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ENERGY FUTURE

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COVER STORY

WOMEN AS AGENTS OF CHANGE IN CLEAN ENERGY TRANSITION

FEATURE

WOMEN'S PARTICIPATION IN INDIA'S CLEAN ENERGY TRANSITION

VIEWPOINT

GENDER MAINSTREAMING IN ENERGY SECTOR

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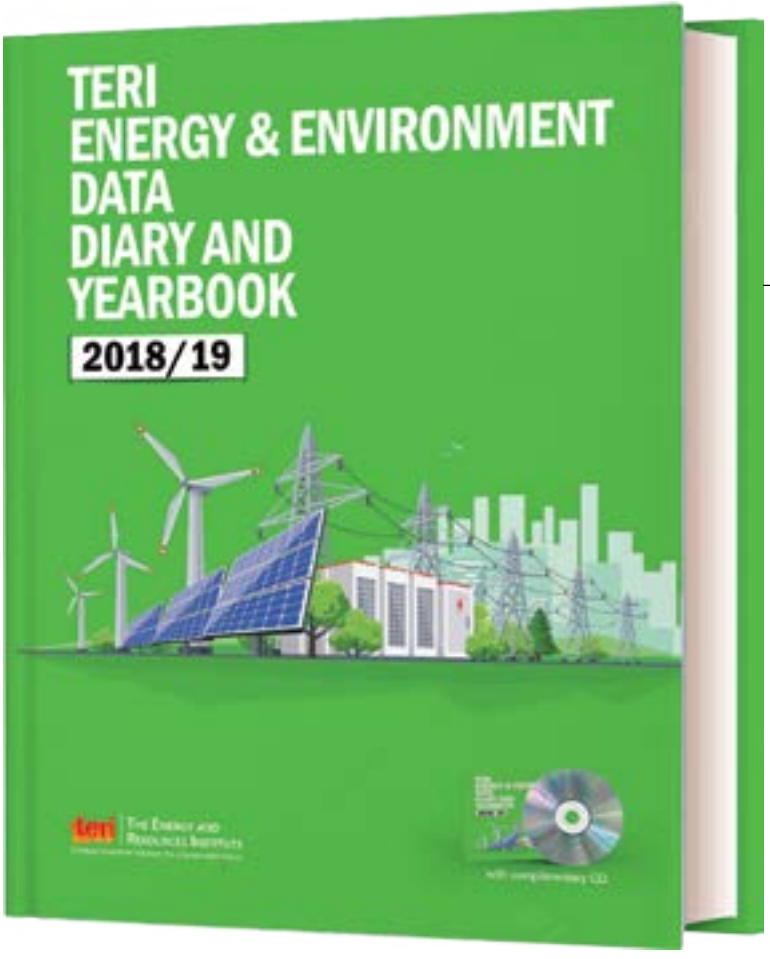

- New chapter on energy consumption in residential and commercial buildings in India
- Section on inter-linkages of various sectors (agriculture, water, land, transport etc.) with Sustainable Development Goals (SDGs) will also be covered.
- Updated data in respective chapters

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Darbari Seth Block, IHC Complex
Lodhi Road, New Delhi – 110 003
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Regional Centres
Southern Regional Centre
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Email: terina@teri.res.in

TERI Europe
27 Albert Grove, London SW20 8PZ, UK
Email: ritukumar@aol.com

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

TERI South-East Asia
Unit 503, 5th Floor, Menara Mutiara Majestic
15 Jalan Othman, Seksyen 3, 4600 Petaling Jaya,
Selagor Darul Ehsan, Malaysia
Email: nimtech@tm.net.my

TERI Gulf Centre
Flat No. 105, Dalal Building, Al Qusais,
Dubai, UAE

From the editor's desk...

What is gender mainstreaming? According to The European Institute for Gender Equality (EIGE), "Gender mainstreaming has been embraced internationally as a strategy towards realising gender equality. It involves the integration of a gender perspective into the preparation, design, implementation, monitoring and evaluation of policies, regulatory measures and spending programmes, with a view to promoting equality between women and men, and combating discrimination." Conventionally, gender considerations in most of discourses around energy have remained in the realm of women as users of energy and appliances. But when clean and renewable energy is viewed from the perspective of sustainable development, one realises that women as users is but a piece of the complicated puzzle energy transition forms. The energy transition – as it is conceptualized now – is not merely about moving from fossil fuels to clean and efficient ones; it is all about this transition being just and inclusive. And seen from that perspective, true dimensions of gender mainstreaming come to fore. And then a woman's role changes from being only a consumer to someone who can contribute meaningfully in myriad ways along the complete energy value chain. TERI itself pioneered it in India when over 15 years ago it helped rural women to become solar entrepreneurs in Sunderbans.

A survey conducted as a part of IRENA's report titled 'Renewable Energy: A Gender Perspective' found out that "Adopting a gender perspective to renewables development is important to ensure that women's skills and views are part of the growing industry…. Greater gender diversity brings substantial co-benefits." Clearly, the pathway to attain SDGs is through enabling much greater and equitable participation of women in decision-making in all the associated spheres. Even from a plain economic viewpoint, it is now a well-established fact that active participation of women in the job markets provides an impetus to the economic growth of that sector or country, which is unparalleled. Thus, carefully crafted policies can help create an environment that brings about a clean energy transformation of which gender equality is the central plank – where positive changes occur around women, they happen because women provided the main motive force, indeed where women act as catalyst for affecting that energy transition in a fundamental manner.

Amit Kumar

Amit Kumar
Senior Director, Social Transformation, TERI

Editor: Amit Kumar Radheyshayam Nigam
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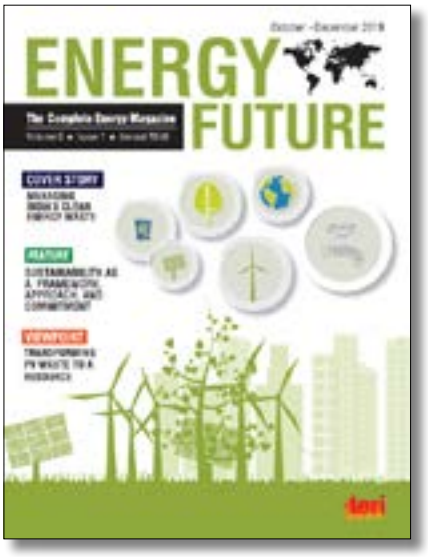

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Letter to the Editor

The cover story of Energy Future October-December 2019 is very pertinent and informative. It elucidates on clean energy waste collection and management. As distributed renewable energy sources such as solar PV and energy storage penetrate deep into the Indian electricity sector, it is necessary to prepare for managing the waste generated from these technologies. The 'reduce, reuse, and recover' approach offers multiple socio-economic co-benefits. There is a need to introduce a holistic policy framework for handling the waste from clean energy technologies.

Biprajit Sarkar
Kolkata, West Bengal

"I liked reading the article on potential and market opportunities for energy generation from agro and livestock waste in India published in the latest issue of Energy Future. It focuses on energy generation from agro and livestock waste in India. India needs a mix of both large-scale grid-connected and decentralized renewable energy to meet its electricity and energy deficits. Development of biowaste energy will also help reduce greenhouse gas emissions. Efforts should be made towards setting up biowaste collection, aggregation and supply chain mechanisms."

Arun Kumar
Bhopal, Madhya Pradesh

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

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

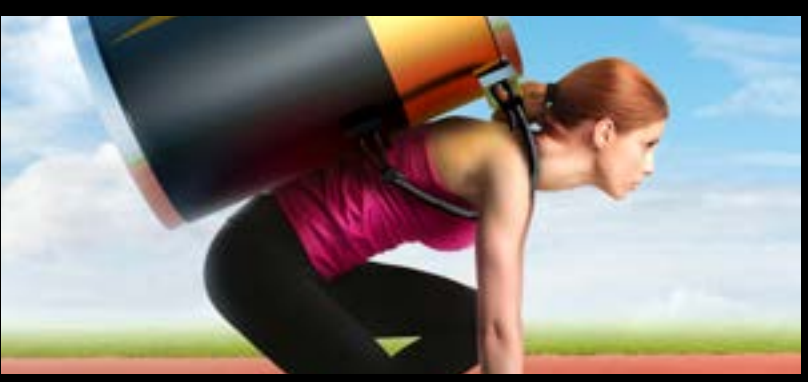
"The Solar Quarterly article published in October-December 2019 issue of Energy Future is very interesting. It discusses the growth made so far in the solar energy expansion in Rajasthan, specifically the setting up of ultra-mega solar parks in the Thar Desert of Rajasthan. India has an immense solar potential . The article has highlighted critical success factors and aspects of the enabling environment in the implementation of solar energy. The issues of clear land and transmission infrastructure are also critical."

Alok Singh
Kanpur, Uttar Pradesh

"The Energy Future magazine provides relevant and interesting information on energy sector. In the latest issue, the article on energy–waste nexus was an interesting read. It talks about sustainable electric vehicle ecosystem that also promotes battery recycling. India needs to overcome resource efficiency challenges and create a sustainable electric vehicle ecosystem. Robust and stable government policies are needed to achieve resource efficiency, circular economy, and transition away from full dependence on imports of rare earth elements."

Arnab Das
Guwahati, Assam

CONTENTS



ANDHRA TO FORMULATE ENERGY EXPORT POLICY TO PROMOTE INVESTMENTS

With an aim to create a conducive environment for increasing power generation and bringing in more investments to the power sector, Andhra Pradesh Chief Minister YS Jagan Mohan Reddy has directed the officials to formulate an energy export policy. The CM noted that promoting investments, and thereby creating employment, in the energy sector should be the objective of the policy.

In a meeting with Energy Department officials on Wednesday, the CM suggested that the policy may encourage companies that set up units in Andhra Pradesh and market them to other states. The CM also directed the officials to explore avenues to reach their objective. A proposal on leasing out land to industrial units in the sector was also discussed, according to a statement from the Chief Minister's Office. EF

Source: https://www.newindianexpress.com/states/andhra-pradesh/2020/feb/27/andhra-to-formulate-energy-export-policy-to-promote-investments-2109123.html

RAJASTHAN PLANS TO SET UP 30,000 MW SOLAR CAPACITY IN 5 YEARS

Rajasthan plans to set up 30,000 MW of solar power plants in next 5 years and is in talks with leading private and state-run companies to develop energy parks, the state's energy minister BD Kalla stated.

"This will add to an already installed capacity of around 50,000 MW in the state," he said.

"We have come up with a new solar policy in which we are giving a host of incentives, including relaxations in stamp duty, electricity duty and transmission and wheeling charges. We are also allowing banking of energy for captive consumption and third-party sale on yearly basis," the minister said.

Recently, the Centre allocated Rajasthan a 25,000 MW ultra mega renewable energy park. The state government has identified land bank of 125,000 ha in three districts, namely, Bikaner, Jaisalmer, and Jodhpur, for this park. EF

Source: https://economictimes.indiatimes.com/industry/energy/power/rajasthan-plans-to-set-up-30000-mw-solar-capacity-in-5-years/articleshow/74310507.cms

CENTRE WEIGHS NEW GREEN ENERGY BOARD TO CALM INVESTORS' NERVES

Concerned with dwindling investor interest, the Union Government plans to set up an inter-ministerial body to settle various issues faced by the green energy sector and attract billions of dollars in investments to successfully execute the world's largest clean energy programme. The proposed Renewable Energy Industry Promotion and Facilitation Board (REIPFB) will be set up along the lines of erstwhile Foreign Investment Promotion Board, which was tasked with handling foreign direct investment proposals and facilitating them.

The government is worried that India's clean energy trajectory may be impacted with banks wary of lending to developers as they suspect the viability of projects that have agreed to sell power at rock-bottom tariffs. There are also issues regarding delay in payments by state-run power distribution companies (discoms), non-allocation of land to wind power projects, besides transmission and connectivity-related challenges.

India is running what will become the world's largest clean energy programme, with an aim of having 175 GW of clean energy capacity by 2022. By then, it plans to add 100 GW of solar capacity, which may need investments of around $80 billion, growing more than threefold to $250 billion during 2023–30. EF

Source: https://www.livemint.com/news/india/centre-weighs-new-green-energy-board-to-calm-investors-nerves-11582134288868.html

TATA POWER PLANS TO HAVE 700 EV CHARGING STATIONS BY 2021

Tata Power is planning to increase its network of electric vehicle (EV) charging stations to 700 by next year, a top company official said.

"We are mapping the locations where EVs are launched and we will be setting up charging stations in those cities. Our aim is to take this number to around 700 by next year," company's CEO and Managing Director Praveer Sinha said.

The government's decision to lower the GST rate on EVs to 5% from 12% is expected to make EVs affordable for consumers with additional income tax deduction.

"We will create infrastructure for home charging as well as public charging like at metro stations, shopping malls, theatres and highways, among others," Sinha said.

The company is already in talks with metro rail authorities and municipal corporations for setting up EV charging stations.

Tata Power has also signed MoUs for setting up commercial EV charging stations at HPCL, IOCL, and IGL retail outlets. EF

Source: https://www.livemint.com/companies/news/tata-power-plans-to-have-700-ev-charging-stations-by-2021-11581944480290.html

AP GREEN ENERGY CORPORATION LTD FORMED

Following the Cabinet decision to set up Andhra Pradesh Green Energy Corporation Ltd (APGECL) to harness solar energy for sustainable power, the Energy Department has issued an order for formation of the same. The Corporation will work on establishment of 10,000 MW solar power projects in the State, mainly to ensure free and sustainable power supply to agriculture sector for 9 h a day.

