Table 3: State/UT-wise availability, seasonality, total, and surplus biomass production of rice along with its bioethanol potential

States/UT	Availability	Seasons	Total production (000 t)	Surplus production (000 t)	Bioethanol potential (million L)
Andaman & Nicobar Islands	+	Kharif, Rabi, early Kharif	33.46	33.46	0.45
Andhra Pradesh	+	Kharif, Rabi, early Kharif	16925.74	9360.01	367.3
Arunachal Pradesh	+	Kharif	35.78	356.78	9.68
Assam	+	Kharif, Rabi, early Kharif	10484.05	651.28	310.89
Bihar	+	Kharif, Rabi, early Kharif	15035.21	1672.26	833.82
Chandigarh	+	Kharif	0.21	0.21	0
Chhattisgarh	+	Kharif	14759.48	14759.48	400.37
Dadra & Nagar Haveli	+	Kharif	48.18	47.01	0.65
Daman & Diu	+	Kharif	4.69	4.69	0.06
Delhi			0	0	0
Goa	+	Kharif, Rabi	248.33	162.4	17.51
Gujarat	+	Kharif	3156.28	2891.88	256.85
Haryana	+	Kharif	7733.03	7733.03	500.65
Himachal Pradesh	+	Kharif	262.43	262.43	42.71
Jammu & Kashmir	+	Kharif	711.71	711.71	19.31
Jharkhand	+	Kharif	7488.94	7488.94	406.29
Karnataka	+	Kharif, Rabi, early Kharif	8315.67	6272.04	113.16
Kerala	+	Kharif, Rabi, early Kharif	1090.07	332.6	25.39
Lakshadweep			0	0	0
Madhya Pradesh	+	Kharif	5776.53	5776.53	156.52
Maharashtra	+	Kharif	6200.23	6200.23	168.18
Manipur	+	Kharif	994.58	994.58	174.48
Meghalaya	+	Kharif	201.64	122.02	16.41
Mizoram	+	Kharif	122.03	120.26	16.36
Nagaland	+	Kharif	857.59	839.76	23.26
Odisha	+	Kharif, Rabi, early Kharif	15502.85	1509.52	540.24
Puducherry	+	Kharif, Rabi, early Kharif	74.77	25.18	1.01
Punjab	+	Kharif	23067.68	23067.68	4599.73
Rajasthan	+	Kharif	586.46	586.46	0
Sikkim	+	Kharif, Rabi	42.38	42.38	1.15
Tamil Nadu	+	Kharif, early Kharif	12598.97	12598.97	341.76
Telangana	+	Kharif	11429.93	6488.25	248.04
Tripura	+	Kahrif	1786.33	1786.33	38.76
Uttar Pradesh	+	Kharif	27701.21	27701.21	2037.99
Uttarakhand	+	Kharif	1240.69	1137.36	50.48
West Bengal	+	Kharif, Rabi	30648.82	1024.15	297.35
All-India			225165.95	142761.08	12016.81

Data source: National Food Security Mission: https://nfsm.gov.in/dbt/admin/login.aspx

Table 4: State-wise availability, seasonality, total, and surplus biomass production of wheat along with its bioethanol potential

States	Availability	Seasons	Total production (000 t)	Surplus production (000 t)	Bioethanol potential (million L)
Andaman & Nicobar			0	0	0
Andhra Pradesh		Rabi	0.85	0	0
Arunachal Pradesh	+	Kharif	9.48	0.94	0.26
Assam	+	Kharif, Rabi	65.38	3.24	0.89
Bihar	+	Kharif, Rabi	8038.65	824.36	227.52
Chandigarh	+		3.9	0	0
Chhattisgarh	+	Kharif	223.78	44.31	12.23
Dadar & Nagar Haveli			0	0	0
Daman & Diu			0	0	0
Delhi			0	0	0
Goa			0	0	0
Gujarat	+	Kharif, Rabi	5570.24	1654.36	456.6
Haryana	+	Kharif, Rabi	1765.3	1469.98	405.71
Himachal Pradesh	+	Kharif, Rabi	919.88	182.14	50.27
Jammu & Kashmir	+	Kharif, Rabi	695.01	68.81	18.99
Jharkhand	+	Kharif	370.73	18.35	5.06
Karnataka	+	Kharif, Rabi	344.15	27.26	7.52
Kerala			0	0	0
Lakshadweep			0	0	0
Madhya Pradesh	+	Kharif, Rabi	22371.73	4500.38	1242.1
Maharashtra	+	Kharif, Rabi	2329.71	691.92	190.97
Manipur	+	Kharif	8.32	0.41	0.11
Meghalaya	+	Kharif	0.83	0.04	0.01
Mizoram		Kharif	0	0	0
Nagaland	+	Kharif	8.39	0	0
Odisha		Kharif, Rabi	0	0	0
Puducherry			0	0	0
Punjab	+	Kharif, Rabi	25446.21	9374.75	2587.43
Rajasthan	+	Kharif, Rabi	15617	0	0
Sikkim	+	Kharif, Rabi	1.84	0.18	0.05
Tamil Nadu			0	0	0
Telangana	+	Rabi	15.26	0	0
Tripura	+	Rabi	0.91	0.03	0.01
Uttar Pradesh	+	Kharif, Rabi	43180.76	6021.02	1661.8
Uttarakhand	+	Rabi	1222.25	121	33.4
West Bengal	+	Kharif, Rabi	1349.49	66.8	18.44
All India			129560.05	25070.28	6919.37

Data source: National Food Security Mission https://nfsm.gov.in/dbt/admin/login.aspx

Table 5: Simultaneous saccharification and fermentation of lignocellulosic bio-residue

Feed-stocks	Biomass (g)	Acid pre-treatment	Enzyme hydrolysis	Fermentation	Initial sugar (g)	Final sugar (g)	Fermented sugar (g)	Ethanol (g)	Theoretical yield	Conversion efficiency (%)
Paddy straw	10	2% H_2SO_4, 121°C for 45 min	*V. paraheamolyticus*, 55°C 100 rpm for 24 h	*Pichia kudriavzevii* (35°C, 100 rpm for 72 h)	8.12	0.75	7.37	2.88	3.76	76.62
Wheat straw					13.8	0.98	12.82	4.24	6.54	64.85

Conclusion

Increased fossil fuel demand, coupled with the dwindling stock and concerns of global warming, has necessitated the exploration of environmentally sustainable, renewable, and economically viable alternatives to cater to the growing demand for liquid fuel in the transportation and industries sectors. The availability of abundant residues of rice (43.86 Mt) and wheat (25.07 Mt) in India demands for their sustainable utilization in the production of bioethanol. India produces large quantities of rice and wheat residues; bioconversion of these residues into biofuels will aid in prudent waste management by minimizing instances of stubble burning. The prospects of utilizing marine bacterial strain *V. parahaemolyticus* for enzyme hydrolysis and yeast strain *P. kudriavzevii* for fermentation is explored in the bioethanol production process. Simultaneous saccharification and fermentation of paddy straw produced 0.28 g/g of ethanol with a conversion efficiency of 76.62%. Similarly, the simultaneous saccharification and fermentation of wheat straw produced 0.42 g/g of ethanol with a conversion efficiency of 64.82%.

The study highlights that biofuel production from lignocellulosic biomass is eco-friendly and cost-effective, considering the need for energy and environmental security. It facilitates the optimal use of agro-wastes, as of now being burnt in most parts of Asian countries and contributing to air pollution and the associated health impacts. Utilization of paddy and wheat straw will likely produce ethanol of 30-60 L per 100 kg of biomass. The surplus biomass residue generation in every state and its bioethanol production potential helps in evolving appropriate strategies for operationalizing biofuel production units across India. Utilizing the hitherto wasted abundant resources of bio-residues for valuable products is quintessential for lowering the carbon footprint associated with its mismanagement. EF

T V Ramachandra is Co-ordinator and Deepthi Hebbale is Research Scholar at the Energy and Wetland Research Group, Centre for Ecological Science [CES], Indian Institute of Science, Bengaluru

EM'POWERING' LIVELIHOODS IN RURAL INDIA

Major solar projects are underway in India, that are set to reorient our traditional energy make-up. Similar developments can also be seen at smaller scales, albeit at a slower pace. It is these small-scale developments that pack a punch in tackling not only the obvious environmental issues, but also socio-economic issue. **Gayatri Ramanathan** and **Aneesh Anand**, in this article, present a case for the success of DRE and solar mini-grids in elevating lives of their users and the hidden potentiality for businesses enabled by them.

Even as India nears 100% electrification under the SAUBHAGYA scheme, questions related to power quality and availability still need to be addressed. India's per capita electricity consumption stands at 1255 kW—which is around one-third of global average per capita electricity consumption.[1]

Another figure which sheds light on the grim reality of electrification in India is that only 87% of the country's population has access to grid-connected electricity, while 13% remains bereft of grid-connected electricity and relies on non-grid sources of electricity to meet their energy needs.[2] Where access to grid-connected electricity exists, the cost of electricity supply and service are exorbitantly high even as the rural demand density remains low and fragmented.[3]

Issues of supply and quality are the most significant challenges associated with grid-connected electricity in rural India. Supply and quality issues include frequent and long blackouts, low voltages, damage to appliances due to voltage fluctuations, and non-availability of electricity affecting livelihoods. According to a study conducted by the Centre for Energy, Environment, and Water (CEEW), most households surveyed reported facing unanticipated supply disruption and voltage related issues with grid-connected electricity.[4]

The challenge of rural electrification and access is a large one. It may require employing approaches which lie outside the ambit of the conventional grid-connected electrification. The emergence of de-centralized models of electricity distribution have ensured access to electricity for millions of people worldwide, including India. These energy systems are privately operated renewable energy mini-grids, providing the rural populace access to reliable and quality supply of electricity.

Powering lives and livelihoods with solar mini-grids

Rural populations deprived of the predominant form of electrification, grid-connected electricity, have found decentralized alternatives particularly attractive. Mini-grids have become a critical source for last-mile connectivity—serving residential, commercial, institutional, and small industrial loads.

A mini-grid is a set of small electricity generators interconnected to a distribution network that supplies electricity to a small, localized group of customers powered by renewable sources of energy (i.e., solar, wind, hydro).[5] A solar mini-grid, which has an electricity generation capacity that ranges anywhere between a few kilowatts to 10 megawatts, operates in isolation from the national grid network, serving only a limited number of consumers. These mini grids have the potential to reduce energy poverty, and create employment opportunities. They play an important role in bridging the urban-rural gap in economic opportunities by providing affordable, reliable, and quality electricity. Solar mini grids have proliferated not just in villages deprived of grid-connected electricity in India, but also in villages connected to the grid, in states such as Uttar Pradesh and Bihar, marking a significant breakthrough in bridging the existing energy access gap, and successfully ensured electricity access in under-served rural areas. Clean energy mini grids can provide 24x7 reliable and locally managed power, at competitive costs at the same time.

The advantages of these systems are manifold and can serve many purposes, cutting across environmental to economic and social.

» **Environmental:** With greater primacy being attached to renewable sources of energy—in the light of India's updated Nationally Determined Contributions (NDC) and long-term target of achieving net-zero emissions by 2070—promoting solar mini-grids can help bring down greenhouse gas emissions drastically. All this by increasing the power system's efficiency to address the carefully identified needs of the local communities.

