produced from that process can be transported and stored, using other $H_2$-Industries technologies, and released on demand for use in industry applications.

## Waste to Energy

Following a multimillion $ investment, $H_2$-Industries is now poised to undertake several projects, which will convert organic waste, including plastic and agricultural waste and even sewage sludge, and turning same into useable hydrogen. That hydrogen can be transported into a "carrier fluid" referred to in the industry as Liquid Organic Hydrogen Carriers (LOHC), which can be transported and used to fill storage tanks much like diesel, but without the carbon emissions upon use. The waste heat from the $H_2$-Industries' process can be used to generate power with steam turbines and generators.

## Egypt Waste-to-Hydrogen Plant—World's First and Largest on this Scale

Preliminary approval has been granted to $H_2$-Industries by the General Authority for Suez Canal Economic Zone (SC°Zone) for the development of a 1 GW LOHC Hydrogen Hub at East Port-Said which will be the first project of its type in the world. The hydrogen plant will be fed with 4 million tonnes of organic waste and non-recyclable plastic per year secured at the Mediterranean entrance to the canal. The Suez Project will produce 300,000 tonnes of green hydrogen per year at half the levelized cost of current green hydrogen production technologies, taking the cost even lower than current levels for low-carbon and grey hydrogen production.

Executive Chairman of $H_2$-Industries, Michael Stusch said: "This is an exciting opportunity and one that will take the tonnes of waste that collects in Egypt and turn it into green hydrogen. The waste-to-hydrogen plant is a breakthrough in making green hydrogen economically viable, helping not only reduce global $CO_2$ emissions but also reducing the pollution and impairment of water resources in the country."

Green hydrogen so produced can be sold and transported for international use in the 20th century infrastructure, e.g., diesel trucks carrying $H_2$-Industries' LOHC or, alternatively, $H_2$-Industries can create low-cost synthetic diesel (eDiesel) or sustainable aviation fuel (SAF), with the captured $CO_2$, which is the only emission in this process, depending on international market demand for same.


## More to Come

$H_2$-Industries is also commercializing other green hydrogen products to meet the commercial needs of end users with applications ranging from the transformation of coal-fired power plants to hydrogen power plants and transforming steel, cement and glass production making it $CO_2$ free by using $H_2$-Industries' technology and green hydrogen.

## About H2 Industries

$H_2$-Industries Inc. is a global hydrogen generation and energy storage solutions company headquartered in New York City, USA. Founded by Dipl.-Ing. Michael Stusch in 2010, the business focused on developing technologies that generate, store and transport green hydrogen using Liquid Organic Hydrogen Carriers (LOHC). The hydrogen can then be economically extracted and converted to electrical energy. At present, $H_2$-Industries Inc. operates in eleven countries on four continents, collaborating with leading suppliers and consultants worldwide. EF

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*To learn more about how $H_2$-Industries is changing the renewable energy supply landscape, visit https://h2-industries.com/en.*

# RENEWABLE ENERGY AT A GLANCE

| Ministry of New & Renewable Energy | | |
|---|---|---|
| Programme/Scheme-wise Cumulative Physical Progress as on April, 2022 | | |
| **Sector** | **FY- 2022-23** | |
| | **Achievements (April 2022)** | **Cumulative Achievements (as on 30.04.2022)** |
| **I. INSTALLED RE CAPACITY (CAPACITIES IN MW)** | | |
| Wind Power | 170.50 | 40,528.08 |
| Solar Power* | 1341.10 | 55,337.66 |
| Small Hydro Power | 2.00 | 4850.90 |
| Biomass (Bagasse) Cogeneration | 0.00 | 9433.56 |
| Biomass(non-bagasse)Cogeneration | 0.00 | 772.05 |
| Waste to Power | 0.00 | 223.14 |
| Waste to Energy (off-grid) | 0.00 | 253.61 |
| **Total** | **1513.60** | **111,399.00** |

*Source: https://mnre.gov.in/the-ministry/physical-progress*

## ADVERTISE IN...

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Industries, Ministries, PSUs, Corporates, Multi and Bilateral Agencies, Universities, Educational Institutions, and Research professionals. Readership of 40,000

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- Monthly
- All colour
- Matte paper
- Number of pages: 56


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| Inside Front cover | 75,000 | 191,250 | 360,000 | 675,000 |
| Inside Full Page | 50,000 | 127,500 | 240,000 | 450,000 |
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### Subscription

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# ENERGY FUTURE

### Circulation information

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### General information

- Quarterly
- All colour
- Matte paper
- Number of pages: 96


### Technical specifications

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|---|---|
| Finished size: | 20.5 cm × 26.5 cm |
| Non-bleed ad size: | 17.5 cm × 23.5 cm |
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| Three issues | 171,000 | 142,500 | 142,500 | 114,000 | 57,000 | 34,200 | 19,950 |
| Four issues | 228,000 | 190,000 | 190,000 | 151,000 | 76,000 | 45,600 | 26,600 |

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