According to an order issued by Ex-officio Principal Secretary G Sai Prasad, the State is incurring more than ₹10,000 crore annually to meet agriculture subsidy, lift irrigation scheme power charges, and aquaculture subsidy. "Solar energy has the potential to fulfil the above requirements. In order to provide free power supply to the agriculture sector and lift irrigation schemes, the total capacity of solar plants required is likely to be 10,000 MW," the order stated. Andhra Pradesh Power Generation Corporation Ltd (APGENCO) will bear the cost of running the corporation till the latter is able to generate its own revenue. APGENCO and Andhra Pradesh Transmission Corporation will extend all the technical assistance needed to it. EF

Source: https://www.newindianexpress.com/cities/vijayawada/2020/feb/16/ap-green-energy-corporation-ltd-formed-2104168.html

IN A WORLD-FIRST, INDIA'S DOZEN MAJOR PORTS NOW RUN FULLY ON RENEWABLE ENERGY

A dozen of state-owned major ports in the country have switched to renewable energy to meet their entire power requirements, making India the first nation to have all government-owned ports running on solar and wind energy.

Under a 'green port' initiative, the Shipping Ministry had directed all the major ports to install grid-connected and rooftop solar and wind power projects to facilitate day-to-day operations, including supplying shore power to visiting ships in an eco-friendly manner.

The 12 state-owned ports are Deendayal Port Trust, Mumbai Port Trust, Jawaharlal Nehru Port Trust, New Mangalore Port Trust, Mormugao Port Trust, Cochin Port Trust, Chennai Port Trust, VO Chidambaranar Port Trust, Visakhapatnam Port Trust, Paradip Port Trust, Kolkata Port, Trust and Kamarajar Port Ltd. The supply of shore-side electricity to ships (all types of vessels) at ports can reduce emissions, noise, and vibrations and is therefore considered environment-friendly. EF

Source: https://www.thehindubusinessline.com/economy/logistics/in-a-world-first-indias-dozen-major-ports-now-run-fully-on-renewable-energy/article30798156.ece

KARNATAKA'S SOLAR INITIATIVE POWERS CENTRE TO RAISE FARMERS' INCOMES UNDER 2020 BUDGET PLAN

The Centre seems to have taken a leaf out of Karnataka's success story in as far as increasing farmers' income is concerned. The Union Budget 2020–21 proposes to increase incomes of farmers through solar power generation on fallow/barren land, which can be sold to the power grid. Farmers across the country will also be provided with solar pumps to encourage solar power generation.

The Siddaramaiah-led Congress government in the state had introduced a policy where farmers were encouraged to set up solar power generation units on their barren land. It had also set up the world's biggest solar power generation plant at Pavagada.

Union Finance Minister Nirmala Sitharaman, in her budget speech, said the 'annadata' can become an 'urjadata'

too as it has helped remove farmers' dependence on diesel and kerosene. She also announced that the scheme will be expanded to help 20 lakh farmers set up stand-alone solar pumps. "We will also help another 15 lakh farmers solarise their grid-connected pump sets," she said. EF

Source: https://www.newindianexpress.com/states/karnataka/2020/feb/02/karnatakas-solar-initiative-powers-centre-to-raise-farmers-incomes-under-2020-budget-plan-2097904.html

POWER GENERATION FROM ROOFTOPS CLOSE TO REALITY

Launching Soura, an ambitious scheme to generate 200 MW power from solar projects by 2021, the Kerala State Electricity Board (KSEB) on Wednesday signed an agreement with Tata Power Solar to install rooftop solar units at consumers' houses. KSEB aims to generate 35 MW power from the units of 42,500 consumers.

As many as 278,264 consumers have applied for installation of solar units on rooftops under the Soura Scheme. The units will have an installed capacity of 1–10 kW.

The board will sign a 25-year agreement with the consumers for power purchase. The installation of first phase units will be completed by June 2020. The units will be connected to the KSEB grid and a two-way meter will be installed to read the power generated

and consumed. The board aims to generate 200 MW power by installing rooftop units at the houses of the 2.78 lakh applicants. Currently, the KSEB is generating 163 MW power through various solar power plants. EF

Source: https://www.newindianexpress.com/states/kerala/2020/jan/23/power-generation-from-rooftops-close-to-reality-2093220.html

WFO LAUNCHES FLOATING COMMITTEE

World Forum Offshore Wind (WFO) has launched a new committee to help accelerate the global deployment of commercial-scale floating wind farms.

According to the WFO, the international initiative aims to "duplicate – if not outperform – the installed capacity and cost competitiveness achieved with bottom-fixed offshore wind today."

The Floating Offshore Wind Committee brings together "international offshore wind industry leaders" with "internationally recognized" floating wind specialists, representing all aspects of the offshore wind value chain.

As an industry-driven initiative, the Floating Offshore Wind Committee has four key aims. The first is education, advocacy, and policymaking. The second is to enable cost reductions and commercial-scale deployment. The third objective is to promote the highest health and safety standards and the fourth is to engage with environmental stakeholders and maritime space users. EF

Source: https://renews.biz/58779/global-floating-wind-committee-launches/

SOLAR TECHNOLOGY BREAKTHROUGH AT THE UNIVERSITY OF QUEENSLAND

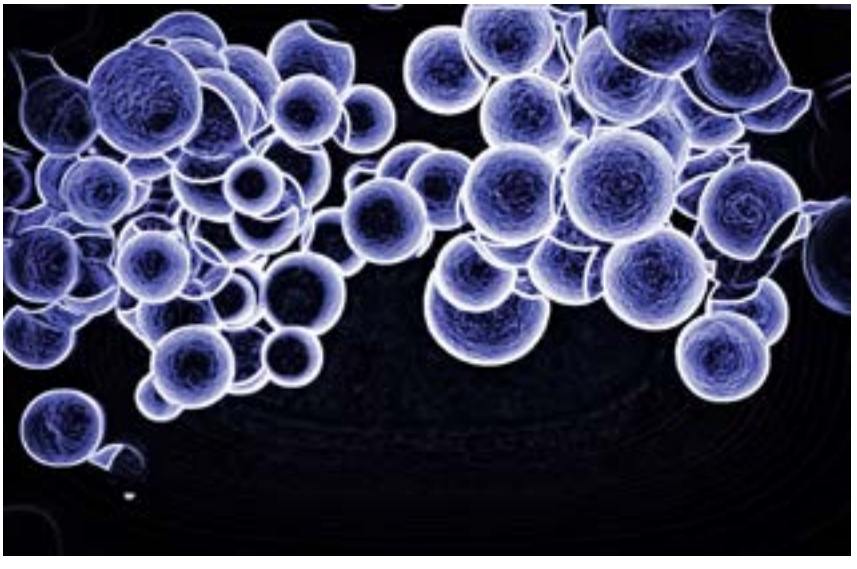
The development of next-generation solar power technology that has potential to be used as a flexible 'skin' over hard surfaces has moved a step closer, thanks to a significant breakthrough at The University of Queensland.

UQ researchers set a world record for the conversion of solar energy to electricity via the use of tiny nanoparticles called 'quantum dots', which pass electrons between one another and generate electrical current when exposed to solar energy in a solar cell device.

The development represents a significant step towards making the technology commercially viable and supporting global renewable energy targets.

Professor Lianzhou Wang, who led the breakthrough, said: "Conventional solar technologies use rigid, expensive materials. The new class of quantum dots the university has developed are flexible and printable."

"This opens up a huge range of potential applications, including the possibility to use it as a transparent skin to power cars, planes, homes and wearable technology. Eventually it could play a major part in meeting the United Nations' goal to increase the share of renewable energy in the global energy mix." EF



Source: https://www.eurekalert.org/pub_releases/2020-02/uoq-stb021420.php

UK'S RENEWABLE ADOPTION RATE "HAS DRIVEN FASTEST DECARBONISATION IN THE WORLD"

The UK's move towards renewable energy sources has helped drive a faster rate of decarbonisation over the last decade than anywhere else in the world. This is according to an independent analysis by academics from Imperial College London for Drax Electric Insights, which says the period saw the power sector's emissions fall from 161 million tonnes in 2010 to 54 million metric tonnes in 2019, a fall of around two-thirds.

The report notes this was largely driven by electricity generators shifting away from coal and natural gas to renewables, combined with a 13% reduction in power demand over the period – this delivered around a third of the sector's emission reductions, while wind energy delivered around a quarter. Dr Iain Staffell of Imperial College London said: "Several factors made significant contributions to falling

emissions, including carbon prices, coal retirements, conversions to biomass, and the growth in wind capacity. But reductions in electricity demand dwarfed all the others – helping to push down power prices and environmental impacts." EF

Source: http://www.energylivenews.com/2020/02/17/uks-renewable-adoption-rate-has-driven-fastest-decarbonisation-in-world/

RENEWABLE ENERGY RISES TO THE TOP OF MIDDLE EAST'S ENERGY AGENDA

The Middle East's energy and utilities sector is undergoing an unprecedented transformation, with the shift towards renewable energy and digital innovation at the heart of ambitious energy diversification programmes. As governments seek to increase energy security and maximize returns from hydrocarbon resources, utilities are pressing ahead with some of the largest renewable energy schemes in the world.

A number of milestones in the push for clean energy across the region were reached in 2019, including the commissioning of the world's largest single-site photovoltaic (PV) solar plant, the 1.17 GW Sweihan independent power project (IPP) in Abu Dhabi. Shortly after the commissioning of the Sweihan plant in March, neighbouring

emirate Dubai reached financial close for a $4.3 billion concentrated solar power (CSP) project, the largest single-site power investment project in the world. EF

Source: http://www.cbnme.com/news/renewable-energy-rises-to-the-top-of-middle-easts-energy-agenda/

THE BIG FOUR IN TECH ARE BUYING INTO THE RENEWABLE BOOM

While the United Nations and expert organizations such as the Intergovernmental Panel on Climate Change (IPCC) have done the professional and diplomatic version of begging, pleading, and crying for more serious and urgent development of renewable energy, the private sector has been slow to respond. As Oilprice reported in November, the "number one bottleneck for clean energy tech" is funding.

Lead sustainability analyst at Bloomberg New Energy Finance Jonas Rooze told PV, "Corporations have purchased over 50 GW of clean energy since 2008. That is bigger than the power generation fleets of markets like Vietnam and Poland. These buyers are reshaping power markets and the business models of energy companies around the world."

Chief among these corporations is the tech sector, which is leading the way for a more emissions-conscious business model going forward. "Google signed contracts to purchase over 2.7 GW of clean energy globally, followed by Facebook (1.1 GW), Amazon (0.9 GW), and Microsoft (0.8 GW)." Let's just hope that the rest of the world is very quick to follow in these footsteps. EF

Source: https://oilprice.com/Alternative-Energy/Renewable-Energy/The-Big-Four-In-Tech-Are-Buying-Into-The-Renewable-Boom.html

PV INSTALLATION RATE SHOULD INCREASE TO MEET RENEWABLE ENERGY TARGETS

The present policies that have been implemented to reduce the emission of global greenhouse gases (GHGs) are not adequate to limit the rising temperature to less than 2°C. The single most crucial component to meet that target is the decarbonization of the energy system. To meet the climate targets, the power industry has to be completely decarbonized much before 2050 and not by 2060. Photovoltaic (PV) represents a major technology for applying this change.

The *PV Status Report* of Joint Research Centre outlines the gap that exists between the European and global climate targets and the deployment speed of solar power.

An installed capacity of 117 GW by the end of 2018 has set back the EU in the global market. In the global installed capacity, the EU's share was around 23%–a marked reduction from the 66% recorded towards the end of 2012. By 2025, the EU should boost its PV capacity from 117 GW to more than 630 GW, and by 2050, the capacity should increase to 1.94 TW to cover 100% of its electricity demands by renewable energy, according to the latest 100% RES scenario of the Energy Watch Group. EF

Source: https://www.azocleantech.com/news.aspx?newsID=26973

UK LOOKS TO OFFSHORE WIND FOR GREEN ENERGY TRANSITION

Britain, a global leader in offshore wind energy, plans to make the sector one of the pillars of its transition to carbon neutrality in the coming decades.

The country aims to quadruple its offshore electricity production capacity by 2030 by utilizing the windswept North Sea and a favourable policy environment.

Prime Minister Boris Johnson's government pledged in its election manifesto to increase power from offshore wind from 10 to 40 GW this decade.

It wants Britain to be carbon neutral by 2050, with onshore wind, solar, hydro, and biomass also set to contribute to its energy mix.

Britain plans to favour the development of colossal offshore wind farms given the country's relatively small land mass. There were 38 operational sites comprising around

2000 turbines at the end of 2018, according to the last available figures from the Crown Estate, the hereditary land and property portfolio of the royal family, which owns most of Britain's seabed.

Nearly 1000 more turbines are already in the planning stages. Johnson has also touted rolling out floating wind farms, which utilize cutting-edge technology still being developed, to tap into windy marine areas with deeper seabeds. EF

Source: https://energy.economictimes.indiatimes.com/news/renewable/uk-looks-to-offshore-wind-energy-for-transition-to-carbon-neutrality/73368665

UAE SUPPORTS, PROMOTES RENEWABLE ENERGY SOLUTIONS IN DEVELOPING COUNTRIES

The UAE has constantly promoted and utilized renewable energy solutions as well as supported and financed developing countries to launch sustainable clean energy projects.