» **Economic**: Solar mini-grid projects have lower capital cost in comparison to large power plants with long transmission lines. Proximity of the generation location to the end-use location ensures that the electricity is supplied at a cheaper rate, with little or no transmission loss. These systems can be operated and maintained by the local community itself and result in job creation, along with other business opportunities.

Solar interventions have been fruitful in increasing crop productivity, providing safe drinking water, and even help power child delivery in health centre; underlining that there is a clear business case for solar mini grids as a mainstream technology for providing

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1 PIB India (2022) Share of non-fossil fuel based generation capacity in the total installed capacity of the Country likely to increase from 42% as on Oct, 2022 to more than 64% by 2029-30, PIB India. Available at: https://pib.gov.in/PressRelease Page.aspx?PRID=1885752#:~:text= India%27s%20per%20capita%20 electricity%20consumption,of%20per%20 capita%20electricity%20consumption.

2 "Distributed Renewable Energy Applications Have a New and Encouraging Framework; Applying It on Ground Is Crucial for Success - ET EnergyWorld." ETEnergyworld.com, May 9, 2022. Available at: https://energy.economictimes. indiatimes.com/news/renewable/ opinion-distributed-renewable-energy-applications-have-a-new-and-encouraging-framework-applying-it-on-ground-is-crucial-for-success/91434372.

3 NITI Aayog, and Smart Power India. Rep. Electricity Access in India: Benchmarking Distribution Utilities. The Rockefeller Foundation, 2020.

4 Palit, Debajit, and Gopal K Sarangi. Rep. Renewable Energy Bases Rural Electrification: The Mini-Grid Experience from India. New Delhi: GNESD, 2014.

5 Agrawal, Shalu, Sunil Mani, Abhishek Jain, and Karthik Ganesan. Rep. State of Electricity Access in India. New Delhi: Council on Energy, Environment and Water, 2020.

power even for non-energy sectors, like agriculture and water.

» **Social**: Solar mini-grids are suitable for rural areas and have the capacity to expedite the process of rural electrification manifold . These systems also support a wide range of social benefits which include improved communications, education, and healthcare.

Policy framework for mini grids in India

Mini grids were first promoted by the Ministry of Renewables Energy (MNRE) under the National Solar Mission as components of the off-grid and decentralized applications programme, about a decade ago. Government of India (GoI) came out with a *Draft National Policy on Mini and Micro-grids* in 2016, which aimed at deploying at least 10,000 renewable energy based mini and micro grids within five years. There is no policy in place as yet; however, the draft managed to inspire various state governments to prepare their own respective policies (Uttar Pradesh Mini-grid Policy, 2016; Odisha Renewable Energy Policy, 2016; Promotion of Bihar New and Renewable Energy Sources, 2017).

The government's policy focus shifted to grid-connected electricity access for all in 2017 and the *Pradhan Mantri Sahaj Bijli Har Ghar Yojana* (Saubhagya) was implemented to cover the 19,679 unelectrified villages. Currently, 18,374 villages have been electrified.[6]

In contrast, it became clear last year that the government had not closed the door on DRE-based electricity access, when MNRE introduced a framework for implementing DREs with livelihoods in focus. The reason is not far to seek—DRE based electricity is cheaper and reliable for the end-consumer. The discoms face considerable challenges in supplying 24x7 electricity to remote villages with low loads–low tariff and collection rates, versus the high cost of supplying continuous power, in addition to significant aggregate technical and commercial (AT&C) losses. MNRE's framework seeks to facilitate the development of an enabling ecosystem for widespread adoption of DRE for sustainable livelihoods in the country; through promoting DRE livelihood opportunities. It also looks at unlocking easy access to finance, by linking with existing financing schemes or through new innovative financial instruments.

The socio-economic case for solar mini grids

We have chosen two case studies to highlight the impact solar-mini grids are having on the rural landscape in India.

6 http://www.saubhagya.gov.in/dashboard (as of 03.05.2023)

» **Study 1: Socio-economic uplift in tribal district of Gumla, Jharkhand**[7]

Installation of a 30-kilowatt solar mini grid in Guniya village, in the Gumla district of Jharkhand, changed the fortunes of its residents. Gumla is among the most backward districts in the state and most of its population belongs to a tribal community. The villages are marred by an erratic supply of power despite being connected to the grid. The entry of solar-based DRE helped ensure access to reliable and quality electricity, as opposed to the erratic grid-connected electricity available earlier. Solar energy was introduced in Gumla district by a West Bengal-based NGO and Indian Renewable Energy Development Agency (IREDA) with the installation of a 30-killowatt solar mini grid.

Birsuni Oraon, a tribal woman in her 50s, saw her life change for the better with the introduction of this min-grid. Birsuni, who was earlier occupied with household chores and farm-related work, now operates a small-scale business that runs on renewable energy. Power from the solar mini-grid ensured uninterrupted supply of electricity for the people of Guniya; where electricity-dependent work was difficult to conceive earlier due to disruptions caused by erratic grid-connected electricity. It remained a big impediment to setting up any machine-run commercial work or enterprise. With the arrival of solar power in the village, that impediment has been taken care of and uninterrupted supply of power from the solar mini grid has given the villagers the liberty to use it as they see fit.

Solar mini-grid enabled Birsuni and many others like her to form a self-help group (SHG) and set up a mustard processing machine to extract virgin mustard oil, which is then sold to nearby rural households. This enterprise, operated purely on renewable energy, helped Birsuni earn an additional income while working at a time of their own convenience.

The story of Nilavati Oraon from the nearby Basua village is similar to Birsuni's. Nilavati, who is in her thirties, uses solar power to run two flour machines for processing whole grain wheat into flour. Solar energy is seen as a reliable alternative to grid-connected electricity for women. For instance, Nilavati enjoys the privilege of working after completing her household work. Solar mini-grids have supplemented and strengthened the supply of electricity in Guniya and Basua, enabling micro-enterprises like Birsuni's and businesses like Nilavati's to thrive. These have triggered economic growth and opportunities for the villagers, by addressing issues of low voltage and frequent power cuts. It has also played a part in bettering the social fabric of these communities, by allowing easy access to resources and propagating innovations at all levels of society.

Study 2: Solar revolution in Maganpur in the Ramgarh district of Jharkhand

Surrounded by at least five coal mines, Maganpur has undergone a kind of green energy revolution, in wide contrast to other villages in Jharkhand's Ramgarh district. The Scroll's coverage cites an exciting tale of DRE-facilitated growth of livelihood opportunities in the small hamlet of Maganpur.

The life of Reyajudin Ansari, a tailor, changed for the better after he acquired two solar panels with the help of Selco Foundation and Agragati, a local NGO. Before the acquisition, power cuts—which lasted anywhere between three to four hours—rendered Ansari's sewing machine unproductive resulting in loss of daily income which amounted to a meagre INR 150/day. The installation allowed for uninterrupted supply of power and helped Ansari raise his daily earnings to up to INR 250 a day. The palpable change (or what Ansari happily terms "*badlav*") inspired his neighbours to follow suit: with more people wanting solar panels of their own.

These are just two examples of individuals and entire villages that have benefitted from DRE installations. A recent study by Power for All foundation showed that the sector employed nearly 80,000 people as of 2021,[8] expected to go up to 89,000 this year. CEEW estimates[9] that if India achieves its target of 500 GW of clean energy by 2030, around 3.5 million jobs will be created and majority of them would be in the rooftop solar systems; that by 2030 nearly 25 million livelihoods can be augmented using DRE-based systems.

Conclusion

It is clear from the foregoing that there is definitely a business case for solar mini grids as an enabler for enhancing rural livelihoods. Additionally, it has the potential to reverse migration from rural areas as well. Last year's framework issued by the MNRE has the potential to scale-up mini grid penetration. A clear policy push combined with market direction can help us unlock the huge potential for transforming rural India. EF

Gayatri Ramanathan is Senior Director, ESG Practice at Kaizzen PR.
Aneesh is Associate, ESG Practice at Kaizzen PR.

[7] Das, Binit, Aditya Batra, and Jasleen Bhatti. Rep. Mini-Grids - A Clean and Just Transition. New Delhi: Centre for Science and Environment, 2022.

[8] https://www.powerforall.org/resources/reports/powering-jobs-census-2022-focus-india

[9] Jain, Abhishek, Fellow and Director (Powering Livelihoods) at the Council on Energy, Environment and Water (CEEW), in Mongabay. Available at : https://india.mongabay.com/2022/09/decentralised-renewable-energy-set-to-see-increased-jobs-in-rural-india-may-aid-in-reverse-migration/


SAMSUNG

A TOOL THAT COULD SCALE UP RTS PROJECTS IN MP

In this article, **Sapna Gopal** provides an overview of an Explorer Tool built by the Centre for Study of Science, Technology, and Policy (CSTEP) to help scale up the installation of rooftop solar projects in the state of Madhya Pradesh. This tool will help ease installation, which can often be an impediment and discourage prospective users.

The Centre for Study of Science, Technology, and Policy (CSTEP) formally launched its Rooftop Solar (RTS) Explorer tool for Madhya Pradesh on March 21, in Bhopal this year. MP has always been a proponent of solar power—strong leadership with a proactive stance towards rooftop solar percolates from the top at the Energy Department to the three discoms (distribution companies) in MP. Based on this, CSTEP began work in five cities, viz. Bhopal, Indore, Gwalior, Jabalpur, and Sanchi.

The Centre for Study of Science, Technology and Policy (CSTEP), one of the leading think tanks in the country, aims to enrich policy making with innovative approaches using science and technology for a sustainable society. "Among the states following Gujarat, which is in a league of its own, MP has the potential to become a leader going forward. Also, one of the factors that CSTEP sees is how receptive the DISCOMs are towards rooftop solar", senior policy specialist at CSTEP, Saptak Ghosh, explained as to why MP was chosen to launch the tool.

What is the tool about?

Essentially, the rooftop solar explorer is an innovative rooftop solar capacity estimator and a business case calculator (for 25 years). It uses drone-based high-resolution aerial imagery and rich datasets including annual consumption profiles and connected distribution transformer details.

"CSTEP's approach is to use high resolution aerial imagery (either drones or satellites if available) to map the rooftop potential of individual buildings across entire cities. The imagery collected is used to reconstruct a 3D model of the city with a point cloud. This is used to develop a web-based tool (Rooftop Solar Explorer) which consumers can use to check the technical and financial viability of rooftop solar after taking shading aspects and monthly consumption patterns into account", Ghosh said.

This tool, he adds, was launched primarily to give the consumer information about whether the system is feasible or not: in terms of technical design and economics. It is also given to the DISCOMs and developers to identify all suitable buildings and thereby aggregate demand. "For example, in a particular ward of Bhopal, the identified potential is ~14 MW on ~3,000 rooftops, in the size range of 3–10 kW. Instead of a developer finding it one by one, the tool can allow a bunch of developers to target 3,000 consumers at a time. So, this leads to economies of scale. Therefore, if the developer was quoting INR 60,000 per kW earlier, now he can quote around INR 52,000."