Since the capital, Abu Dhabi, was chosen to be the headquarters of the International Renewable Energy Agency, IRENA, the UAE has led in encouraging the use of renewable energy in many countries, through launching innovative initiatives and reinforcing the multilateral cooperation between the agency's member states, to combat the challenges facing the use of renewable energy sources and promote sustainable development around the world.

The Abu Dhabi Fund for Development, ADFD, has contributed to financing renewable energy projects through joint financing agreements with

the governments of many developing countries.

The UAE has allocated ($350 million) IRENA/ADFD Project Facility, the AED183.6 million ($50 million) UAE-Caribbean Renewable Energy Fund (UAE-CREF), as well as the UAE-Pacific Partnership Fund, UAE-PPF, valued at AED183.4 million ($50 million). EF

Source: https://www.wam.ae/en/details/1395302813595

WOMEN AS AGENTS OF CHANGE IN CLEAN ENERGY TRANSITION

Globally, the energy sector continues to remain the most gender-imbalanced sector. Efforts towards planned engagement and inclusion of women throughout the energy sector are still lacking. In this article, **Fawzia Tarannum** talks about gender mainstreaming or participation of women in clean energy transition, which can propel social and economic transformation in their communities.

The effort to mainstream gender in decision-making, planning, advising, implementing, and managing environment and developmental activities dates back to the Rio Declaration in 1992. Principle 20 of the 1992 Rio Declaration states that "women have a vital role in environmental management and development and their full participation is therefore essential to achieve sustainable development". The need for education and training of women, involvement of women in power and decision-making, and including women in economic activities, among others, were further reinforced during the fourth World Conference on Women entitled 'Action for Equality, Development and Peace' held in 1995 in Beijing (United Nations, 1995). Women empowerment and gender equality were the goals in the Millennium Development Goals (MDGs), and they also find a significant place in the UN Sustainable Development Goals (SDGs). Notwithstanding the efforts, there are crucial challenges in translating rhetoric into reality. The *Global Gender Gap Report* brought out in 2017 by the World Economic Forum (WEF) places India at the 108th position in the overall Global Gender Gap Index, with a poor 139th position in economic participation and opportunity, 112th position in educational attainment, and 141st position in health and survival out of 144 countries (WEF, 2017). According to the Periodic Labour Force Survey (PLFS) data published by the NSSO in 2017–18, female labour force participation rate (LFPR) fell to a historic low of 23.3% from 31.2% in 2011–12 (MoSPI, 2019), indicating that three out of four women in India over the age of 15 are unemployed or not seeking work. Policies, norms, and institutions, which are needed to drive gender mainstreaming in workforce, are mostly gender blind, resulting in inequity in representation and absence of inclusiveness in the development processes.

While involvement of women in the development process specifically related to environmental sustainability cannot be overemphasized, the reality is that their inclusion in energy transition solutions meant for climate change mitigation efforts is rarely considered. The United States Agency for International Development (USAID) in a white paper on *Women at the Forefront of the Clean Energy Future* published in 2014 states that globally the energy sector continues to remain the most gender-imbalanced sector (Pearl-Martinez, 2014). The difference is starker in the conventional energy sector, wherein the percentage of women employed in the mining industry, including coal, is meagre 15% in Australia, 20% in the United States, and 25% in Canada (Pearl-Martinez, 2014). The estimates are higher in the non-traditional sectors such as solar and wind. A survey conducted by IRENA in 2018 with 1500 respondents from governmental and non-governmental organizations, private companies, academic institutions, and other individuals working in the energy sector across 144 countries revealed that women constituted 32% of their renewable energy workforce (IRENA, 2019). However, their participation in science, technology, engineering, and mathematics (STEM) jobs was low at

28%. The situation is quite similar in India with about 30% of the women enrolling in engineering courses and taking up STEM careers (IRENA, 2019). The report also highlighted that women find the multidisciplinary nature of the renewable energy field more attractive than the traditional energy field.

A study by Council on Energy, Environment and Water (CEEW) in 2017 titled 'Greening India's Workforce' underlined that India would add approximately 300,000 jobs in the solar and wind energy sector to meet the Government of India's ambitious target of 175 GW by 2022 (CEEW, 2017). However, the study is silent on gender mainstreaming or participation of women in clean energy transition.

Why Women in Energy Transition?

Energy transition is not just about changing technologies and adopting cleaner energy options, but is also about bringing a social and cultural transition (Fraune, 2015). Therefore, the shift to renewables demands a bouquet of skills (for example, technical, management, social, economic, legal) and is a pragmatic reason for furthering the participation of women in renewable energy. The advantages of gender mainstreaming and inclusion of women in energy transition can be categorized under the three pillars of sustainability, namely, environmental, economic, and socio-cultural.

Environmental

Studies carried out on the impact of women's leadership on environmental gains suggest that companies having more women on the board of directors are more likely to invest in initiatives to reduce carbon emissions (Pearl-Martinez and Stephens, 2016). Likewise, efforts to cut carbon emissions and demarcate protected areas are more likely in countries with higher representation of females in the parliament (UNDP, 2011). Significant gender differences have also been documented in environmental engagement with women showing greater pro-environmental behaviour and concern than men (McCright and Xiao, 2014; Kennedy and Dzialo, 2015).

Economic

Mckinsey, in its report *The power of parity: advancing women's equality in India* published in 2015, pointed out that enabling women to participate in the workforce shall result in 60% higher GDP in 2025 than business as usual (McKinsey & Company, 2015). The World Bank and the World Economic Forum have reiterated that gender diversity at workplace is the driver of economic growth and the performance on gender equality metrics determines a country's national competitiveness (World Bank, 2012; WEF, 2015). Goldman Sachs in its report *Womenomics 5.0* brought out in 2019 stated that Japan is one of the largest beneficiaries of closing the gender employment gap

in the developed world and is placed above the United States and Europe (Goldman Sachs, 2019). The report also stated that if women shift from the part-time employment, which currently stands at 56%, to full time, it will further boost the Japanese economy (Goldman Sachs, 2019). Likewise, the findings of the research conducted in Fortune 500 companies reveal that companies with higher representation of women have higher net income as a percentage of revenue (Pearl-Martinez and Stephens, 2016).

Socio-cultural

'Energy democratization' and 'energy citizenship' are the new terminologies being used to make the energy sector more inclusive (Sweeney, 2012; van Veelen and van der Horst, 2018). It is widely researched and accepted that the vulnerabilities related to transitions and disruptions are gendered and women, poor, and the underprivileged are more affected due to less education, lack of skill, lower access to institutional support and information, and little or no participation in the decision-making (Goh, 2012; Moosa and Tuana, 2014; Rao, Lawson, Raditloaneng, *et al*., 2019; Yadav and Lal, 2018). Policymakers, planners, practitioners, and the public recognize the social risks due to inequity in energy access, but efforts towards planned engagement and inclusion of women throughout the energy sector are still lacking. Access to energy is critical for human livelihoods and wider representation of both men and women can help in generating social awareness, better integration of community needs, and involvement of public in decision-making, resulting in stronger and resilient societies (Wilkinson and Pickett, 2009). Research reveals that engagement of people from diverse groups has resulted in enhanced organizational performance and project outcomes in comparison to homogeneous groups (Hong and Page, 2004). A study conducted by Massachusetts Institute of Technology, Carnegie Mellon University, and Union College to document collective intelligence among teams revealed that the propensity to collaborate effectively is linked to the number of women in the team as women are better at reading non-verbal cues and soliciting greater participation of colleagues than men (Woolley, Chabris, Pentland, *et al*., 2010).

Women and Energy Policy

Even though extensive research has been conducted to establish mutual interdependencies between gender relations and energy policy in both the developing and the developed world, gender mainstreaming continues to remain on the periphery of energy policy (Ryan, 2014). In the case of developing countries, women are generally considered as the beneficiaries of interventions and are seldom involved in the decision-making process (Clancy, Winther, Matinga, *et al*., 2012). The initiatives such as 'Ujjwala' and 'Saubhagya' by the Indian Government are focused primarily on enabling women to fulfil their traditional reproductive tasks with greater ease and in healthier environment. The Integrated Energy Policy drafted by the Planning Commission in 2006 was both inclusive and equitable. It very vividly highlighted the drudgery of gathering fuelwood being borne by women and girl child. It also emphasized on publishing of annual renewable energy report highlighting the social benefits, employment created, and women's participation and empowerment (Planning Commission, 2006). The policy also stressed upon creating women self-help groups (SHGs) and providing finance through these SHGs to transform women from energy gatherers into micro-entrepreneurs engaged in rural energy markets and energy management (Planning Commission, 2006). However, the provisions of that policy barely got reflected in the National Energy Policy of India. The draft National Energy Policy of India dated 27 June 2017 treats gender as a subcategory of poverty and not as a separate category. Consequently, the policy mentions gender only once in the section on clean fuel access, wherein it states that the strategy to provide clean fuel shall have positive ripple effects on public health, gender, livelihoods, and environmental aspects of the country (Niti Aayog, 2017). The word 'women' is mentioned on three instances and all of them are in the context of making clean fuel accessible to rural women.

Operationalizing Women Inclusion in Energy Sector

Inclusion of women in the clean energy transition can be considerably enhanced by taking actions at several levels:

- **Gender disaggregated data**: Projects on energy seldom report gender-disaggregated information and there is very limited data available on inclusion of women in clean energy transition (Cecelski, 2000; Clancy and Feenstra, 2019). Gathering and reporting of gender-disaggregated data is vital to set a baseline for mainstreaming gender in policy design and project implementation in the energy sector (Pearl-Martinez and Stephens, 2016).
- **Gender budgeting**: In order to ensure gender-responsive implementation of projects, it is critical to set an inclusive budget that caters to the specific needs of both women and men and also the budget includes allocations related to gender mainstreaming, hiring of gender experts, conducting gender impact assessment, and collecting sex-disaggregated data (Climate Investment Funds, 2017; SEforALL, 2018).
- **Empanelling gender experts**: Gender relations are embedded in informal institutions and as men usually take decisions on the adoption of energy technologies,

their preferences take priority over women's choices (Clancy, Winther, Matinga, *et al*., 2012). However, gender budgeting and mainstreaming requires awareness of gender issues and knowledge of procedures and ways to include gender in planning and development. Thus, there is a need to include a gender expert in the panel engaged in decision-making related to the energy sector (Clancy, Winther, Matinga, *et al*., 2012).

» **Capacity building**: Women can be integrated in clean energy supply chain at all levels through training and upskilling. While global representation of women is high in administrative and management jobs, such as order booking, customer support, sales and marketing, monitoring and evaluation, their representation in jobs such as research and development and installation and maintenance is low due to a lesser number of women opting to enrol in STEM fields (IRENA, 2019). Enrolment of women in these programmes can be enhanced through targeted scholarships and internships, adjustment in curricula, and vocational training programmes for women (Clancy and Feenstra, 2019; IRENA, 2019). An example of this affirmative action is seen at King's College London, which instituted 'Women in Science Scholarships' in mathematics, physics, computer science, and chemistry to help reduce gender imbalances in STEM fields.

» **Creating supportive and safe workplaces**: Women often are apprehensive of taking up field-based jobs due to lack of appropriate infrastructure, such as toilets, creche facility, and transport, to cater to their specific needs. Implementing policies that provide an enabling environment in the workplace for all gender types shall result in more inclusive hiring. In addition, a forward-looking human resource policy that ensures better work–life balance through provision to work part-time or flexitime, has adequate paid maternity leave, and addresses the issue of motherhood penalty shall attract a large number of women to the energy sector (Clancy and Feenstra, 2019; IRENA, 2019).

» **Gender-balanced teams**: Gender imbalance in the energy sector can be addressed through gender targets, quotas, or reservation for women in teams. For example, Engineers Canada adopted a '30-by-30' programme in 2011 to increase the number of female engineers in the country to 30% by 2030 (C3E, 2017). Even when the national energy policies seldom include gender diversity targets, countries such as France, Germany, and Norway with mandatory seats for women in corporate boardrooms have made considerable progress in gender mainstreaming (IRENA, 2019). Likewise, EnergyAustralia raised women's salaries in 2018 to achieve pay parity with men and attract more women into the clean energy sector (IRENA, 2019).

» **Energy financing**: While financing renewable energy projects continues

to be a challenge, credit from formal banking institutions is particularly a major constraint for women as they do not have land or property in their names to offer as collateral. This is despite the findings of several research studies that women have a better record of credit repayment than men. Committed financing schemes are particularly crucial for active engagement of women in the renewable energy sector, especially the off-grid renewables value chain (Cecelski, 2000). A successful example of this is the Self Employed Women's Association (SEWA) in India, which connects women to financing options through the thrift and credit cooperative, providing affordable payment options to enable women to invest in livelihood activities. SEWA has also established a company that employs women to market, sell, install, and service solar home lighting solutions (Clancy, Barnett, and Cecelski, 2019; IRENA, 2019).

Barriers to Women's Engagement in Clean Energy

Some of the most critical barriers to engagement of women in the clean energy sector are as follows:

- **Role as homemakers:** Women have been traditionally viewed as taking up only reproductive roles, and their integration in the energy value chain remains a challenge in a highly patriarchal society, which considers women taking up traditionally male jobs as a social stigma.
- **Wage inequalities:** Gender wage gap, especially in the semi-skilled and the unskilled category, is another critical factor that impedes the fair integration of women in the renewable energy sector. Women continue to earn lower wages in comparison to their male counterparts for the same type of job, resulting in hardships for them and their families (Pearl-Martinez, 2014).
- **Persistent glass ceiling:** IRENA describes 'glass ceiling' as the "lack of equal representation of women in decision-making roles". Globally, the representation of women in the senior executive positions in the renewable energy sector is quite bleak. Several impediments such as lack of childcare facilities, training, workplace flexibility and mentorship opportunities, and social and cultural norms hamper the advancement of women in the energy sector regardless of their qualification (IRENA, 2019).
- **Lack of role models:** While many key initiatives are being undertaken to

include women in the clean energy transition, there is still a dearth of women role models in leadership positions in the energy domain who can be an inspiration for other women to join the sector.

» Lack of flexible working hours, supporting work environment, mentoring and training opportunities, childcare facilities, and limited mobility are the other barriers to the women integration in the clean energy sector.

Women as Agents of Change

In India, where differences based on gender, caste, class, and ethnicity are embedded in the social fabric and govern the roles, rights, and responsibilities of men and women and the relations between them, women as agents of change in the clean energy transition can propel social and economic transformation in their communities. IFC's 'Lighting Asia' programme in India that focuses on women as distributors and customers to overcome the last-mile challenges associated with creating off-grid market for the solar lighting system is a good example. They partnered with Frontier Markets to build a network of *Solar Sahelis* (solar friends). The women run alliance is nurturing women entrepreneurs in solar lighting space by providing access to funds and technical assistance. The plan is to expand the number of *Solar Sahelis* from 250 women in 2016 to 20,000 women in 2020 (IFC, 2017).

Initiatives to engage more women in the clean energy space are being taken up globally and can be used as a reference point to augment the efforts. The Clean Energy Education and Empowerment (C3E) Initiative launched by the Clean Energy Ministerial in 2010 has mentored over 60 women from 11 countries and built an International Ambassador Corps to mentor other women and promote gender diversity in the energy sector (C3E, 2019). A group of women started a co-operative named 'Quinnovindar' in Sweden to help develop wind companies. Vietnam and West Africa have shown narrower gender divide in engineering training conducted in the renewable space. The Clean Energy Council's Women in Renewables initiative in Australia enables and champions women working in the renewable energy industry and has also instituted Women in Renewables scholarship to enable the professional development of female employees in the clean energy industry (Clean Energy Council, n.d.). It is evident that integration of women in delivering clean energy solutions works as a force multiplier and results in a paradigm shift in socio-cultural norms that have traditionally acted as impediments to their agency. It also provides them the confidence to assert their position in the family and question the oppressive social norms that prevented them from partaking in traditionally 'masculine' roles.

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Dr Fawzia Tarannum is Assistant Professor, TERI School of Advanced Studies, New Delhi. She may be reached at <fawzia.tarannum1@terisas.ac.in>.

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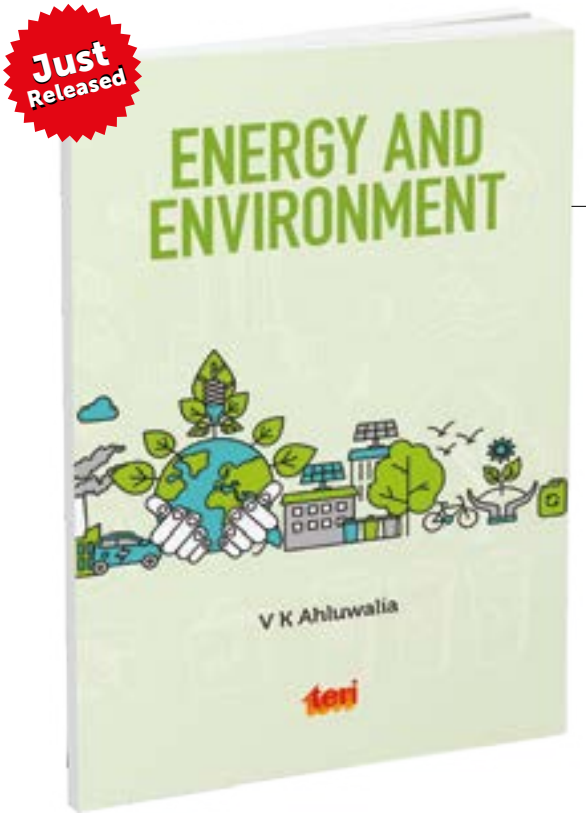

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WOMEN'S PARTICIPATION IN INDIA'S CLEAN ENERGY TRANSITION

A Look at the Rooftop Solar Sector

The energy sector workforce in India is characterized by an underrepresentation of women. Given both the high number and diverse types of jobs that the rooftop solar sector generates, it is well positioned to adopt a gender-inclusive approach to employment, which will attract highly skilled women in particular. In this article, **Shaily Jha**, **Sasmita Patnaik**, and **Yoko Nobuoka** emphasize the need to improve gender diversity and encourage more women to be a part of rooftop solar sector's workforce.

The clean energy transition in India provides enormous potential to embrace a larger female workforce compared to the conventional energy sector. India's commitment towards renewable energy target of 175 GW (gigawatts) in installed capacity by 2022 provides the opportunity to achieve four of the Sustainable Development Goals, namely, SDG 7 on access to affordable clean energy, SDG 5 on gender equality, SDG 8 on decent work and economic growth, and SDG 13 on climate change mitigation. Employment in the clean energy sector has often been associated with positive phrases, such as "new and dynamic" and "contributing to the society through clean energy", and it is known to offer a "flexible work environment". These perceptions provide the opportunity to create a more gender-balanced workforce in the sector.

The need for greater inclusion of women in workforce has been discussed extensively in the literature on labour studies. Studies have revealed a positive correlation among the factors of gender diversity of the workforce, the leadership of an organization, and better financial performance. As per the estimates of International Monetary Fund,[1] India would be richer by 27% if it balances the gender profile of its workforce. Women's involvement in the paid job market leads to their increased financial autonomy, resulting in improved intra-household power dynamics, reducing the likelihood of domestic abuse by male family members, increased spending that benefits their children,[2] and improving the standard of living for women and their families.[3]

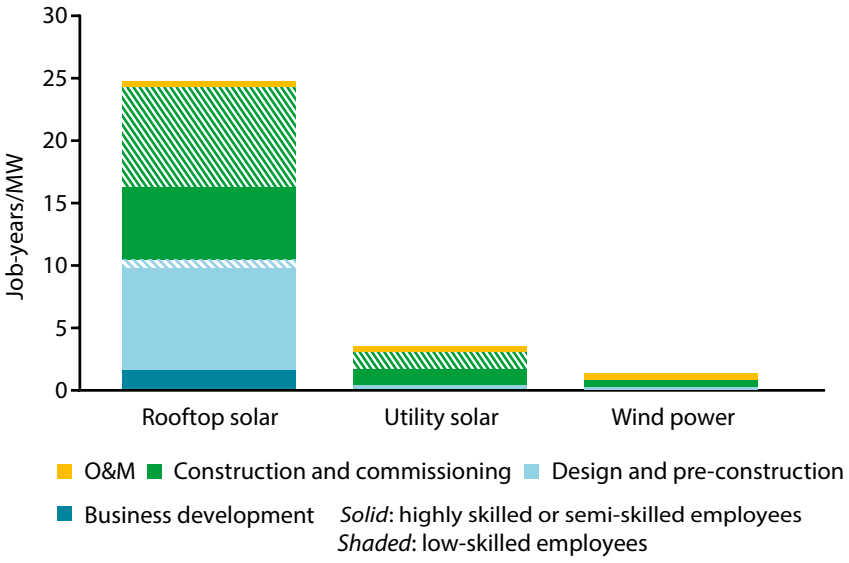

Figure 1 Rooftop solar creates more quality jobs than utility solar and wind power for every GW installed

Note: Excluding solar module manufacturing. O&M stands for operations and maintenance.

Source Kuldeep, N., K. Chawla, A. Ghosh, et al. 2017. Greening India's workforce: gearing up for expansion of solar and wind power in India. CEEW-NRCD report. Details available at https://www.ceew.in/publications/greening-indias-workforce

Why Rooftop Solar?

Despite the strong commitment towards clean energy transition, deployment of rooftop the solar technology has been slow. Although 40 GW of the 175 GW targeted is allocated to rooftop solar photovoltaic, less than 10% of the target has been installed. Thus, the rooftop solar sector has the potential to accelerate its growth towards the government's target in the coming years and create a large number of jobs. The deployment of rooftop solar is relatively more labour intensive among the prevailing renewable technologies, with a particularly high share of high-skilled jobs. Rooftop solar creates about 25 jobs per megawatt (MW) installed across the value chain in India, which is 7–20 times more than that of utility solar or onshore wind technologies.[4] The number of quality jobs created by rooftop solar is eight times higher than that of utility solar.

Given both the high number and diverse types of jobs that the rooftop solar sector generates, it is well positioned to adopt a gender-inclusive approach to employment, which will attract highly skilled women in particular.

What Does the Gender Profile of India's Rooftop Solar Sector Look Like?

Worldwide, while women account for more than 40% of the labour force, this figure is as low as 26% in India. As per the International Labour Organization

[1] IMF (International Monetary Fund). 2017. Girl power. *Finance & Development* 54(1). Details available at https://www.imf.org/external/pubs/ft/fandd/2017/03/picture.htm

[2] Duflo, E. 2012. Women empowerment and economic development. *Journal of Economic Literature* 50(4): 1051–1079. Details available at https://www.aeaweb.org/articles?id=10.1257/jel.50.4.1051

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(ILO),[5] women's participation in the workforce falls below 20% in non-agricultural sectors. The energy sector workforce in India is no exception, characterized by an underrepresentation of women. According to a recent study by International Energy Agency (IEA) and Council on Energy, Environment and Water (CEEW),[6] women account for only 11% of the workforce in the rooftop sector in India. Although this is significantly lower than the overall global average of 32% for women in the renewable sector, it is slightly higher than the percentage of women employed in other energy sectors in India, which is less than 10% in coal, oil and gas companies, and electricity utilities. However, it compares poorly to service sectors, such as technology services and financials, where women represent 20–30% of the workforce.

The rooftop solar sector creates several professional jobs, such as engineers and business professionals (for example, financial professionals, accountants, and human resources professionals), some of which are attractive to highly qualified women. According to Organisation for Economic Co-operation and Development,[7] in 2013 nearly half of all first-time tertiary graduates in India were female. The increase in the number of professional jobs that pull in highly skilled women in the labour market has not kept pace with the increased supply of these qualified women.[8] The emerging rooftop solar sector could leverage this existing pool of qualified and highly skilled women graduates and lead more young women to invest in higher education and vocational training.

While the workforce of India's rooftop solar sector is far from gender parity, office-based jobs in corporate positions and the design and pre-construction segment have more women than onsite jobs. Women's participation is relatively high in the design and pre-construction phase and corporate functions (at 18% and 34%, respectively). However, women constitute less than 3% in the area of construction and commissioning and only 1% in operations and maintenance, which involves frequent travel and onsite project work.

Although women's participation in the sector is important, their ability to access senior positions is equally essential for inclusive development. At the top of the corporate hierarchy, only one-third of the companies surveyed have a female board member. None have more than one woman. Women in senior and mid-level management, in most cases, lead a team or department in the support functions in divisions such as human resources, accounting and finance, and institutional relations. It is rare for women to head engineering or project management teams.

Don't We Have Enough Women with Relevant Academic Background?

The share of women studying engineering and technology in India, a highly recognized academic background for the rooftop solar sector, is over 30%, one of the highest in the world. Despite this, the number of female applicants remains low for positions in the core phases requiring civil, mechanical, and electrical engineering education or professional experience.

Similar sectors, such as technology services, have been able to attract more women (over 30%) owing to an enabling ecosystem that supports women across positions. Relatively high salaries, ease of international mobility, gender-neutral policies based on the possession of knowledge-centric skills, flexible work routines, and physically less demanding work in comfortable indoor work environment are among the most important factors that influence the high participation of highly skilled women in the technology services sector.[9]

The value chain in the rooftop solar sector is inherently different from that of technology services. However, the rooftop solar sector (or, more broadly, the clean energy sector) could emulate the success of technology services in creating work environments and conditions that facilitate women's careers. This could provide the momentum that is necessary if India is to achieve the 2022 target inclusively.

What Prevents Women from Joining and Staying in the Sector?

The emerging and non-traditional nature of clean energy technologies like rooftop solar presents the sector with an opportunity to adopt a gender-responsive approach. To do so, it would be prudent to focus on the barriers in the sector as well as the enabling practices across companies that could be adopted by all in the sector.