As of now, this has been done for consumers in four cities, across 650 km: Bhopal, Gwalior, Jabalpur, and Indore. All that the consumer has to do is log in with the IVRS number. Every consumer in India has a number associated with the electricity bill. Once the consumer logs in with that number, he/she will go to his/her locality—for instance, when a consumer wants to book a cab, the app asks for the location—and allows access to location. This tool is similar and enables the consumer to access his/her rooftop. Once the consumer clicks on that, electricity bills for the past months come up, because this data is available to CSTEP from the discoms (through a non-disclosure agreement). Based on the electricity bill, the most optimal system is designed for the consumer in terms of minimizing rooftop solar-based generation export to the distribution grid. So, if a consumer has a sanctioned load of 10 kW and the bills are around INR 3,000 to INR 4,000 a month, the tool designs it at 3.5 kW and shows the consumer the best place on his/her rooftop to place that 3.5 kW plant. Along with the system design and placement on the roof, other important techno-economic parameters (such as internal rate of return and payback period) are also shown. If the consumer is not happy with the area shown or wants a lower/higher system size, he/she can customize using the tool and draw polygons on his/her rooftop, or increase/decrease the system size. Then, the tool recalculates based on user inputs and gives the resultant business case and system design.

Detailing on its usage, he added, "It can be used by DISCOMs and developers, to see which are the suitable rooftops in every city and thereby, aggregate demand. If a developer wants to install rooftop solar on a case-by-case basis, that adds 10% to the cost of acquisition to the entire system. It also takes a lot of time and has the possibility of errors, due to manual interventions in terms of drawing complex and abstract shapes during simulations in normal software. CSTEP's approach eliminates these by using the aforementioned 3D point cloud. CSTEP's shading simulations and system size calculations are performed with actual data and pre-feasibility reports are provided for

each rooftop, irrespective of who the consumers are—residential, industrial, or commercial."

The tool can be accessed on *https://rtse.cstep.in/mp/#/*

How is it different from the experiment carried out in Bengaluru?

In Bengaluru, the LiDAR project was carried out from the year 2018 to 2020. At that time, drones were not legal in India. As Ghosh recalls, "We had to use the very expensive light detection and ranging (LiDAR) technology which uses laser machines and flying a helicopter across the city, and this was done at a very high cost. This time, since the use of drones has been legalized, we have used drones—and they are half the cost of LiDAR. Now, it is very affordable and we would like to do it across other states as well."

The proof of concept was Bengaluru; that this kind of technology, using high resolution aerial imagery works. Although the proof of concept was technically viable, it was not economically feasible, due to infrastructural and legal restrictions. Now, the solution that CSTEP are providing is both technically and economically viable.

Will it scale up the use of rooftop?

The state of Madhya Pradesh has some of the most advanced solar projects, which includes the Rewa solar park: the new 600 MW floating solar project (of which 278 MW is already installed), and a project with the World Bank: a public-private partnership (PPP) model wherein 35 MW was installed on more than 250 buildings, including schools and government buildings. However, on the overall, rooftop is still only 258 MW, whereas the target is around 2.2 GW. The target of 2.2 GW was to be achieved by the end of 2022, but that has not been possible.

Ghosh believes this is a very good tool when used properly. "We can launch a tool similar to the one that was done in Bengaluru, but if we expect only the discoms to take it forward, it is not going to work. That is why this in Phase I, we ended it with the launch of the tool on March 21, 2023. The second phase (Phase II) has begun, wherein we are collaborating with local CSOs, NBFCs, developing consumer engagement/awareness activities with the likes of J-PAL, and working with the discoms and the energy department, to ensure that the tool is used correctly."

Companies like J-PAL will do the consumer engagement. They will be involved in the trial, wherein their representatives will go and visit houses/buildings and convince them about the benefits of the tool and that it is apt for them to use rooftop. On the other hand, there is Comfy which is a small financing firm, which will provide loans at 8% to 10%.

However, Ghosh clarifies that the tool alone is not going to scale up rooftop solar. "It needs promotion and must be accompanied by developers/implementing agencies to increase consumer engagement. Also, it needs finances that are coming through. A combination of these factors is what is going to help the rooftop solar sector to grow."

Way forward

CSTEP is in discussions with the Ministry of New and Renewable Energy and state governments. "We use aerial imagery with drones in densely populated areas because there are different buildings, there are different shadow obstacles of trees/poles: that is where a drone-based solution is needed. In rural areas, where it is not so densely populated, satellite imagery can be used without a problem. This is again half the cost of drones."

Ghosh adds that CSTEP is also in talks with many states and is in the process of signing MoUs with them. "The process has begun in the state of Chhattisgarh, with its rural areas. In other states, we have around 11 in the pipeline, where we are partnering with other companies as well."

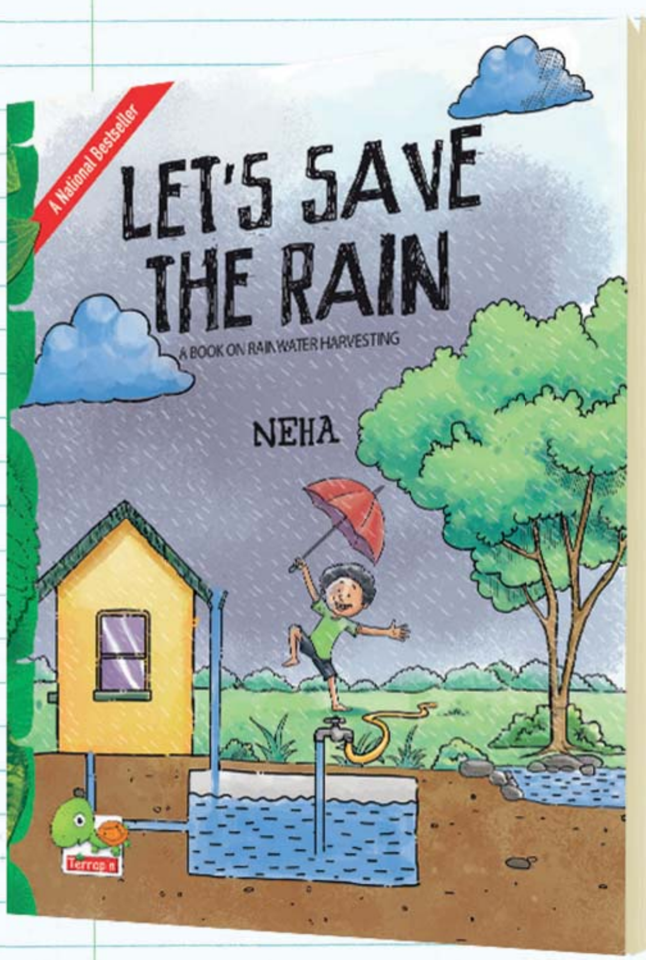
Solar rooftop installations in Madhya Pradesh have seen a huge growth in the last few years. As per the Solar Rooftop Map 2020, by clean energy research and consultancy firm Bridge to India, 313 MW solar rooftop plants were installed in the state of Madhya Pradesh. With plans to make cities within the state net-zero, the number of rooftop installations are definitely going to increase. A case in point is the MP government actively working on a plan to develop Sanchi (a small town in Raisen district), as the world's first net-zero city—and this includes tapping into rooftop solar. Sanjay Dubey, Principal Secretary, Department of Energy, Government of Madhya Pradesh, was recently quoted as saying, "In such a scenario, the tool is surely going to help scale up rooftop solar in the stateIt would be great if you could add a short concluding para, connect RTS tool installation with meeting the energy target of MP".

Suggested links

» https://cstep.in/
» https://www.povertyactionlab.org/initiative-project/increasing-adoption-rooftop-solar-bangalore
» https://www.ecofy.co.in/rooftop-solar

Sapna Gopal is an independent writer and specializes on renewable energy teri

Rain Is Gain When We Harvest Rainwater



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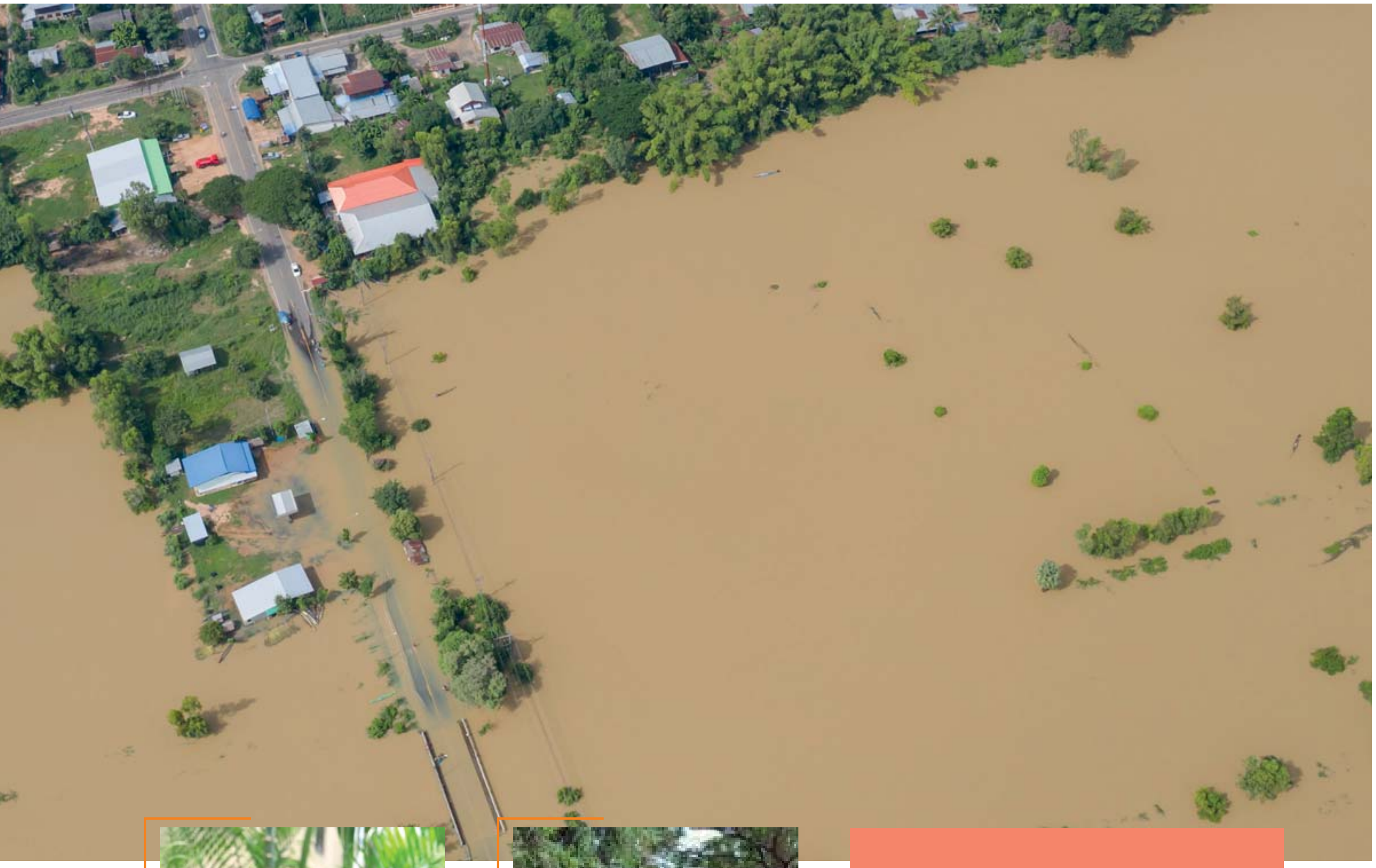
PURSUING INDIA'S CLIMATE VISION



Dr Dhruba Purkayastha
India Director
Climate Policy Initiative India

Debal Mitra
Senior Manager
Climate Policy Initiative India

Dr Dhruba Purkayastha, India Director, Climate Policy Initiative India and **Debal Mitra**, Senior Manager, Climate Policy Initiative India provide their insights about India's climate action journey in conversation with *Dorothy Ashmita Biswas*, Research Associate, TERI.