The 'Gender at Work' framework has been used widely to identify opportunities and barriers to gender equity, evaluate progress, and build constructive strategies at workplaces. The framework analyses barriers for women across four dimensions, while also classifying them as individual, formal, informal, and systemic. This intersection enables a rethinking of strategy within and beyond workspaces, with a focus on formal policies and

[5] ILO. 2018. Statistics and databases. May 2018. Details available at https://www.ilo.org/global/statistics-and-databases/lang--en/index.htm

[6] IEA and CEEW. 2019. *Women working in the rooftop solar sector: a look at India's transition to clean energy.* Paris: IEA Details available at https://www.ceew.in/publications/women-working-rooftop-solar-sector

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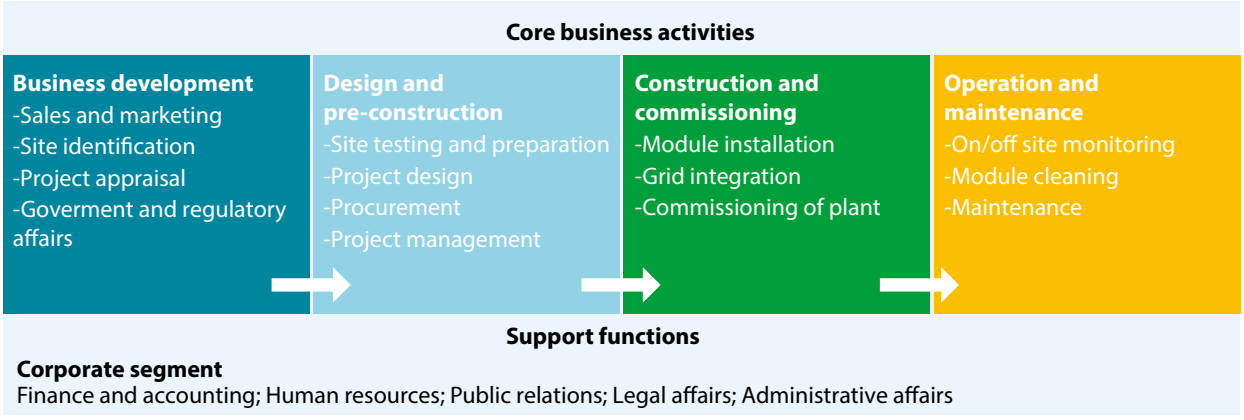

Figure 2 The value chain of a rooftop solar project

Source: Kuldeep, N., K. Chawla, A. Ghosh, et al. 2017. Greening India's workforce: gearing up for expansion of solar and wind power in India. CEEW-NRCD report; Ghosh et al. 2016. Filling the skill gap in India's clean energy market: solar energy focus; IEA and CEEW. 2019. Women working in the rooftop solar sector: a look at India's transition to clean energy. Paris: IEA

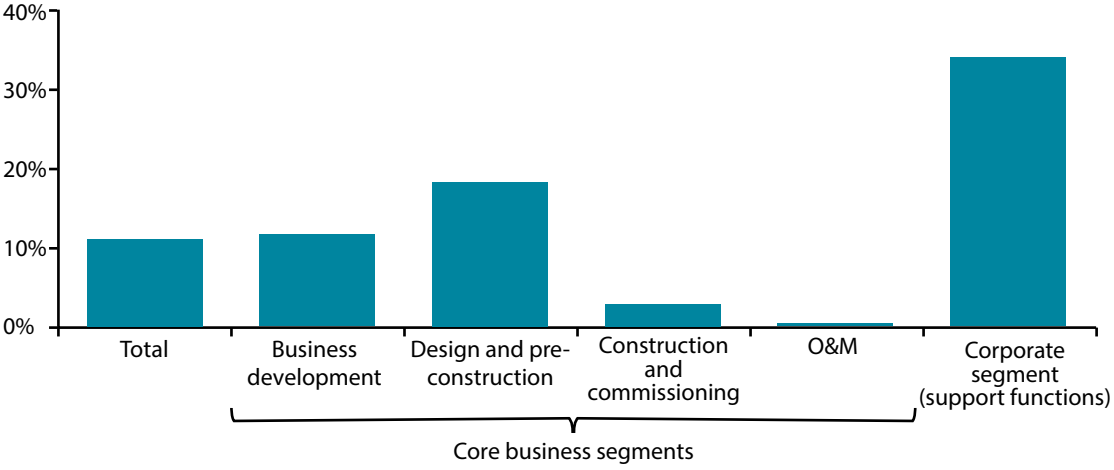

Figure 3 Gender diversity varies across the workforce

Source: IEA and CEEW. 2019. Women working in the rooftop solar sector: a look at India's transition to clean energy. Paris: IEA

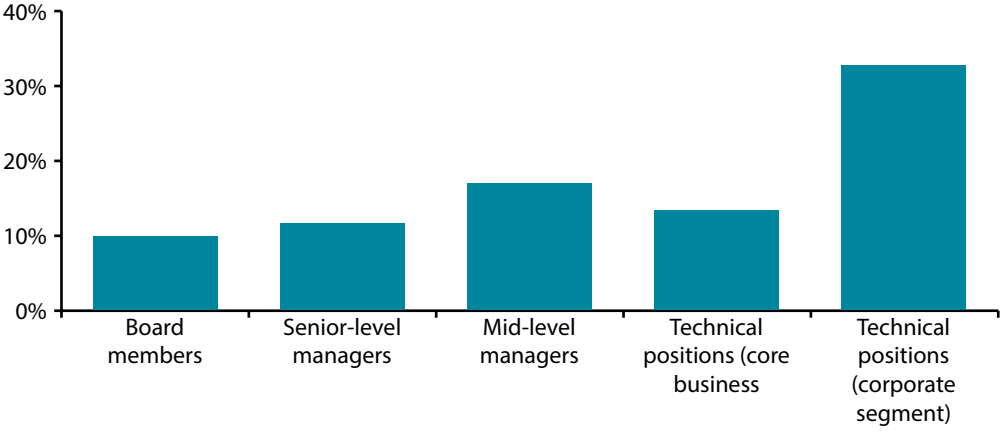

Figure 4 Professional workers are predominantly men at all levels except technical staff in corporate functions

Note: Technical positions indicate positions classified as highly skilled jobs, for example, engineers and project managers in core business and accountants and HR specialists in the corporate segment.

Source: IEA and CEEW. 2019. Women working in the rooftop solar sector: a look at India's transition to clean energy. Paris: IEA

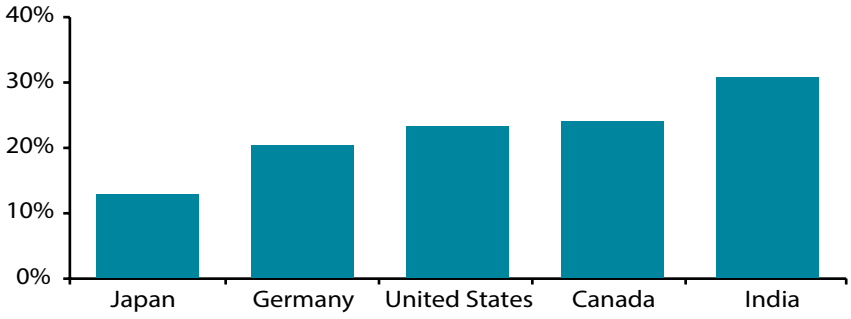

Figure 5 The share of female students in the engineering field in India is among the highest in the world

Note: The figure indicates the share of women out of the graduates who completed education at bachelor's, master's, and doctorate levels in the field of engineering, manufacturing, and construction in 2016.

Source: Details available at https://stats.oecd.org/

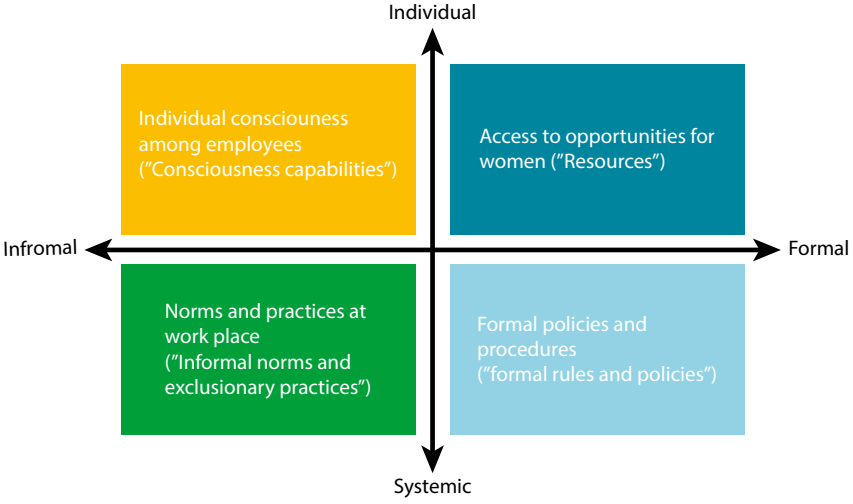

Figure 6 Existing barriers and support for women's participation in the rooftop solar sector

Source IEA and CEEW. 2019. Women working in the rooftop solar sector: a look at India's transition to clean energy. Paris: IEA; Gender at Work. 2018. Gender at work framework. Details available at https://genderatwork.org/analytical-framework/

culture. Many barriers are not particular to the clean energy sector, but the emerging nature of the industry allows for change early on.

Access to Opportunities for Women

The current work culture leads to unequal access to opportunities and resources for men and women. As conventional workspaces are designed for men, women find it challenging to pursue career trajectories that do not account for the socio-cultural differences in the lived experiences of men and women. Further, the perception around work influences access to opportunities for women. For instance, the adverse perception of safety and security at project sites could discourage women from undertaking work in male-dominated positions, such as engineers and project managers. The generalized anxieties about women's safety at site locations often keep women out of many roles, furthered by biases of supervisory authority among contractors, vendors, and clients onsite.

Some companies have actively taken steps to alter this inequity in opportunities by providing appropriate accommodation and sanitation facilities, transportation, and careful planning. Nonetheless, companies, in general, are in the process of developing the capacity to accommodate the needs of female employees in a manner that encourages more women to pursue this workstream. This leads to self-selection of women opting out of roles that conflict traditional familial obligations. Women in the workforce, especially those in core positions traditionally held by men, tend to act as mentors and role models for other women who are interested in joining the sector. Mentorship and support from women in leadership positions are crucial for the career development of junior colleagues.

Formal Policies and Procedures

Formal policies define the work culture of an organization. Although policies such as six months of maternity leave and the prevention of sexual harassment exist in all companies, very limited support is available beyond the legally mandated provisions. Companies in the sector do not have childcare facilities (owned or shared) as part of their formal policies. Childcare support acts as an important factor in supporting a woman's career during the initial years after childbirth.

In terms of the gender pay gap, most companies in the rooftop solar sector have no policy in place to ensure equal pay for equal work. Most often the salary structure is based on educational qualifications, work experience, previous salary, and negotiation skills. In the absence of formal policies to ensure equality of pay for particular roles, a company's assessment of how much to compensate a candidate financially is subjective and variable. This leads to a prominent gender pay gap since women employees are more likely to take breaks in their career after childbirth and because of childcare obligations.

Norms and Practices at the Workplace

The positive impact that gender diversity can have on decision-making in business operations and financial

performance is not widely recognized in the sector. The hiring of women candidates is largely based on the cost of their maternity leave and the cost of a temporary replacement during the period. This is mainly because of the pre-existing social norms that assume women to be primary caregivers of children. In addition, the rooftop solar sector is currently a rapidly changing industry with small teams, which makes it difficult for young organizations to find appropriate replacements quickly when employees go on extended leaves.

The existing societal norm of women leaving their jobs after marriage or childbirth is a major reason for less women working in this sector. The choice of prioritizing work over family often does not reside with women in a patriarchal framework. Cultural norms around parenting, as well as economic reasons, have prevented companies from providing childcare support unless there are enough 'women' in the organization. Most companies in the sector provide a supportive work culture, including flexible working hours and remote working, which makes it easier for both genders to balance personal and professional lives. Organizational support in the form of flexible working hours, a corporate culture that encourages women in leadership, the freedom to bring children to work occasionally, accounting for maternity leaves in formal work experience, and the flexibility to plan business travel for new parents will help many women balance their family obligations with professional growth while transitioning from early career to mid-level or senior-level positions.

Individual Consciousness Among Employees

Individual consciousness represents values and personal experiences that can align with or deviate from the existing social norms. Increasing the individual employee's ability to understand the bias embedded in society helps to create a culture of equality than a culture of policies only that are not necessarily internalized. In the absence of this internalized sense of values promoted by policies, individual employees could reinstate patriarchal notions and perceptions instead of challenging them.

Interventions focused on sensitization of employees through informal sessions, training, off-site and group meetings and workshops can lead to creating a more empathetic work culture. Cultural diversity among rooftop solar companies has a positive influence on employees. It broadens employees' perspectives regarding work–life balance, career aspirations, and personal obligations, and it increases the individual consciousness of employees. In companies where women and men in senior positions are cognizant of the need for gender equality and systemic bias in processes, this awareness has translated to increased discussion on policies for encouraging a larger proportion of women in the organization, implementing progressive policies for employees, and introducing initiatives to retain valuable female employees outside of formal policies.

Way forward – What Can Be Done to Increase Women's Participation in the Clean Energy Transition?

At the policy level, it would be important to accelerate the deployment of rooftop solar by addressing the general challenges that the sector faces. There is a need to introduce targeted policies to improve gender diversity and encourage more women to be a part of rooftop solar sector's workforce. Governments need to formulate more gender-inclusive policies rather than gender-specific policies, for example, mandatory parental leaves over maternity leaves for both female and male employees.

Investor lending requirements could include gender elements, such as encouraging companies to hire women for projects, gender-based audits, and facilitating compliance with the law against the sexual harassment of women. In the past, private equity firms that invested in rooftop solar companies have encouraged them to set internal goals to increase the number of women in the workforce and improve gender diversity, including the representation of women in the board of directors. Policymakers could also incentivize companies and investors to improve gender parity in their workforce.

For companies, sharing best practices among peers and learning from other sectors that have greater participation of women could improve the gender balance in the rooftop solar sector. Companies also need to build a supportive work culture through more employee diversity and gender sensitization workshops. Most organizations in the solar rooftop sector are in their nascent stages and still in the process of developing their formal policies. The work culture, therefore, plays an important role in ensuring a healthy support system for employees, both women and men. Formal and informal initiatives, such as flexible work policies, mentorship programmes, childcare facilities, and women's caucus to discuss challenges directly with the senior management, could be introduced more widely to help attract and retain women within the sector. EF

Shaily Jha is Research Analyst, CEEW; Sasmita Patnaik is Programme Lead, CEEW; and Yoko Nobuoka is Energy Analyst, IEA.

WOMEN IN THE SOLAR WORKFORCE

It is important to evaluate where we are in terms of women's participation in the renewable energy (RE) workforce. While there is a consensus regarding lower female participation in the RE workforce, the efforts towards the achievement of SDGs 5 and 7 are invisible due to their presence in the informal sector. In this article, **Arunima Hakhu** discusses the gender and employment in the RE sector and highlights that women self-help groups are crucial for the uptake of solar solutions in the informal sector.

The Indian energy sector is experiencing changes in line with India's Nationally Determined Contributions (NDCs). The ambitious target of a 33–35% emission intensity reduction with the conditional target of 40% power generation capacity by non-fossil fuels has enablers in the domestic policy sphere. Policies and missions such as the Jawaharlal Nehru National Solar Mission, National Wind-Solar Hybrid Policy, and National Policy on Biofuels have been adopted along with National Mission for Enhanced Energy Efficiency. As a result, while the share of renewable capacity grew at a CAGR (compound annual growth rate) of 19% during 2010–19 (CEA, 2010, 2019), the emission intensity dropped by 21% (MoEFCC, 2018).

In addition, India is committed to achieve Sustainable Development Goals (SDGs) 5 and 7, that is, Gender Equality and Affordable and Clean Energy, through various schemes and policies. While efforts such as the Deen Dayal Upadhyaya Gram Jyoti Yojana and Ujwal DISCOM Assurance Yojana are targeted at SDG 7 and Beti Bachao Beti Padhao Yojana and National Policy for Women are in line with SDG 5, both SDG targets are touched upon by the Pradhan Mantri Ujjwala Yojana. On the face of it, the transition to LPG seems to be the only intervention targeting SDGs 5 and 7 simultaneously. This article argues that there are efforts already underway vis-à-vis the achievement of both goals. It scrutinizes existing reports on gender-disaggregated employment creation in the renewable energy (RE) sector. Further, this article argues that while there is a consensus regarding lower female participation in RE workforce, the efforts towards achievement of SDGs 5 and 7 are invisible due to their presence in the informal sector.

Gender and Green Jobs

Council on Energy Environment and Water (CEEW) and Skill Council for Green Jobs capture co-benefits in terms of the net employment generated due to a shift to renewables in the power sector. Key results were that rooftop solar and small hydro projects create the maximum number of jobs for every megawatt (MW) of capacity installed, approximately 25 and 14 jobs/MW, respectively. The study also notes higher employment in RE in scenarios that are more ambitious in their commitment to renewable deployment—to the order of 25%. Keeping India's NDCs in mind, this means that the workforce in the renewables sector will increase in the coming decade.

With this growth trajectory in mind, it is important to evaluate where we are in terms of women's participation in this workforce. International Renewable Energy Agency (IRENA) finds that women comprise 45%, 28%, and 35% of the administrative, technical, and non-technical workforce, respectively, in the RE sector, making an average of a

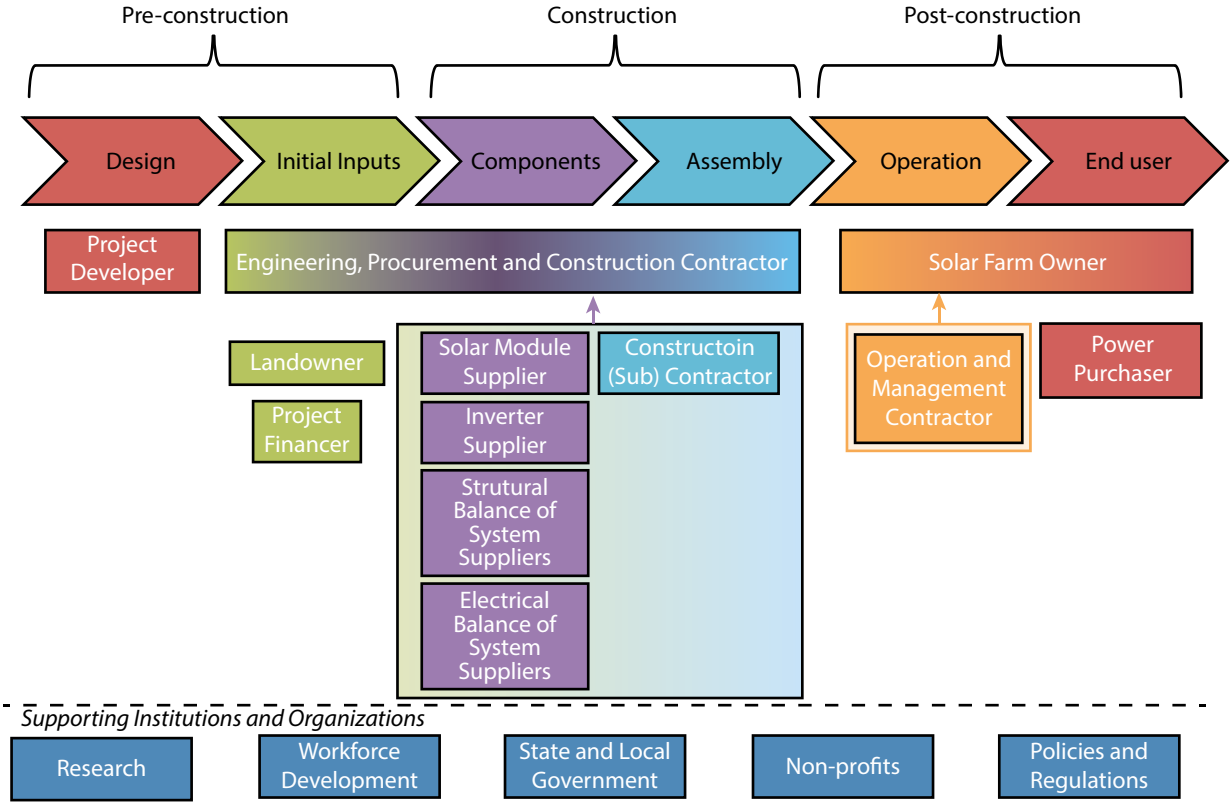

Figure 1 Utility-scale solar PV value chain

Source: Brun, Hamrick, and Daly (2015)

mere 32% of the total workforce (IRENA, 2019). It is reported that women are less in number in trading, operation, and maintenance positions requiring science, technology, engineering, and mathematics (STEM) expertise, entrepreneurship, and senior leadership.

This article focuses on employment opportunities in the solar economy. According to the Global Value Chain (GVC) methodology (Brun, Hamrick, and Daly, 2015), jobs in the solar PV value chain can be classified as pre-construction, construction, and post-construction. Figure 1 shows the profiles of each employment opportunity created.

While there are variations across the solar rooftop value chain, International Energy Agency (IEA) and CEEW peg female participation in the solar rooftop at 11% of the total workforce in India (IEA and CEEW, 2019). The study reports the share of female employees at 18% in the pre-construction phase. Construction and operations and maintenance have 3% and 1% female representation, respectively. Two conclusions drawn from these numbers are: (i) there are impediments to making STEM fields attractive to women and (ii) women do not take up opportunities that entail field engagements. While the first conclusion is a systemic issue, the second is curious as a lot of grassroots-level organizations have reported success in deploying solar alternatives—training women as salespersons and marketing experts, engineers and electricians, and entrepreneurs.

Change in Perspective: Electrifying End Use

TERI analysis of scenarios wherein India achieves its 275 GW RE capacity target shows a high concentration of solar capacity in the states of Tamil Nadu and Rajasthan (Palchak, Chernyakhovskiy, Bowen, *et al.*, 2019). Considering capacity as a proxy for solar potential and deployment, it can be predicted that these states will see the highest number of solar PV employment opportunities. Yet these figures are an artefact of the estimation of grid integrated electricity supply. What it does not reflect is the end use-driven deployment of solar technologies on ground. The same issue surfaces while evaluating existing studies on gender and employment in the RE sector: they are either limited to solar PV value chain in particular or the formal RE sector in general.

As many as over 60 non-governmental organizations (NGOs) and not-for-profit organizations (NPOs) are enlisted with the Ministry of New and Renewable Energy (MNRE) as institutions providing solar-based rural energy access solutions. These solutions include solar lamps, solar cookers, or even solar water heaters (MNRE, n.d.). Many of the enlisted NGOs and NPOs happen to work with women self-help groups (SHGs) to train them as service providers (as electricians or engineers) and entrepreneurs. Through these women, networks that feed back into demand for the technology

in question have been created and sustained. For example, Barefoot College touts training more than 15,000 rural women through its International Solar Engineer Training Programme (Solar Mamas) (Asnani, 2018). It selects marginalized women from non-electrified villages around the world to deploy solar heating, cooking, and electricity solutions (Winther, Ulsrud, and Saini, 2018; Zhang and Shivakumar, 2017). Community engagements like Solar Sahelis run by Frontier Markets have reported generating income worth US$2 million by gathering customer insights and selling products, such as solar home systems, clean cookstoves, and renewable energy appliances, to 400,000 agricultural households in Rajasthan alone by targeting women SHGs (Kapoor, 2019; Arya, 2018). 'Women in Power' project launched by Simpa Networks aims to deliver pay-as-you-go solar PV systems through women SHGs by training women to become village-level entrepreneurs (Power for All, 2018; Ferrario, 2015).

These illustrations are made to point out the disaggregate nature of end use-driven solutions. These examples reflect the complexity inherent in evaluating RE employment generation from the point of view of an end user. The evaluation of such solutions for gender justice is difficult because of the informal channels through which these solutions are deployed. Inclusion of social services associated with solar technology deployment on ground and mapping gendered implications on employment created to maintain and run these solar technologies will make for an interesting addition to existing estimations regarding employment generation in the RE sector.

Uptake through SHGs: Why It Works

The answer to 'why it works' is straightforward: deployment of solar solutions through SHGs encourages effective participation of its members. This section breaks this argument into three parts: unlocking and honing social networks, diversity of perspectives, and building confidence and challenging restrictive socio-cultural narratives.

Unlocking and Honing Social Networks

An SHG entails social reach within a community. All illustrations cited in the earlier section rely on these social networks to create and sustain demand for solar solutions. Members of an SHG, through shared knowledge and kinship networks, are more likely to be aware of public entitlements, avail them, and hold public entities accountable for the provision of their rights (Kumar, Raghunathan, Arrieta, *et al*., 2019). The efforts on ground recognize this and use it to create awareness regarding benefits such as time savings and less drudgery, creating positive feedback

through greater uptake. In addition, SHG members have a greater likelihood in terms of continuity of employment compared to their counterparts in the formal sector (Chatterjee and Ghosh, 2012). Once established, these networks seem to deliver additional benefits, or co-benefits, from shifting to RE to members and the wider community, such as a greater number of women participating in the labour force, their enrolment in skilling programmes, and increase in study hours for children in schools (Barefoot College, 2017; Kumar, Raghunathan, Arrieta, *et al*., 2019; Venkatesh and Kala, 2010).

Diversity of Perspectives

Including gender perspectives promotes diversity at two levels: designing the intervention and evaluating its impact (Cornwall and Aghajanian, 2017). It also helps identify unplanned and secondary effects from the intervention. With the testing of RE solutions for user-friendliness, end users from the field share ideas that may help increase efficiency and uptake. As illustrated in the case of solar cookers, the feedback from end users influenced its deployment at the community-level cooking instead of the household-level cooking (Down To Earth, 2015; Otte, 2013; Scheffler and Sutter, 1997).

Engaging women at pre-construction and construction phases remains important. This helps women's engagement in voicing their needs as end users (IRENA, 2019) and honing in on traditional knowledge, making sure that the dominant narrative does not just reflect the interests of the privileged (Moosa and Tuana, 2014).

Building Confidence and Challenging Restrictive Socio-cultural Narratives

As women participate in the decision-making at planning, deployment, and evaluation phases, they develop socio-economic agency (Moosa and Tuana, 2014). They learn language and financial skills that enable them to participate effectively (Venkatesh and Kala, 2010). Effective engagement further enhances their socio-political status through income generation, which in turn helps them challenge socio-cultural norms within and outside of their households, bringing transformations as envisioned in SDG 5 (Jyothi, 2016; ARE and ENERGIA, 2017). Finally, younger generations of women start to take on more leadership roles in communities as there exist precedents in the form of female role models (IEA and CEEW, 2019; IRENA, 2019; ARE and ENERGIA, 2017).

Conclusion

This article highlights that women SHGs are crucial for the uptake of solar solutions in the informal sector. Through these informal channels, many women have been trained to become entrepreneurs, solar engineers and electricians, and marketing experts. This phenomenon has not been fully captured in the evaluation of green jobs generated. While it is understood that estimating the number of such jobs and its gendered implications is difficult because of the disaggregated and diverse nature of RE solutions, it can be concluded that women have indeed been included into the post-construction phase of the solar sector.

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Arunima Hakhu is a former Research Associate, Centre for Global Environment Research, TERI, New Delhi.