India is emerging to be a global leader in climate action. What are the foreseeable challenges and opportunities on the way?

India has emerged as a global climate leader due to its sustained legacy of positive climate action, policy intent, and global commitments. The country has implemented energy-efficiency initiatives and competitive bidding for grid-scale renewables, demonstrating its dedication to addressing climate change. It has also shown policy intent by promoting electric vehicles and charging infrastructure, battery storage, and green hydrogen. India has set ambitious targets for net-zero emissions, non-fossil fuel energy proliferation, and meeting and exceeding its Nationally Determined Contributions (NDCs) ahead of schedule. As a result of these efforts, India is now ranked 8th in the Climate Change Performance Index (CCPI) and first among all large economies. It has the lowest per capita greenhouse gas emissions and energy use and has expanded its climate-regulating land cover by approximately 6% compared to 1992 levels. India is the only G20 country within the top 10 ranks.

As the world's largest emerging economy, India faces significant challenges in pursuing its climate vision while maintaining high economic growth, energy security, and affordable clean energy access for all citizens. Some of the prominent challenges include ensuring a just transition away from fossil fuels—without causing widespread stranded assets and job losses in coal-dependent regions. Decarbonizing hard-to-abate sectors such as steel, cement, oil and gas, and aviation presents complex challenges as these sectors rely on deeply embedded technologies that are difficult to replace with low-carbon alternatives. India also needs to develop a long-term adaptation strategy and institutionalize resilience to cope with increasing climate events and protect vulnerable sectors like agriculture. Additionally, there is a significant climate finance gap that needs to be addressed to achieve India's climate goals.

Despite these challenges, India has several opportunities to further its climate leadership. It can continue to lead in solar energy and extend its expertise to disaster resilience by collaborating with other vulnerable countries; through initiatives like the International Solar Alliance (ISA) and the Coalition for Disaster Resilient Infrastructure (CDRI). India's position

as an interface between the Global North and Global South allows it to advocate for the interests of developing countries, while leveraging its climate leadership and bargaining power. The country can also focus on developing off-grid renewable energy solutions, utilizing its low solar costs, abundant biomass resources, technical skills, and social impact sector to benefit rural and semi-urban communities. Furthermore, India can capitalize on its competitive renewable energy rates to become a significant developer of green hydrogen, which has the potential to address multiple energy transition challenges and replace fossil fuels in various sectors.

India has set ambitious goals through the National Green Hydrogen Mission, aiming to develop significant green hydrogen production capacity, and associated renewable energy capacity, attract substantial investments, create jobs, reduce fossil fuel imports, and abate greenhouse gas emissions. The country's industrial giants, such as RIL, GAIL, NTPC, IOC, and L&T, are already investing in green hydrogen manufacturing facilities. Green hydrogen can serve as a panacea for energy transition problems, with applications ranging from petroleum refining and ammonia production to powering heavy transport and replacing fossil fuels in hard-to-abate sectors like steel, cement, and aviation. India aims to become an exporter of hydrogen, contributing to global electrolyzer capacity and driving down green hydrogen prices worldwide.

In conclusion, India has made remarkable strides as a global climate leader, but faces significant challenges on its path to achieving its climate vision. By addressing these challenges and capitalizing on opportunities, India can continue to lead in renewable energy, disaster resilience, and green hydrogen development, contributing to global efforts in combating climate change.

What effect will India's ambitious climate commitments have on Indian economy, and its growth prospects?

According to the High-level Policy Commission on Getting Asia to Net Zero, achieving net-zero emissions by 2070 could boost India's economy by as much as 4.7% above the projected baseline growth in GDP terms by 2036—worth a total of USD 371 billion—with long-run effects still maintaining 3.5% growth above baseline by 2060.[1] A substantial part of this positive payoff (estimated at USD 236 billion) is attributed to the improved trade balance due to reduced demand for imported fossil fuels. This will be complemented by the impact of an estimated net increase in employment opportunities (additional 15 million jobs created beyond a baseline scenario by 2047) and household savings of USD 9.7 billion in energy costs by 2060. This makes India an ideal candidate country to demonstrate the approach to green growth.

This may be also seen in contrast to the negative impact on the economy of climate change in business-as-usual scenarios, as modeled by other researchers.[2] Even while capping the

1 https://asiasociety.org/sites/default/files/2022-09/ASPI_Getting%20India%20to%20Net%20Zero_Report.pdf

2 Kahn, M.E., Mohaddes, K., Ryan, N.C., Ng, R.N., Pesaran, H., Raissi, M., Yang, J. Long-term macroeconomic effects of climate change: a cross-country analysis. IMF Working Paper

global temperature rise below 2°C, India's per capita GDP gets depleted by 2100. On the other hand, if global temperature is allowed to increase by 4°C, the de-growth by 2100 could go up to 9.9%. In the event of a tardier adaptation, GDP depletion could rise even further to 13.4%.

There is a lot of noise about the gaps in climate finance. How do you see it? How can the current climate finance gap be addressed on the road to net-zero by 2070?

Climate finance flows are insufficient for India and the global community. Global financial flows in 2022 reached USD 1.3 trillion, but investments need to increase fourfold to meet the 1.5°C scenario. Developed economies, which possess funding sources, have been slow or unwilling to provide adequate climate finance to emerging economies in the Global South, creating a gap in funding for climate action.

In the case of India, the country received green finance flows of INR 3 lakh crore (approximately USD 44 billion) in 2019–20, while annual investments of around INR 11 lakh crore are required to meet its NDCs. Most financing came from commercial banks and institutions, federal and state governments, and public sector units. Foreign inflows accounted for only 12% of the total, with bilateral and multilateral development finance institutions and foreign direct investment as the main sources. Philanthropic funding was minimal.

India, along with other developing economies, has consistently voiced concerns about the inadequate finance flows from developed countries. Given that the historical consumption of fossil fuels by developed nations is responsible for the majority of current emissions, they should bear a greater burden of financing, in line with the principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC) under the UNFCCC.

However, India's case differs slightly from other emerging economies due to its rapid economic growth and financialization of savings. The country has experienced significant growth, and there has been a shift towards financial investments, which could provide a potential solution for bridging the climate finance gap.

If fund managers allocate 30% of the incremental yearly addition to managed investments into green projects, it could help bridge the financing gap. However, effective intermediation and policy levers are needed to direct incremental financial savings toward green initiatives and establish channels for adequate flow. Government policies favouring green sectors, such as electric vehicles and green hydrogen, are crucial for directing financial flows. The greening of the financial system is also essential, as a significant portion of investments has traditionally gone to the banking, financial services, and insurance sector. Banks and financial institutions have started tracking financed emissions and are expected to limit exposure to high-emitting businesses in the future.

The issuance of green bonds can also guide financial flows toward green applications. India has witnessed a healthy increase in green bond issuance, including sovereign green bonds and municipal green bonds. Carbon pricing

and carbon ratings can drive financing towards green assets and away from carbon-intensive sectors.

Supportive mechanisms like blended finance and risk mitigation structures can address bottlenecks in financing. Institutional support, including dedicated vehicles capitalized by public money, can facilitate large-scale investment in capital-intensive technologies like carbon capture and green hydrogen. On the other hand, climate tech startups and microenterprises with unproven concepts need support in the form of patient capital.

Micro, small, and medium-sized enterprises (MSMEs) face challenges in accessing finance for energy efficiency projects. Aggregating such debt in special-purpose vehicles supported by blended finance or securitization structures can diversify risks and provide liquidity. While the climate finance gap remains substantial, India can leverage its resources to bridge a significant portion of it through supportive policies, market direction, and collaboration among stakeholders. Seeking guarantees from multilateral development banks and bilateral partners can unlock private capital.

Technical assistance from overseas sources and increased collaboration with donors can aid in the creation of more climate projects. India's geopolitical position and climate leadership can be used to secure multi-sovereign guarantees and attract investment for large climate-positive projects. The country should also tap into overseas sources for technical assistance to support project development.

What role do international partnerships and cooperation play in India's decarbonization project?
India has exhibited its commitment to international partnerships and cooperation, both at bilateral and multilateral levels, within the principle of CBDR-RC as outlined in the UNFCCC to strengthen collaborative initiatives towards climate action.

Bilateral partnerships, such as the EU-India Clean Energy and Climate Partnership, have provided India an opportunity—often beyond official negotiating positions of the collaborating countries—to partake of the best practices and policy frameworks, to acquaint itself with innovative technologies and working of markets, and get access to channels of public and private investments in climate-positive projects. The First EU-India Green Hydrogen Forum instituted in September 2022 has since extended this bilateral cooperation to the realm of green hydrogen. The EU Global Gateway launched on 1 December 2021, focuses substantially on financially supporting green projects in India like green affordable housing, urban green mobility, and sustainable smart cities with concessional loans from development finance institutions (DFIs), like AFD and KfW.

India also participates in multilateral collaborations, where the underlying themes are more broad-based and universally applicable. A singular feather in the cap for India has been setting up International Solar Alliance (ISA) – a global platform on solar energy – along with France and bringing together Governments (114 signatories), multilateral institutions, and developers. The focus has been on analytics and advocacy, capacity building, and programmatic support to member countries in solar production. With the credentials of mooting and running a successful solar programme, India itself has been providing capacity building, financial, and organizational support.

Similar to ISA, the Coalition for Disaster Resilient Infrastructure (CDRI) has also been promoted by India as an international partnership forum of governments, multilateral banks, UN agencies, the private sector, and knowledge institutions to improve the resilience of existing and future infrastructure in the face of growing climate risks and disasters. The Government of India has allocated USD 70 million to support the work of the CDRI. During COP26, India co-launched along with the UK, Australia, and a few island nations the Infrastructure for Resilient Island States (IRIS) Initiative, which focuses specifically on improving the resilience of infrastructure to climate and disaster risks in Small Island Developing States (SIDS) and builds capacity and partnerships towards this objective.

To sum up, India leverages international climate-related collaborations in two ways:

a. with countries of the Global North, it benefits from their support in terms of shared knowledge, technologies, and best practices, apart from possible overseas investments
b. with countries of the Global South, its payoffs from extending similar support are strengthening climate leadership among emerging economies

In your view which aspects are included in the idea of just transition? What would be the role of climate finance in ensuring a just transition in India?

The overall idea of just transition encompasses the following facets:

1. **Recognition justice**: involves recognizing that parts of society might suffer as a result of energy and environmental decisions and identifying such individuals and groups
2. **Procedural justice**: highlighting the right to a fair process for different stakeholders to take part equitably in the decision-making process
3. **Distributional justice**: concerning the equitable distribution of burdens and benefits of energy and environmental decisions
4. **Restorative justice**: primarily aiming to repair the harm done to individuals, instead of focusing on punishing the offender

The gamut of considerations for just transition is, thus, wide in the context of India. It would include stranded assets and loss of jobs/pensions (due to closure of fossil fuel-based industries or cessation of fossil fuel-related economic activities); the decline of communities sustaining on such sectors; loss of revenue streams for public sector corporations (central/state) including royalties, cess, and other levies for governments; increased prices of post-transition products in the event of the significant cost of abatement; and increased financial risk for financial institutions exposed to transition impacts.