WOMEN AT THE FOREFRONT OF ENERGY FUTURE

FROM EVIDENCE TO INCLUSIVE POLICIES

The benefits of inclusion of women in the energy value chain are increasingly recognized. Involving women at different levels of the energy supply chain promotes gender equality and women's empowerment. In this article, **Mini Govindan** highlights the approaches adopted towards involving women in energy supply chain to encourage gender equality in employment and improve the effectiveness of the supply chain.

Gender mainstreaming in the energy sector is gaining traction globally and the development community clearly recognizes the benefits of inclusion of women in the energy value chain. Moving beyond identifying women as only 'passive end users and consumers of energy' towards acknowledging their potential to formally participate as key agents and providers of energy supply and services has often resulted in increased opportunities to expand their horizons and benefit from the energy sector. Moreover, it is well recognized that women participating in energy supply chain will encourage gender equality in employment and also improve the effectiveness of the supply chain. All these factors correspondingly contribute to achieving the SDGs goals 5 and 7.

With this logic and a mission to empower women, the Maharashtra State Electricity Distribution Company Limited (Mahavitaran), which is one of the largest state distribution utilities in India, initiated a number of programmes to encourage and induct women in the electricity supply sector across the state. Besides, a number of studies in the academic literature have highlighted the importance of having an equal right for women in developing solutions for electricity supply.[1] Women-targeted approaches and inclusion of women in the supply side of the value chain are found to have contributed to empowerment processes.[2]

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Gender Equality Policies and Quota Implementation

Mahavitaran distributes electricity to consumers across the entire state of Maharashtra except Mumbai. Its consumer base is spread across categories, such as residential, agricultural, commercial, and industrial. It has 4 regions, 16 zones, 44 circles, 140 divisions, and 633 subdivisions across the state. The current human power in the utility is 80,918, and it has around 25,484,496 consumers spread across 41,928 villages and 457 towns. It has also achieved the target of 100% electrification under the Saubhagya Yojana. Mahavitaran has also received 'Special Recognition Award' for Efficient Distribution and Operations for excellent management of large consumer base. It also bagged the 'National Energy Conservation Award 2014' presented by the Ministry of Power for its contribution in the field of energy conservation.

In its endeavour to promote women's empowerment and gender equality, Mahavitaran has introduced critical policy measures where there is 30% horizontal reservation for women as per a resolution of the Government of Maharashtra (No .82/2001/MSA-2000/PK 415/K-2). Till 2013, women in Mahavitaran were working mainly in technical jobs as engineers and in non-technical jobs as managers. However, after 2013, Mahavitaran broadened its scope to train and recruit women in the energy value chain to include line staff, operators, and vigilance squad amongst other technical jobs, which were earlier dominated by men. Till 2018, around 1141 women were employed as technicians and 233 as operators.

Engendering the Supply Chain: Unlocking the Potential of Women

Numerous studies worldwide have indicated that integrating women into

different levels of the energy supply chain unlocks greater productivity, efficiency, and customer satisfaction in addition to promoting gender equality. For instance, the Jamaica Power Services witnessed an improvement in their customer satisfaction when women were included as part of their customer service roster in the electricity supply chain. Similarly, findings of a Berkeley-Haas School of Business study suggest that companies with more women on their board of directors are more likely to be proactive in improving energy efficiency and lowering company costs. Hence, agencies like the Alliance for Rural Electrification (ARE) have strongly advocated for the involvement of women as change agents in the supply of rural electricity and for promotion of social and economic empowerment along all the levels of energy value chains. Although the national policies in India show general goals for gender mainstreaming, the impact of these policies on implementation and operation practices at the local level is yet to be seen. Moreover, it is also noted that only in a few cases have women been involved and taken into consideration in the formulation of electrification policies.

Mahavitaran, being a flag bearer of gender inclusion in electricity policies, has undertaken the following key initiatives to involve women in the value chain:

1 *Vidyut Sahayak*: Vidyut Sahayak literally means someone who helps in dealing with electricity. In this case, women are appointed as 'wire women' (line staff) to work hands-on with transformers, electricity poles, live cables, and other pieces of field equipment that function as the part of power supply network. Women are trained along with men to handle the power supply network and systems. This is the first time that women have been recruited as wire women at the national level. These trained women fearlessly climb poles and work on transformers to do repairs, detect theft, and collect power dues. Currently, 682 women are employed as Vidyut Sahayak in Mahavitaran. This is the first time in India that a government company has a policy to employ women as line staff.

During our recent visit to the training centre at Nasik, we observed that women are diligently undergoing various types of training. Donning a khaki uniform, Savitribai Karmakar, who is in her late twenties and mother of two, confidently said, "I climb electric poles much to the amusement of the nearby onlookers, mainly men, and fix the faulty cables and wires". She further added, "I take pride in my government job and after all I am also the breadwinner of the family".

Expressing his views on women fearlessly receiving training, the Chief General Manager (Training and Safety) at Nasik proudly said, "After the initial apprehensions and reluctance, we have noticed women performing better in jobs which were earlier considered as masculine".

2 *Upkendra Sahayak*: Upkendra Sahayak literally means someone who is in charge of operation of power substations. In this case, women assume the role of Upkendra Sahayaks after undergoing training. The recruitment is based on competitive exams and the selected candidates undergo training before taking up the role of operators. Currently, only 11 women are employed as Upkendra Sahayak.

Uma Joshi, who is in charge of the Tapovan substation in Nasik circle, said, "We perform the same duties as our male counterparts and we are appreciated for discharging our duties diligently and also we get good support from our male colleagues".

3 *Damini Pathak*: It is an all-women squad headed by a woman engineer and assisted by women employees to address consumer complaints regarding photo meter reading and check meter tampering. They carry out surprise checks of the meter readings and are actively involved in loss and theft reduction. They are also involved in the distribution of electricity bills and address consumer complaints. Mahavitaran utilizes this vast women power by offering the Mahila Bachat Gat (women self-help groups)/Mahila Mandal across the state to come forward and undertake the work of meter reading and distribution of electricity bills. Periodic monitoring

of Damini Phatak is undertaken and penalty for mistakes in meter reading/data punching is charged at ₹20 per mistake.

Various studies undertaken in Kenya, Mali, and India have revealed that in contexts where women became directly involved in electricity supply and became associated with electricity services, they gained a new type of skill and higher status.[3] There has also been an increase in women's agency, which is reflected in their decision-making power, and this has positively affected gender norms and women's social position in the local community.

4 *Tejaswini Samiti*: It is led by a very senior lady officer at the head office, who ensures the smooth working of the women line staffs. The Samiti also supports women and helps in resolving difficulties/grievances (if any) at the workplace. Such samitis are formed in each zone for attending complaints.

Women and men with basic qualification like SSC/ITI are eligible to apply for the posts of technicians, operators, and line staff and the candidates have to appear for an online test. The selection is strictly based on merit. However, there is a 30% horizontal reservation for women as per the provision of the Government of Maharashtra. After selection, men and women undergo a series of training, capacity development, and induction programmes without discrimination to deal with meter testing, replacement of faulty meters, giving new connections, collecting bills, theft reduction, and vigilance. Apart from this, security awareness campaigns and refresher training to engineers, line persons, and operators are organized regularly.

To boost the morale of women, they are given special counselling to change the mindset regarding the profession. Moreover, interactive sessions are conducted at the corporate office, at the zonal level, and also with women working in other sectors, such as Women on Wheels (motor training school for women) and operators of JNPT (Jawaharlal Nehru Port Trust).

Structural Barriers and Cultural Constraints

Gender roles, responsibilities, and time use also affect women's participation and retention in the electricity sector. Even when women are gaining interest, they face a series of challenges, especially rising to leadership positions and manoeuvring in a male-dominated sector. Some of these challenges include long working hours and requirements of a large number of site visits to distant locations. They are also challenged by lack of good infrastructure facilities like health and education in rural areas and hence do not prefer rural posting. Another common challenge often faced by women is the difficulty in achieving a work, life and family balance since women traditionally are also the primary caregivers of households.

During our interaction with the line staff, some of the women explicitly stated that their families were initially reluctant and scared to send their girls for jobs which required them to climb poles and deal with live cables and wires. Women also faced initial opposition from their peers since their jobs seemed too technical and risky. Hence, the initial preferences were desk-based jobs, which seemed to be easier and convenient. Also, women had to change their mindset to accept the uniforms (pant and shirt), which were similar to those of men and also did not match their traditional attire sensibilities.

An enthusiastic new employee Dipika Tawde said, "I have often been warned by elderly men and women in my village about my marriage prospects being affected due to the nature of my job since they feel it is too technical and risky. And I have always wondered why they do not advise or ask such questions to men who just hold similar jobs like mine".

Women's increased economic opportunities through involvement in the energy supply chain do not necessarily lead to their increased control of these resources. For instance, a study undertaken in Afghanistan indicated that women's involvement in the supply of electricity challenged existing gender norms, while at the same time the socio-cultural context continued to be a barrier to women's agency through their lack of influence over household expenditures. Hence, their material endowments did not increase.[4] Nevertheless, studies in Nepal and Kenya have noted that when women are involved in electricity supply at the local level, they are well noticed by village community and it also impacts the way they think about women's capability and the aspirations they have for their daughters.[5]

Social stereotyping during early education also acts as a hindrance and young girls in rural Maharashtra, just like in many parts of India, are less likely than boys to be encouraged to engage in activities that would increase their options later for joining science, technology, engineering, and mathematics (STEM) field studies. These technical qualifications are essential for taking up several technical and professional positions in the electricity sector.

Value of Engaging Women: Setting an Example

Maharashtra is credited as the first state in India to have a policy to formally induct women in a sector traditionally

[3] Winther, T., M. N. Matinga, K. Ulsrud, and K. Standal. 2017. Women's empowerment through electricity access: scoping study and proposal for a framework of analysis. *Journal of Development Effectiveness* **9**(3): 389–417

[4] Standal, K. 2008. Giving light and hope in rural Afghanistan: enlightening women's lives with solar energy. Master Thesis, University of Oslo, Norway

[5] Details available at https://www.energia.org/cm2/wp-content/uploads/2019/04/RA1-Womens-empowerment-and-electricity-access.pdf, last accessed on 11 March 2020

dominated by men. Till date, more than 2200 women have been recruited and trained as line women. They have also started to lead the vigilance squad and the overall recovery of dues in the state has improved tremendously.

The following are the most tangible benefits of recruiting women:

» *Theft and loss reduction*: Women squads regularly undertake vigilant activities and stringent actions are immediately initiated against the defaulters after initial warning.
» *Collection of arrears of electricity bills and permanent/temporary disconnection of supply of defaulting consumers*: It was noted that women squads have more freedom and comfort than men at the household level to deal with defaulters and pursue them with regular payment of tariff on time.
» *Resolve consumer complaints*: Teams led by trained women also work tirelessly to resolve consumer complaints at the earliest.

Moreover, these women employed by Mahavitaran carry the tag of having a government job and get all benefits, including job security, maternity leave, childcare leave, and so on. Women technicians are proud of their jobs and have become role models for other young girls in the villages to take up technical education and pursue careers that were earlier dominated by men.

Additional support from Mahavitaran in terms of access to diverse formalized support systems, such as childcare and sanitation facilities, has also facilitated the active induction and retention of women in these jobs.

Madhya Pradesh West Power Distribution Company (MPWPDC) started a similar initiative in 2018 known as 'Pink Electricity Zone' comprising all women technical staff in the electricity board to look after the energy maintenance work. In the Pink Electricity Zone, assistant engineer, junior engineer, line supervisor, line persons, meter readers, accountant, and computer operators are all women. After undergoing rigorous practical training, women are handed over 'pink uniforms' and become trained to read meters, recover dues, and repair energy supply lines. This initiative has helped the women not only to boost their morale but also to break the stereotypical beliefs of the society in terms of the masculine label attached to technical jobs in the electricity sector.

Mahavitaran has clearly set an example for other states and demonstrated that appropriate training, skill development, motivation, and counselling can break barriers and change notions about technical jobs, which carry 'masculine tag'. It has further endorsed that adoption of gender or women targeted approaches results in women's inclusion in supply and wider empowerment processes. EF

Mini Govindan is Fellow, Centre for Impact, Evaluation and Energy Access, TERI, New Delhi.

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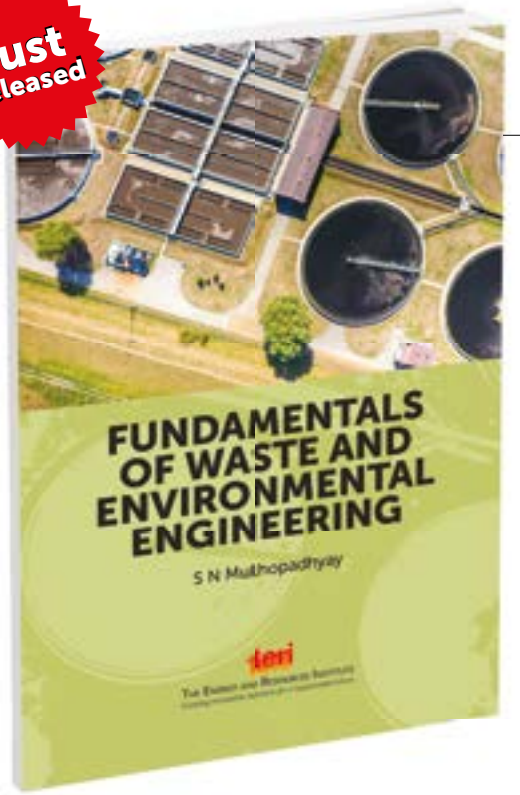

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RESHAM SUTRA

WEAVING NARRATIVES OF SUSTAINABLE EMPOWERMENT

Silk products are gaining market interest across the world. In fact, silk and cotton textile production has emerged as a major generator of employment in India. This article discusses the success story of Resham Sutra, an innovative start-up, by **Kunal Vaid**, which has created a range of machines for the silk industry. With their highly efficient spinning and reeling machines for silk yarn production, being primarily powered by solar energy, they hope to empower women in the wild silk industry in India.