The role of climate finance would be to facilitate extraneous interventions to counter these transition impacts, broadly serving the following ends:

» Minimizing costs of—and/or compensating affected stakeholders for—early retirement of fossil fuel-based assets
» Managing/reducing the increased cost of energy (services) or cost of adoption of alternate technologies through lumpsum payments,

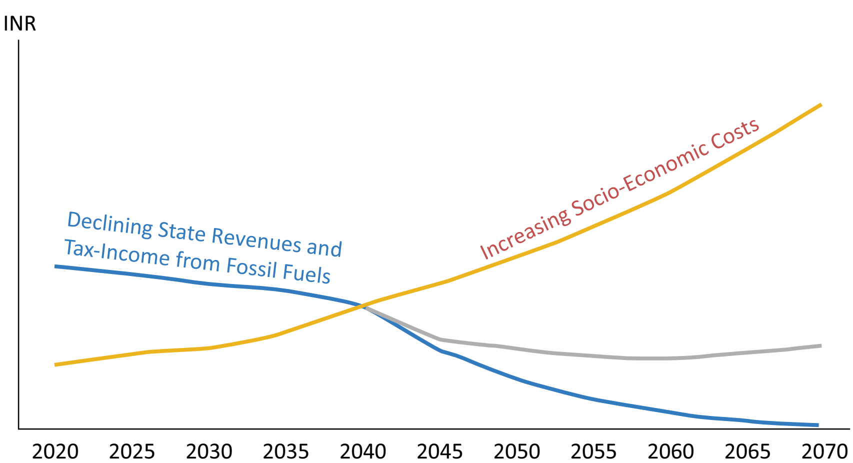


Figure 1: Just transition assistance finance would have to provide for the decline in revenue from fossil fuels

subsidies, tax rebates, loan guarantees, etc.

- Minimizing cost of research, design, development, and demonstration (RDD&D) of renewable energy/energy efficiency technologies at the proof-of-concept stage (e.g., R&D subsidies, credit guarantee mechanisms)
- Guaranteeing employment/compensation for a job or pension loss (e.g., transition funds, job guarantee programmes); transition services for fossil fuel sector workers including training, reskilling, and finding new jobs
- Identifying business diversification options and devising strategies for sustainable growth
- Identifying economic diversification options for coal-dependent regions, devising development plans and funding infrastructure development in fossil fuel-dependent regions; planning and funding remediation of environmental assets (like coal mines)
- Identifying options to diversify revenue streams for public institutions and devising strategies to recuperate losses

To return all pre-transition actors to *status quo ante*, just transition assistance finance would have to provide for their decline in incomes, as also increased socio-economic costs (net of possible carbon finance mopped up from carbon markets that would presumably have evolved through decades). These solutions are unlikely to yield market returns on their own, consequently must be supported by funding from donor capital, and domestic and international development finance, besides project preparation support from economic and climate think tanks.

What enabling factors would be needed to drive investments in climate action in India?

To drive investments in climate action in India, several enabling factors are needed:

1. **Increased funding from developed countries:** Developed countries should provide a greater share of climate finance, considering that their historical consumption of fossil fuels is responsible for the majority of emissions. This aligns with the principle of CBDR-RC outlined in the UNFCCC.
2. **Greening of public finance:** India's fiscal federalism implemented through finance commission, intergovernmental transfers, and centrally supported schemes, needs major reforms including green tagging and budgeting. It should be directed towards adaptation and resilience investments in cities and climate-vulnerable states.
3. **Directing financial savings towards green initiatives:** Policies should be implemented to guide incremental financial savings towards green end uses. This can be achieved through governmental and institutional policy levers that incentivize investment in green sectors.
4. **Greener financial system:** The financial system should prioritize green investments. Tracking financed emissions and gradually reducing exposure to emitting businesses can help redirect funds towards climate-friendly projects. The greening of the financial system is crucial, especially considering that a significant portion of investments traditionally goes to the banking, financial services, and insurance (BFSI) sector.
5. **Expansion of green bond issuance:** Increasing the issuance of green bonds can effectively channel financial flows towards green applications. India has already seen a rapid growth in green bond issuance, including that of the recent sovereign green bonds (SGBs), and continued efforts in this direction can attract both domestic and international investors. SGBs issued at sovereign rates could benefit sectors in dire need of low-cost capital for sustenance, e.g., energy efficiency and rooftop solar projects of MSMEs.
6. **Implementation of carbon pricing:** Carbon pricing mechanisms can incentivize investments in green assets while discouraging carbon-intensive sectors. India is moving towards the establishment of carbon markets, which will play a crucial role in driving finance towards low-carbon technologies.

By addressing these enabling factors, India can bridge a significant portion of the climate finance gap through its own resources, while also leveraging international support and collaboration.

An analytical framework for state level water-energy-food nexus analysis in India: Insight from implemented policies

Environmental Science & Policy **141**: 33–49
Krishna Mondal, Chandranath Chatterjee, Rajendra Singh

Despite the importance of water-energy-food (WEF) evaluations in disseminating information about WEF security challenges, no study on WEF security at a state or union territory (UT) level has been conducted in India. We have quantitatively analysed the WEF nexus at state/UT level in India using Pardee RAND WEF Nexus Index (PR-WEFNI) for 2015–16 and 2019–20. The Government of India has implemented several policies to ensure India's WEF security. However, none of the studies has analysed the potential impact of implemented policies in WEF nexus changes. We have proposed an indicator-based approach, i.e., a policy implementation score (PIS), which indicates a policy's progress (in %). PIS is calculated by aggregating indicators related to WEF policy implementation to quantitatively investigate the impact of implemented governmental policies on WEF nexus changes. Results indicated significant variations in WEF sub-indices across states/UTs over the two years under consideration. Most states/UTs showed an increase in the Water Sub-index (WSI) and Energy Sub-index (ESI) due to higher values of Water PIS and Energy PIS but a decrease/no changes in the Food sub-index (FSI) due to lower Food PIS. Moreover, overall WSI, ESI, FSI and WEFNI of India increased by 15%, 6.6%, 0.1% and 8%, respectively, in 2019–20 compared to 2015–16. This study assessed the WEF security status of Indian states/UTs, which helped to recognise respective resource-insecure areas. This approach can help policymakers identify problems, make further modifications, and develop area-specific policies to achieve resource security across India's states/UTs and other developing economies worldwide. EF

Keywords: PR-WEFNI, Policy Implementation Score, WEF Nexus, Water Sub-index, Energy Sub-index, Food Sub-index

Optimal sizing and assessment of grid-tied hybrid renewable energy system for electrification of rural site

Renewable Energy Focus **44** : 259-276
Shubhangi Mishra, Gaurav Saini, Anurag Chauhan, Subho Upadhyay, Deepanraj Balakrishnan

In the developing countries, rural and remote sites are rarely connected with the national grid due to the lack of transmission and distribution infrastructure. The development of hybrid renewable energy model is an alternate solution to provide electricity accessibility in such areas. In the present research work, a grid-connected hybrid system model has been developed based on the available renewable resources. The proposed model consists of local renewable sources i.e., solar and biomass along with batteries for storage purposes. Major objectives of the study are to optimize the sizing of PV panels and batteries with power sales or purchases from the grid. The net present cost of the system has been minimized which is subjected to power reliability, SOC of batteries, upper and lower bound of SPV and batteries. Discrete Harmony Search (DHS) Algorithm has been adopted to optimize the system. Among the various considered scenarios, optimal configuration includes 30 kW biomass, 83.50 kWp solar PV, 78.70 kW converter and 38.40 kWh battery bank. Further, the optimization result yields the minimum cost of energy and net present cost as 4.66 INR/kWh and 13.07 million INR, respectively. EF

Keywords: Cost of energy, Hybrid energy system, MATLAB, Optimization, Renewable energy

Financial technology stocks, green financial assets, and energy markets: A quantile causality and dependence analysis

Energy Economics **118** : 106498

Aviral Kumar Tiwari, Emmanuel Joel Aikins Abakah, Xuefeng Shao, TN-Lan Le, Matthew Ntow-Gyamfi

With the development of Industry 4.0 and the urgency of transitioning to a low-carbon economy, fintech and environmentally friendly financial instruments have been widely employed because they have played a crucial role in restoring investor confidence in the financial services sector since the global financial crisis in 2008. They not only help investors diversify their portfolios to hedge against risks and enhance returns, but they also help to reduce the negative impacts of climate change. In this study, we analyze the connections among financial technology stocks, green financial assets, and energy markets using nonparametric causality-in-quantile and cross-quantilogram approaches based on the financial contagion theory. We explore whether the performance of fintech prices across booms and busts affects the prices of eco-friendly assets and energy market prices. Our results indicate that in the short run, fintech is highly directionally predictable in all markets except that of green bonds in the lower quantile. Additionally, in the bullish state, the predictability of all lag lengths is negative. Thus, price movements in fintech markets contribute to the vulnerability of the price levels of renewable and non-renewable energy stocks, green bonds, green equities, and sustainable development. Because financial contagion is closely related to asset pricing, portfolio allocation, risk measurement, and monetary policy, the findings of this paper will be informative to investors, portfolio managers, and policymakers. EF

Reaction engineering during biomass gasification and conversion to energy

Energy **266** : 126458

Shivpal Verma, Andrei Mikhailovich Dregulo, Vinay Kumar, Preeti Chaturvedi Bhargava, Nawaz Khan, Anuradha Singh, Xinwei Sun, Raveendran Sindhu, Parameswaran Binod, Zengqiang Zhang, Ashok Pandey, Mukesh Kumar Awasthi

Bioenergy, as a perspective of the global energy paradigm, makes a significant contribution to the increase in global energy demand and the development of technologies for converting biomass into energy. Biomass gasification is the most preferred option for thermochemical processing. We conducted a comprehensive analysis of biomass gasification and concluded: 1) that the properties of biomass can be both attractive from the point of view of obtaining value-added products and limiters in the final use of biomass products; and 2) most publications are focused on a narrow range of issues dedicated to a specific technology. To eliminate these shortcomings, we consider as common factors affecting the efficiency of thermochemical processes: type of biomass and humidity; gasification agents range of operating temperatures of gasifiers; efficiency of heat transfer; pressure and actually obtaining the necessary characteristics of the final products obtained in combinations of various thermochemical methods of processing biomass, and particular factors: the influence of new techniques (chemical cyclic gasification and catalysis), design features of gasifiers and variability of their use. Based on the conducted research, we believe that the hybrid approach (combining thermochemical, hydrothermal and biological methods) could help in solving the above-mentioned problems and can contribute to the circular economy by reducing waste production and obtaining value-added by-products through the use of machine learning and artificial intelligence methods. EF

Solar energy: A promising renewable source for meeting energy demand in Indian agriculture applications

Sustainable Energy Technologies and Assessments
55: 102905
Authors: Ch. Mohan Sai Kumar, Suman Singh, Manglesh Kumar Gupta, Yogesh M. Nimdeo, Ravi Raushan, Ankit V. Deorankar, T.M. Ananda Kumar, Prasant Kumar Rout, C.S. Chanotiya, Vinod D. Pakhale, Ashween Deepak Nannaware

India is the fifth economic power in the world, and 20% of its GDP is contributed by the agriculture and allied sector. The agricultural sector entails various activities involving land preparation, irrigation, crop growth, harvesting, food processing, etc. For meeting the current agricultural energy demand in India, renewable solar energy has come up as a prime energy source that can reduce the farmer's dependency on the use of conventional energy sources. The regular usage of fossil fuels leads to its depletion and releases considerable CO_2 into the atmosphere. It is estimated that 4600 GW of installed solar energy systems would circumvent about 4 gigatonnes of CO_2 emissions yearly by 2050. As a result, solar energy has been recognized as one of the most promising renewable alternatives to create heat and electricity via solar technologies for agriculture as well as various industrial processes. This review focuses on the status, importance, availability, and applications of solar energy technologies in numerous agricultural operations that are currently taking place all over India. This review also highlights the socioeconomic importance, environmental impact, economic analysis, SWOT analysis, and future technological potential of solar energy uses along with some limitations to its extensive utilization in India.

Keywords: Agriculture, SWOT analysis, Renewable energy, Solar energy, Economics and environmental sustainability, Distillation

Decentralized local electricity market model using Automated market maker

Applied Energy **334** : 120689
Bevin K.C., Ashu Verma

The desire of prosumers to participate in the markets has led to the setting up of Decentralized Local Electricity Markets (DLEM). These markets are usually confined to a small geographical location, often with a small number of participants. Such markets have very low liquidity for participants to trade, so price discovery becomes a cumbersome process. To solve the issue of market liquidity, this paper introduces a DLEM model where market participants can trade with a Liquidity Pool (LP) created by Energy Storage Units (ESU). The market model provides iteration-free price discovery by using an automated market maker (AMM) protocol, which automatically updates energy price in the LP based on demand–supply balance. The efficiency of AMM is further improved using the concept of concentrated liquidity by restricting the trading range. A network loss compensation method is applied to ensure DLEM transactions do not affect the power contracts already committed. Simulation studies are conducted on IEEE 33 bus and 123 bus distribution networks for various energy demand scenarios to show operation of the proposed market model.

How solar radiation forecasting impacts the utilization of solar energy: A critical review

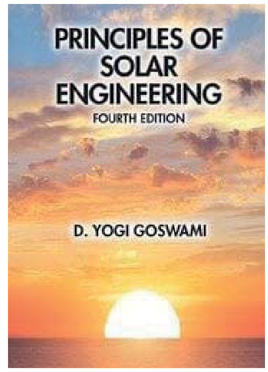
Journal of Cleaner Production **388** : 135860

Authors: Naveen Krishnan, K. Ravi Kumar, Chandrapal Singh Inda

The demand for energy generation from solar energy resource has been exponentially increasing in recent years. It is integral for a grid operator to maintain the balance between the demand and supply of the grid. Solar radiation forecasting paves the way for proper planning, reserve management, and elude penalty since solar energy is sporadic in nature. Several methods can forecast solar radiation; the prior classifications are machine learning models, numerical weather prediction models, satellite imaging, sky imager and hybrid model. This article presents a comprehensive review of all those models with the working principle, challenges and future research direction. Sky imagers provide the Normalized Root Mean Square Error (nRMSE) value of 6%–9% for a time horizon of 30 min, and the satellite imagery technique provides the Root Mean Square Error (RMSE) value of 61.28 W/m^2 – 346.05 W/m^2 for a time horizon of 4 h ahead. Similarly, NWP mesoscale models provide the RMSE value of 411.6 W/m^2 - for three days ahead of forecasting with a spatial resolution of 50 km. Machine-learning models are good at delivering accurate results with the time horizon up to 1 day ahead by yielding the results of RMSE in the range of 0.1170 W/m^2 – 93.04 W/m^2. Deep learning and hybrid models are being developed to overcome the issues faced by the stand-alone techniques. In many research works, artificial intelligence techniques are integrated with NWP models, sky imagers and satellite imagers to improve the data handling algorithm, which implicitly results in forecasting accuracy. EF

Principles of Solar Engineering

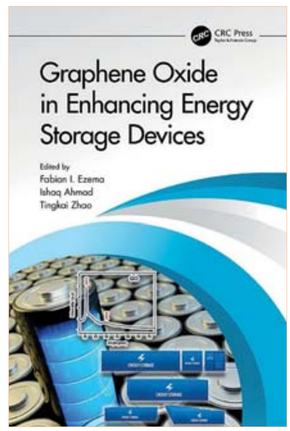
Principles of Solar Engineering, Fourth Edition addresses the need for solar resource assessment and highlights improvements and advancements, involving photovoltaics and solar thermal technologies, grid power, and energy storage. With updates made to every chapter, this edition discusses new technologies in photovoltaics, such as organic, dye-sensitized, and perovskite solar cells, and the design of solar systems and power plants. It also features battery energy storage for distributed and bulk storage and electrical integration with the main solar systems. In addition, the book includes the latest advancements in concentrating solar power plants, such as supercritical CO_2 cycle. Readers will benefit from discussions of the economics of the solar energy systems, which apply to all the systems covered in the subsequent chapters. EF



Author: D Yogi Goswami
Publisher: CRC Press; 656p
Year: 2022

Graphene Oxide in Enhancing Energy Storage Devices

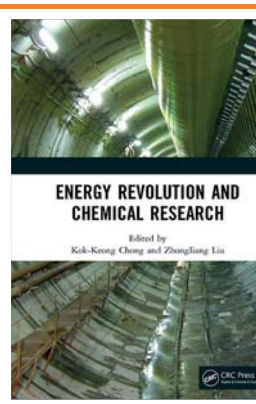
This book provides a broad review of graphene oxide synthesis and applications in various energy storage devices. The chapters explore various fundamental principles and the foundations of different energy conversion and storage devices with respect to their advancement due to emergence of graphene oxide, such as super capacitors, batteries, and fuel cells. This book will enable research towards improving the performance of various energy storage devices using graphene oxides and will be a valuable reference for researchers and scientists working across physics, engineering, and chemistry on different types of graphene oxide-based energy storage and conversion devices. EF



Authors: Fabian Ifeanyichukwu Ezema, Ishaq Ahmad, Tingkai Zhao
Publisher: CRC Press; 302p
Year: 2022

Energy Revolution and Chemical Research: Proceedings of the 8th International Conference on Energy Science and Chemical Engineering (ICESCE 2022), China

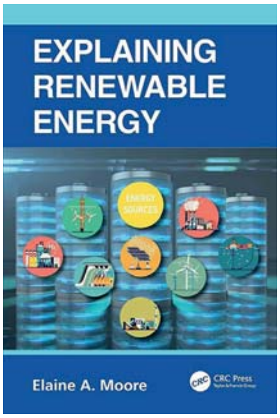
The conference conducts in-depth exchanges and discussions on relevant topics, such as energy engineering, environment technology and advanced chemical technology, aiming to provide an academic and technical communication platform for scholars and engineers engaged in scientific research and engineering practice in the field of saving technologies, environmental chemistry, clean production and so on. By sharing the status of scientific research achievements and cutting-edge technologies, it helps scholars and engineers all over the world comprehend the academic development trend and broaden research ideas; so as to strengthen international academic research, academic topics exchange and discussion, and promote the industrial incorperation of academic achievements. EF



Editors: Kok-Keong Chong and Zhongliang Liu
Publisher: CRC Press; 776 p.
Year: 2022

Explaining Renewable Energy

This undergraduate text aimed, primarily at high schoolers and lower-level undergraduates, focuses on explaining how the various forms of renewable energy work and the current ongoing research. It includes sections on non-scientific aspects that should be considered, such as availability of resources. A final chapter covers methods of removing carbon dioxide from the atmosphere. This text provides students with an introduction into the science behind the various types of renewable energy, enabling them to access review literature in the field and options that should be considered when selecting methods.



Author: Elaine A Moore
Publisher: CRC Press; 102p
Year: 2022

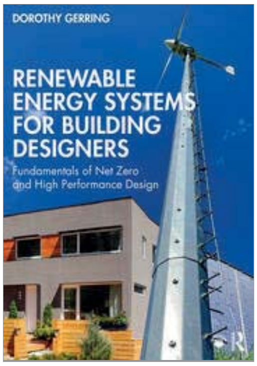
Advances in Energy Materials and Environment Engineering: Proceedings of the 8th International Conference on Energy Materials and Environment Engineering (ICEMEE 2022), China

This new book, *Advances in Energy Materials and Environment Engineering*, covers the timely issue of green applications of materials. It covers the diverse usages of carbon nanotubes for energy, power, protection of the environment, and new energy applications. The diverse topics in the volume include energy saving technologies, renewable energy, clean energy development, nuclear engineering and hydrogen energy, advanced power semiconductors, power systems and energy, and much more. This book addresses the need of the hour and will prove to be valuable for environmentally conscious industry professionals, faculty and students, and researchers in materials science, engineering, and environment with an interest in energy materials.

Editor: Chong Kok Keong
Publisher: Routledge; 972p.
Year: 2022

Renewable Energy Systems for Building Designers: Fundamentals of Net Zero and High Performance Design

Renewable Energy Systems for Building Designers presents a comprehensive introduction to the latest resources and technologies used in high performance and net-zero energy buildings, with a practical focus on the design and integration of these systems. This textbook and convenient reference offers a single-source guide to renewable technologies, balancing broad knowledge with the details of implementation that are crucial for successful sustainable design. It equips students and professionals with foundations and critical information needed to confidently plan for and meet the highest standards of energy efficiency, in new construction and retrofitted buildings.



Author: Dorothy Gerring
Publisher: Routledge; 336p
Year: 2022

RENEWABLE ENERGY TECHNOLOGY DEVELOPMENT

Solar-powered system converts plastic and greenhouse gases into sustainable fuels

Scientists at the University of Cambridge have developed a system which can convert two waste streams into two chemical products at the same time—the first time this has been achieved in a solar-powered reactor.

The reactor converts the carbon dioxide (CO_2) and plastics into different products that are useful in a range of industries.

- In tests, CO_2 was converted into syngas, a key building block for sustainable liquid fuels, and
- Plastic bottles were converted into glycolic acid, which is widely used in the cosmetics industry.

The system can easily be tuned to produce different products by changing the type of catalyst used in the reactor. Converting plastics and greenhouse gases—two of the biggest threats facing the natural world—into useful and valuable products using solar energy is an important step in the transition to a more sustainable, circular economy.

As said by researchers, solar-driven technology that could help to address plastic pollution and greenhouse gases at the same time, could be a game-changer in the development of a circular economy. The researchers developed an integrated reactor with two separate compartments: one for plastic, and one for greenhouse gases. The reactor uses a light absorber based on perovskite; a promising alternative to silicon for next-generation solar cells.

The team designed different catalysts, which were integrated into the light absorber. By changing the

catalyst, the researchers could then change the end product. Tests of the reactor under normal temperature and pressure conditions showed that the reactor could efficiently convert PET plastic bottles and CO_2 into different carbon-based fuels such as CO, syngas or formate, in addition to glycolic acid. The Cambridge-developed reactor produced these products at a rate that is also much higher than conventional photocatalytic CO_2 reduction processes.

» Generally, CO_2 conversion requires a lot of energy, but with this system, basically just shine a light at it, and it starts converting harmful products into something useful and sustainable

» What's so special about this system is the versatility and tuneability

Source: https://www.sciencedaily.com/releases/2023/01/230109112706.htm

Nanoparticles self-assemble to harvest solar energy

The technology transforms sunlight into thermal energy, but it's challenging to suppress energy dissipation while maintaining high absorption. Existing solar energy harvesters that rely on micro- or nanoengineering don't have sufficient scalability and flexibility, and will require a novel strategy for high-performance solar light capture while simultaneously simplifying fabrication and reducing costs.

The device employs a quasiperiodic nanoscale pattern, most of it is an alternating and consistent pattern, while the remaining portion contains random defects (unlike a nanofabricated structure) that do not affect its performance. In fact, loosening the strict requirements on the periodicity of the structure significantly increases the device's scalability.

The fabrication process makes use of self-assembling nanoparticles, which form an organized material structure based on their interactions with nearby particles without any external instructions.

Thermal energy harvested by the device can be transformed to electricity using thermoelectric materials.

» Solar energy is transferred as an electromagnetic wave within a broad frequency range
» A good solar-thermal harvester should be able to absorb the wave and get hot, thereby converting solar energy into thermal energy.

The process requires a high absorbance (100% is perfect), and a solar harvester should also suppress its thermal radiation to preserve the thermal energy, which requires a low thermal emissivity (zero means no radiation).

To achieve these goals, a harvester is usually a system with a periodic nanophotonic structure. But the flexibility and scalability of these modules can be limited due to the rigidity of the pattern and high fabrication costs.

Their quasiperiodic nanophotonic structure achieves high absorbance (greater than 94%), suppressed thermal emissivity (less than 0.2), and under natural solar illumination, the absorber features a fast and significant temperature rise (greater than 80°C).

Based on the absorber, the team built a flexible planar solar thermoelectric harvester, which reached a significant sustaining voltage of over 20 millivolts per square centimetre. They expect it to power 20 light-emitting diodes per square metre of solar irradiation. This strategy can serve low-power density applications for more flexible and scalable engineering of solar energy harvesting.

Source:https://www.sciencedaily.com/releases/2023/02/230221113135.htm

Scientists develop inexpensive device that can harvest energy from a light breeze and store it as electricity

Scientists have developed a low-cost device that can harness energy from wind as gentle as a light breeze and store it as electricity.

When exposed to winds with a velocity as low as two metres per second (m/s), the device can produce a voltage of three volts and generate electricity power of up to 290 microwatts, which is sufficient to power a commercial sensor device and for it to also send the data to a mobile phone or a computer.

» The light and durable device, called a wind harvester, also diverts any electricity that is not in use to a battery, where it can be stored to power devices in the absence of wind.
» Measuring only 15 centimetres by 20 centimetres, the device can easily be mounted on the sides of buildings, and would be ideal for urban environments.

The device, developed also serves as a potential alternative to smaller lithium-ion batteries, as wind harvester is self-sufficient and would only require occasional maintenance, and does not use heavy metals, which if not disposed of properly, could cause environmental problems.

The device was developed to harness efficient wind energy at low cost and with low wear and tear. Its body is made of fibre epoxy, a highly durable polymer, with the main attachment that interacts with the wind and is made of inexpensive materials, such as copper, aluminium foil, and polytetrafluoroethylene, a durable polymer that is also known as Teflon.

Due to the dynamic design of its structure, when the harvester is exposed to wind flow, it begins to vibrate, causing its plate to approach to and depart from the stopper. This causes charges to be formed on the film, and an electrical current is formed as they flow from the aluminium foil to the copper film.

» It could also trigger a sensor device, and power it sufficiently to send the room temperature information to a mobile phone wirelessly.
» It could store excess charge that was sufficient to keep the device powered for an extended period in the absence of wind.

Source:https://www.sciencedaily.com/releases/2022/10/221006092331.htm

Revolutionary battery technology to boost EV range 10-fold or more

A research team developed charged polymeric binder for a high-capacity anode material that is both stable and reliable, offering a capacity that is 10 times or higher than that of conventional graphite anodes. This breakthrough was achieved by replacing graphite with silicon anode combined with layering-charged polymers while maintaining stability and reliability.

High-capacity anode materials such as silicon are essential for creating high-energy density lithium-ion batteries it can offer at least 10 times the capacity of graphite or other anode materials now available. The challenge here is that the volume expansion of high-capacity anode materials during the reaction with lithium poses a threat to battery performance and stability.

However, research to date has focused solely on chemical crosslinking and hydrogen bonding. Chemical crosslinking involves covalent bonding between binder molecules, making them solid but has a fatal flaw: once broken, the bonds cannot be restored. On the other hand, hydrogen bonding is a reversible secondary bonding between molecules based on electronegativity differences, but its strength (10-65 kJ/mol) is relatively weak.

The new polymer developed by the research team not only utilizes hydrogen

bonding but also takes advantage of Coulombic forces (attraction between positive and negative charges). These forces have a strength of 250 kJ/mol, much higher than that for hydrogen bonding, yet they are reversible, making it easy to control volumetric expansion. The surface of high-capacity anode materials is mostly negatively charged, and the layering-charged polymers are arrayed alternately with positive and negative charges to effectively bind with the anode. Furthermore, the team introduced polyethylene glycol to regulate the physical properties and facilitate Li-ion diffusion, resulting in the thick high-capacity electrode and maximum energy density found in Li-ion batteries.

The research holds the potential to significantly increase the energy density of lithium-ion batteries through the incorporation of high-capacity anode materials, thereby extending the driving range of electric vehicles. Silicon-based anode materials could potentially increase driving range at least tenfold.

Source:https://www.sciencedaily.com/releases/2023/03/230329091806.htm

Scientists create high-efficiency sustainable solar cells for IoT devices with AI-powered energy management

Researchers have created environmentally-friendly, high-efficiency photovoltaic cells that harness ambient light to power internet of things (IoT) devices.

Researchers created dye-sensitized photovoltaic cells based on a copper (II/I) electrolyte, achieving an unprecedented power conversion efficiency of 38% and 1.0 V open-circuit voltage at 1,000 lux (fluorescent lamp). The cells are non-toxic and environmentally friendly, setting a new standard for sustainable energy sources in ambient environments.

Them more sustainable and efficient, and opening up new opportunities in industries such as healthcare, manufacturing, and smart city development.

The team also introduced a pioneering energy management technique, employing long/short-term memory (LSTM) artificial neural networks to predict changing deployment environments and adapt the computational load of IoT sensors accordingly. This dynamic energy management system enables the energy-harvesting circuit to operate at optimal efficiency, minimizing power losses or brownouts.

The energy-efficient IoT sensors, powered by high-efficiency ambient photovoltaic cells, can dynamically adapt their energy usage based on LSTM predictions, resulting in significant energy savings and reduced network communication requirements.

Source:https://www.sciencedaily.com/releases/2023/04/230413154354.htm

A solar hydrogen system that co-generates heat and oxygen

Researchers have built a pilot-scale solar reactor that produces usable heat and oxygen, in addition to generating hydrogen with unprecedented efficiency for its size.

A parabolic dish on the EPFL campus is easily overlooked, resembling a satellite dish or other telecommunications infrastructure. However, this dish is special, because it works like an artificial tree. After concentrating solar radiation nearly 1,000 times, a reactor above the dish uses that sunlight to convert water into valuable and renewable hydrogen, oxygen, and heat.

With an output power of over 2 kilowatts, it cracked the 1-kilowatt ceiling for pilot reactor while maintaining record-high efficiency for this large scale. The hydrogen production rate achieved in this work represents a really encouraging step towards the commercial realization of this technology.

» Hydrogen production from water using solar energy is referred to as artificial photosynthesis, but the LRESE system is unique for its ability to also produce heat and oxygen at scale.

After the dish concentrates the sun's rays, water is pumped into its focus spot, where an integrated photoelectrochemical reactor is housed. Within this reactor, photoelectrochemical cells use solar energy to electrolyze, or split water molecules into hydrogen and oxygen. Heat is also generated, but instead of being released as a system loss, this heat is passed through a heat exchanger so that it can be harnessed for ambient heating, for example.

» In addition to the system's primary outputs of hydrogen and heat, the oxygen molecules released by the photo-electrolysis reaction are also recovered and used.
» Oxygen is often perceived as a waste product, but in this case, it can also be harnessed for example for medical applications.

The system could be used to provide residential and commercial central heating and hot water, and to power hydrogen fuel cells. At an output level of about half a kilogram of solar hydrogen per day, the EPFL campus system could power around 1.5 hydrogen fuel cell vehicles driving an average annual distance; or meet up to half the electricity demand and more than half of the annual heat demand of a typical four-person Swiss household. EF

Source:https://www.sciencedaily.com/releases/2023/04/230417142442.htm

ENFINITY GLOBAL ADDS 205 MW OF RENEWABLE ENERGY CAPACITY IN INDIA

Enfinity Global, a leader in renewable energy, has added 205 MW of solar capacity in India through the interconnection of a 135-MW portfolio of projects in the state of Maharashtra and the acquisition of 6 operational projects from Rays Power Infra in the states of Telangana and Karnataka.

"This capacity addition marks an important milestone on Enfinity Global's growth strategy in India. We will continue to strengthen our market presence by developing a hybrid renewable portfolio of about 3 GW as part of our current pipeline and continue to acquire operational assets across segments. We are also expanding into other sustainability areas such as water management, sustainable mobility, hydrogen generation and circular economy" said Sandip Agarwal, Enfinity Global CEO for India.

Commissioning of 135 MW solar energy portfolio in Maharashtra

During the first half of 2022, the company has built and interconnected 135 MW in 10 different solar power plants in the state of Maharashtra. These projects constitute one of the largest portfolios built by any company under Maharashtra state's prestigious Mukhyamantri Saur Krishi Vahini Yojana, which seeks to push forward India's Agri-PV growth and provide day time power to the local farmers, while contributing to a more sustainable agricultural activity. The power produced will be sold to Maharashtra State Power Generation Company (Mahagenco), which has the highest generation capacity amongst all state power utilities in India, under a 25-year power purchase agreement (PPA).

The 250,000 solar panels installed will generate 225 million units of electricity per year, equivalent to lighting 189,000 Indian homes and reducing some 200,000 tonnes of CO_2 emissions, equivalent to the amount absorbed by 9.5 million mature trees.

Acquisition of a 70-MW solar energy operational portfolio in Karnataka and Telangana

Enfinity Global has acquired a 70-MW solar power portfolio from Rays Power

Infra, one of India's most reputed solar developers and EPC management company, which includes six operational plants in the states of Telangana and Karnataka.

The portfolio acquired in Karnataka includes 47 MW spread over three sites, while the plants acquired in Telangana comprise three other sites, totaling 23 MW. All the projects have PPAs signed with state-owned power distribution companies. In six sites total 226,000 solar panels have been installed, generating 108 million units of electricity sufficient to power 98,352 households and save 103,000 tonnes of CO_2 emissions, equivalent to planting 4.9 million mature trees.

"Given their breadth of investing experience in the renewable space around the world and in India in the past, Enfinity Global was uniquely qualified for this acquisition. They are dealmakers and are very innovative and flexible in deal structuring which gives them a huge advantage over others. We are very excited to work with Enfinity on this acquisition and many more projects in the future; as Rays Power Infra continues to expand its operations and portfolio", said Ketan Mehta, Managing Director, Rays Power Infra.

About Enfinity Global

Enfinity Global Inc., together with its subsidiaries, is a US-based leading renewable energy and sustainability services company established in 2019. As a global renewable energy solutions platform, it focuses on developing, financing, building, operating, and owning renewable energy assets. With offices across US, Asia, and Europe, the company develops sustainable solutions that help achieve zero-carbon footprints and enable a smooth transition to a carbon-free economy worldwide (www.enfinity.global).

Enfinity Global is present in India since early 2021—thanks to the integration of Tepsol, a Hyderabad-based solar energy joint venture previously owned by EverStream Energy Capital Management LLC and Think Energy. Enfinity Global envisions a diversified approach to tackling concerns of climate change in India through renewable energy production, water treatment and circular economy solutions.

About Mahagenco

Mahagenco (formerly known as MSEB) is a power generating company in the state of Maharashtra, India and a wholly owned subsidiary of Maharashtra State Electricity Board. Mahagenco has the highest generation capacity among all state-owned utilities in India, it has operating capacity of 13,602 MW comprising thermal, MW hydel, gas turbine and solar. It was established by the Government of Maharashtra under the Central Electricity Act, 2003 with the principal objective of engaging in the business of generation of electricity.

About Rays Power Infra

Rays Power Infra Private Limited is a leading integrated solar power company with presence across the entire solar value chain, including EPC, O&M, and consulting. The company has gained expertise in the transmission, power distribution, and rooftop segment as well. EF

REINVENTION BY BALANCING ENERGY SECURITY AND SUSTAINABILITY

Accenture Report Finds Oil and Gas Leaders Taking Holistic Approach

Reinvention 'reset' seen as critical to achieving a more resilient, agile, sustainable, innovative and profitable future

As recent events—including threats to energy supply in Europe and uncertainty about commodity prices—have led the majority of oil and gas companies to increase their focus on energy security. The more progressive firms are accelerating reinvention plans with a holistic approach to balance energy supply with adopting low-carbon initiatives, according to a new report from Accenture (NYSE: ACN).

The report, titled *The Reinvention Reset – From Bold Plans to Pragmatic Actions*, is based on proprietary industry research and a global survey of more than 200 oil and gas executives. An update of the inaugural report Accenture published last year, the report focuses on identifying the executives' plans to reinvent their companies according to a "5C" model, encompassing competitiveness, connectivity, carbon, customer, and culture.

Participants' responses were aggregated to arrive at a Reinvention Index score for each company. The 10% of companies scoring highest—those taking decisive, holistic actions to bolster capabilities across the value chain, showing signs of total enterprise reinvention—were classified as "Leaders", with the bottom 25% labeled "Laggards."

"Faced with a host of disruptions, from longstanding underinvestment in production to the effects of the pandemic and the war in Ukraine, oil and gas companies must bolster their reinvention efforts now", said Muqsit

Ashraf, a senior managing director at Accenture who leads Accenture Strategy and the company's Energy practice. "An enterprise-level approach is crucial. Companies might be tempted to pay less attention to non-hydrocarbon investments because energy security in the near-term depends on maintaining oil and gas production, but balancing near-term energy security and longer-term energy sustainability will be key to their ability to compete and deliver 360° Value."

Reinvention is dominating the industry agenda, with nine out of 10 respondents (92%) in this year's survey claiming they plan some form of reinvention, whether radical, significant or encompassing fundamental changes. Indeed, 70% of leaders and 50% of laggards view enterprise-wide transformation as a critical component in ensuring they remain competitive.

Hari Shankaranarayanan, Managing Director and Lead for Accenture's Energy Practice in India said, "To manage current and future disruptions, leading oil and gas companies in India are already on a steady path of digital transformation. However, in the new energy system, there is a need to adopt a holistic approach to reinvention using digital tools and platforms. This will enable more value, choices, and customized products and services to build greater customer loyalty, drive future growth, and explore newer revenue streams."

"Building ecosystem partnerships will become critical as customers expand their demand beyond fuel to new areas such as electric mobility, carbon offsets, and non-fuel retail" he further added.

While embarking on such broad, holistic transformations, the report suggests that oil and gas companies should aim for balanced energy portfolios to underpin the future energy system. Indeed, all companies indicate they are increasing their focus on both security and sustainability, but Leaders are taking a more balanced approach, while Laggards are more focused on energy security.

» Leaders are more than twice as likely as Laggards (43% vs 18%) to say that their top portfolio priority involves investing more in natural gas. Additionally, more than half (59%) of the Leaders plan to invest 5–10% of their capital expenditures in low-carbon businesses over the next five years, compared with just 45% of Laggards.
» Emissions reduction has become a key priority for Leaders with 9 in 10 (92%) Leaders setting net-zero targets, compared with 30% of Laggards.

Closing capability gaps in digital connectivity will also be critical as oil and gas firms seek to reinvent themselves; the report identified a large gap between Leaders and Laggards in this area. For instance, 94% of Leaders said that their remote operations are already highly connected and monitored in real-time, compared with just 52% of Laggards.

"Although some companies are making progress with their connectivity efforts, more can be done to scale capabilities in this area", Ashraf said. "To improve digitally enabled connectivity, they can combine technologies, including 5G, edge computing, and AI; invest in new areas like the metaverse to drive the future evolution of connected operations; and invest in people's skillsets to unlock their potential."

This and other Accenture reports can be explored in the company's thought leadership app, Accenture Foresight, which provides a personalized feed of Accenture's latest reports, case studies, blogs, interactive data charts, podcasts and more. For more, visit http://www.accenture.com/foresight.

About the Research

In early 2021, Accenture conducted its inaugural 'Oil and Gas Reinvention Index research' to understand the actions that companies were taking to meet the challenges of energy transition, their progress towards reinvention, and the outcomes they expect to achieve. This initiative, comprising surveys and industry research, was updated in 2022 to track the industry's reinvention progress over time. The 2022 edition of the research included a survey of 201 C-suite executives from 201 companies globally. Responses from each of these participants were aggregated to arrive at a Reinvention Index (RI) Score for each company. The top 10% of the companies on this score were designated as "Leaders" and the bottom 25% designated as "Laggards."

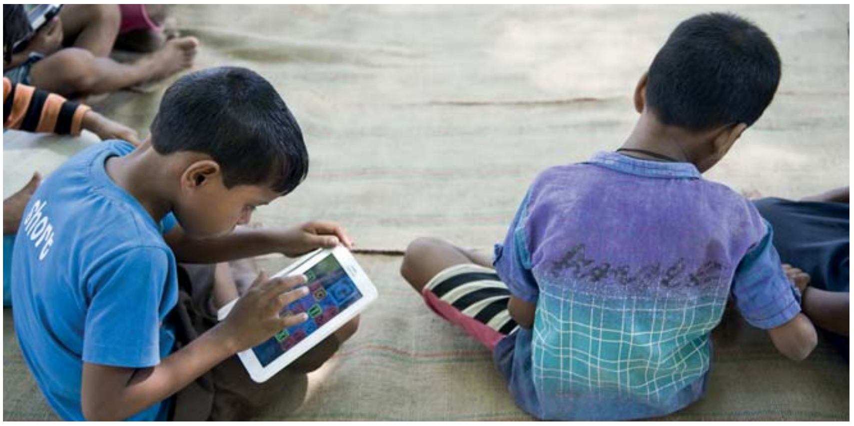
About Accenture

Accenture is a global professional services company, with leading capabilities in digital, cloud, and security. Combining unmatched experience and specialized skills across more than 40 industries, we offer strategy and consulting, technology and operations services, and Accenture Song—all powered by the world's largest network of advanced technology and intelligent operations centres. EF

WIKA'S CSR INTERVENTION

Supporting Quality Education (SDG4) and Affordable and Clean Energy (SDG7)

WIKA Instruments India Pvt. Ltd, the global market leader in pressure and temperature measurement technology, has been implementing CSR projects and activities in the fields of education, health, environment sustainability, and conservation of natural resources in keeping with their commitment to strategies in sustainability efforts and social impact, commemorating their 75th anniversary. As they aligned their business practices to UN's Sustainable Development Goals (SDGs), targeting



positive reporting in 2023, in Social Impact also they rendered a push to social projects that can change lives of the beneficiaries.

They launched *#AccessToDigitalWorld* initiative that enabled students from economically disadvantaged families to enter and better navigate the world of digital learning and tuition to successfully participate in classes, during the difficult times of the Covid-19 pandemic. To facilitate online learning, specially adapted tablets were given to more than 300 students under the corporate social responsibility programme.

Under this same initiative, the Kasturba Balika Vidyalaya of Delhi got complete support from WIKA, to overhaul the school infrastructure and equipment availability; thus, boosting overall development and empowerment of girl child.

According to Mr Gaurav Bawa, Sr Vice President, WIKA India, "It is our pride that we have been able to make a difference for the children we have reached out to. We realized that any intervention will need to be holistic if we want results. Hence, we got associated with Kasturba Balika Vidyalaya and were able to create a difference—in terms of infrastructure, sustainability, and individual student capacity. The school caters to girl students from BPL and average families. WIKA has helped this school in rebuilding its classes, library, as well as in buying computers and tablets required for online education and technology enablement of these students."

While education has been one of the important CSR interventions of WIKA, the company also went onto use the funds for installation of solar energy and investing in renewables. Solar panels have been installed in the school, along with all-four factories of WIKA in India, that are fitted with Solar panels making them a positive supplier to the electricity board. Adhering to the strategy of environmental protection and energy policy, WIKA used solar rooftop solutions to make themselves energy positive.

"Environment is one of our big goals. We not only device tools for alternate energy solutions, we walk the talk by being 100% energy positive ourselves. Our facilities are fully covered by solar power and we provide energy back to the grid. At WIKA, we understand that implementation of sustainable solutions begins at home and an all-round approach to reduce our carbon foot print has been a big agenda for us," Bawa added.

About WIKA India

WIKA India is a wholly-owned subsidiary of WIKA Alexander Wiegand SE and Co KG, Germany, a global market leader in pressure, temperature measurement technology.

WIKA India has established and operates a quality and environment management system according to requirements of international standards (ISO 9001, ISO 14001). Calibration laboratory has received NABL accreditation and is equipped with a high-level primary standard equipment for the calibration.

WIKA in India has state-of-the-art manufacturing operations at Pune, Chennai, Ghaziabad, and Faridabad, drawing upon global experience of WIKA Germany. EF

RENEWABLE ENERGY AT A GLANCE

Ministry of New & Renewable Energy		
Programme/Scheme-wise Cumulative Physical Progress as on April, 2023		
Sector	**FY 2022-23**	
	Achievements (April 2023)	**Cumulative Achievements (as on 30.04.2023)**
I. INSTALLED RE CAPACITY (CAPACITIES IN MW)		
Wind Power	234.95	42868.08
Solar Power*	297.53	67077.88
Small Hydro Power	0.00	4944.30
Biomass (Bagasse) Cogeneration	0.00	9433.56
Biomass(non-bagasse)Cogeneration	0.00	814.45
Waste to Power	0.00	248.14
Waste to Energy (off-grid)	0.00	305.89
Total	**532.48**	**125692.30**

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

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