In India, rural women have always strived to use minimal energy for cooking and other household needs. The advent of solar energy for household needs and for their livelihoods fits perfectly with their mindset of conservation of scarce resources. It enables them to meet all their energy needs with only one-time investments. In recent years, solar energy has been utilized by women to increase their productivity and income, realize their true capacity and potential, and meet the aspirational needs of their children. Solar energy has the additional advantage that it eliminates the concerns for rising fuel costs. By enabling women to earn decent livelihoods, solar energy contributes to their empowerment.

Silk sarees, dresses, and scarves have a special place in weddings and other ceremonial occasions in almost all communities. Prized throughout history for their quality and diversity, silk products have been gaining market interest across the world. Silk and cotton textile production, in fact, has emerged as a major generator of employment in India.

While China is the leading producer of silk, India is the largest consumer of silk. Almost one-third of the country's requirement of silk for the domestic demand is met through imports from China. Producing silk in India to substitute imports could create millions of additional rural jobs. However, technologies employed in India for the production of yarn, fabrics, and other products of silk continue to be highly inefficient and obsolete. Therefore, India continues to import silk required for domestic production and consumption.

Traditionally, silk has been produced by women living in rural areas. These women mostly live in or near forest areas and have limited access to education and technology. Therefore, silk production by tribal communities is plagued with challenges of productivity and cost-effectiveness. The silk yarn used to make exquisite sarees and other products is reeled using traditional

manual process of thigh reeling – rolling silk thread on thighs. The process is physically demanding and gives low yields. Women work painstakingly for long hours but earn little.

For example, 'ahimsa' silk, which is famous for being produced without killing the silk worm, is made in the villages around Bilaspur (Chhattisgarh) through a laborious and painstaking process using a small wooden spindle called 'Takli'. Made in this way, even the most skilled spinner can produce only 30–40 g of silk each day.

A result of the process is that the entire industry is finding it hard to survive. The challenges the industry faces call for reliable and affordable options that would free these women from this drudgery, improve the quality of their output, and give them a healthy income.

Resham Sutra, an innovative start-up, has created a range of machines for the silk industry. With their highly efficient spinning and reeling machines for silk yarn production, being primarily powered by solar, they hope to empower women in the wild silk industry in India.

Their silk reeling machines such as 'Unnati' and 'Buniyaad' operate easily on solar energy. These machines use just about one-tenth of energy and are up to ten times more efficient than the existing traditional options.

These productive machines vastly improve the working conditions of the rural women as well as help dramatically improve the quality and quantity. The women from the rural silk-producing communities have been closely involved in all stages of machine designing. Their feedback is used to constantly improve the machines, which further helps in their better adoption by communities and ensures that they become a part of their everyday lives. The new machines developed by Resham Sutra for different stages of silk textile production chain, that is, reeling, twisting, spinning, and weaving, are truly a grassroots solution to the problems faced by the rural women engaged in the silk textile industry.

Many of the women are able to more than double their income with these productive machines. Women are able to grow their business, purchase the raw material in larger quantities, and sell directly to weavers and end users. This has improved their ability to generate income and better the lives of themselves and their families. The new-found independence and increased self-confidence of the newly emerging rural micro-entrepreneurs have the potential to revolutionize India's rural economic landscape.

The solar-powered machines have helped increase earning capacities of silk spinners near Bilaspur by increasing their productivity more than fivefold, with even beginners being able to generate 200 g of silk per day. The spun silk retains the touch and feel as that produced by the Takli, but with a significant improvement in yield.

Providing holistic support for customers for technology, servicing, training, raw material sourcing, and finding markets for finished goods is the key to ensuring that such innovations reach their true potentials and make a lasting impact on the lives of people. Rural women are emerging as agents of change in the Indian scenario. Their timely and invaluable contributions have the potential to help India, as well as the world, reach its sustainability goals much faster. EF

Kunal Vaid is Director, Resham Sutra Pvt Ltd.

WOMEN-LED ENTREPRENEURSHIP IN THE ENERGY SECTOR

Women continue to play a major role in the energy value chain. However, women-led businesses in the energy sector are alarmingly low. POWERED Accelerator is a first of its kind accelerator, globally, focusing on women-led businesses in the energy value chain, integrating the efforts towards SDG 5 and SDG 7. In this article, **Asmita Moon** talks about the efforts of POWERED Accelerator to foster the economic empowerment of women-owned businesses in the energy sector.

In the recent years, the energy sector has seen rapid changes with the rise of renewables, decentralization of the energy system, policy modifications, and emerging disruptive new technologies. The year 2012 was announced as the International Year for Sustainable Energy for All and although women continue to play a major role in the energy value chain, the number of women-led businesses in the energy sector remains alarmingly low.

About POWERED Accelerator

POWERED Accelerator is a first of its kind accelerator, globally, focusing on women-led businesses in the energy value chain, integrating the efforts towards SDG 5 (Gender Equality) and SDG 7 (Affordable and Clean Energy).

The objective of the POWERED Accelerator is to support selected ventures by helping them expand their innovative and consumer-responsive services, products, and financing, with the ultimate goal to foster the economic empowerment of women-owned businesses in the energy sector. Some of the themes of the focus are access to energy, sustainable mobility, waste to value, energy efficiency, and so on. The programme operates with a tiered approach, including multiple stakeholders, policy think tanks, government, educational/research institutions, networks and enablers, investors, industry and regional partners, with an aim to scale innovative businesses in the energy domain.

Search of Women-led Energy Enterprises

Since its launch in April 2018, POWERED Accelerator has attempted to find some unknown names in the renewable energy sector from the nooks and corners of India. These entrepreneurs will be the next set of role models inspiring more and more women build momentum. The team did roadshows in six cities, namely, Ahmedabad, Dehradun, Delhi, Guwahati, Chennai, and Bengaluru, and reached out to multiple stakeholders of local ecosystems for referrals. This led to 180+ applications for two cohorts. It was important to go beyond the conventional methods of selecting entrepreneurs. Hence, the process was flexible with the language and mode of communication; multiple rounds of calls were conducted. This was not about pitching, but about the ideas that these set of women entrepreneurs would bring on the table.

Learnings: Progress of programme brought certain key elements to light – primarily, there are many brilliant attempts made by women entrepreneurs in this sector.

- They are not just IT software solutions or assembly units but deep tech solutions focusing on addressing issues at large scale. Eighty-eight per cent of the portfolio start-ups are B2B or hybrid. They are looking at industry and policy-level solutions for energy crisis and climate change.
- While there are a few working on energy access issues in remote tribal areas, more and more innovations are emerging out addressing energy-linked applications and solutions for sectors such as agriculture, healthcare, livelihoods, and education. This comes after government attempts to bring people under grid through various installations and schemes.

Deep Diving in the Sector

The programme also conducted a study with some industry experts and influencers to understand what is coming up next in the sector for these entrepreneurs to focus on. In this study, cold storage solutions, EV charging solutions, batteries, and infrastructure management systems, monitoring technologies have been identified as major sought-after disruptive innovations in clean-tech sector. The start-up applications that we had were largely from access to energy, waste to energy, and energy application sectors.

Learnings: While there is an alignment of these start-ups towards some of the sectors highlighted in the study, there are still a large number of opportunities to be intervened by clean-tech women entrepreneurs and are to be supported by an initiative like POWERED Accelerator.

We have to build role models, provide these enterprises visibility, and connect them to ecosystem stakeholders. In the applications received, we noticed that most of the women entrepreneurs in the energy space are early stage entrepreneurs. This intrigued us in having a boot camp for idea stage entrepreneurs where five women-led energy enterprises went through 1-week training and three of them graduated to the second cohort.

Programme Approach

Focusing on a niche segment of women-led entrepreneurship in the energy sector helped us bring in relevant mentors and support during cohort sessions. Founders appreciated the industry connects, partnerships, and business opportunities created because of this approach. It was surprising to have such a significant added advantage being in a niche market space.

Recommendation: Build programmes on specific growth sectors or segments, even if the programme is just for women entrepreneurs.

The first cohort witnessed a spectrum of diversity on the basis of start-up stage, experience of entrepreneurs, geographies, and sectors. It created a great atmosphere of sharing and learning, but also brought challenges to deliver sessions covering needs of everyone. The team spent significant time understanding these individual requirements and provided relevant connect and support. We kept one-on-one sessions in between weeks for entrepreneurs to have a relevant mentor discussing their needs in detail. These proved out to be the most effective sessions. This also helped in exploring mentor's network relevant to entrepreneur's work.

Mentor-in-Residence Programme: The demand for follow-up sessions of one-on-one meetings sowed seeds of Mentor-in-residence (MIR) programme. We brought four mentors on board after second cohort to guide on the topics for which most of the start-ups required support, namely, product development, business strategies, market access, and fundraising. In the MIR programme, a dedicated mentor guides the founder on specific issues she is facing by meeting over a call or in person once a week/fortnight in presence of POWERED team. We follow up on each 'to do's' with both the parties, building the efficiency of the initiative. This initiative will provide the necessary push to start-ups to take leap to the next stage. It is about creating a safe platform to communicate the challenges.

Peer-to-peer Network: Founders believe that the peer-to-peer community building is a crucial value addition for women entrepreneurs as it provides them with a support system of other women going through similar challenges. This network allows for cross-collaboration, knowledge and resource sharing, and peer advice. In one of the recent peer meetups, one founder was found looking to pilot her energy-efficient furnace for jaggery production, while the other was looking for agro-processing machinery for her jaggery farmers. It was a perfect match! Similarly, one fin-tech start-up for clean-tech in the cohort opens a window for in-house knowledge on funding options for many others in the group. The service-based start-ups working on energy access in remote areas can collaborate with product start-ups relevant to their areas. They can become supply chain partners for each other. The opportunities are immense once they are brought together.

> "It was interesting to see the approach of different women entrepreneurs towards different matters and their feedbacks helped in getting clarity on what is missing and how important POWERED is"
> **– Monika Jha, Founder at Cydee Technologies**

As in their nature, it was necessary for these women entrepreneurs to discuss their learnings with their team. Hence, these sessions were open to team members to attend and most of the entrepreneurs utilized this opportunity. We also realized that the teams needed time to implement these learnings. The POWERED Accelerator format was changed from a 6-week programme (in-person sessions twice a week) to a 4-week programme spread over 3 months (in-person sessions thrice a week).

Going Beyond Sessions

At the end of the second cohort, POWERED supported 18 active women-led clean-tech enterprises from 10 different cities, most of them from Tier

II and Tier III cities. The next step was to give these pioneers visibility in local ecosystems and create a sustainable process of involving more women in the sector. Some of them are discussed next.

REVY Environmental Solutions develops a cost-effective and indigenous process of making anaerobic granulated sludge optimized to enable quick start-up and easy operation of UASB in wastewater treatment. The system generates biogas which will be commercialized.

The vision of Upcycler's Lab is to change the mindset and behaviour around the environment by making sustainability fun! Their work is based around UN SDG 12 – Responsible Consumption and Production. Currently, they make sustainability-based learning tools and programmes for young children (age 5+).

TARU is an endeavour to empower and safeguard small-scale farmer communities and protect their livelihood. TARU strives to protect India's ancient wisdom and sustainable agricultural practices, while ensuring value-added livelihood incomes for the community. TARU intervenes through climate smart agriculture and small-scale technology.

Cydee Technologies is developing unique patented streetlights to help public and private sectors reduce the number of light poles by 60%, saving material, manufacturing, deployment, and maintenance cost along with 30% extra energy saving compared to the conventional LED streetlights.

DD Bio Solution produces green energy from agro-waste, providing livelihood for rural women and an optimized supply chain of agro-waste utilization. It has developed prototypes for eight products for commercialization. Main products of the company are smokeless combustion chamber, pellet machine, bio-pellets, and stoves catering to rural households.

Field Visits: POWERED Accelerator team visits the operational area of each start-up regularly. This involves visiting their plants, offices, meeting their team, and understanding operations on ground. Conversations over call and common meetups help in understanding strategic-level problems, whereas these visits help identify operational challenges. A combination of these two helps draft tailor-made solutions for each organization. With one of the start-ups, we were discussing her challenges with the manufacturer. During the field visit, we realized the focus could be shifted on getting the orders from current pipeline of customers on percentage advance payments to start the bulk manufacturing. Another start-up in Rajasthan, run by tribal women, had been facing challenges in managing demand pipeline. During the visit, we travelled to various potential stakeholders, partners, and influencers in Rajasthan with the entrepreneur. The exposure to this ecosystem itself created base of business model changes. One of the influencers has now joined that start-up as an independent director.

Roundtable Discussion: Field visits are often coupled with roundtable discussions. This is to encourage local ecosystem participation. The major learning from such events was that upcoming start-ups need a platform to increase awareness of the support system around them and a local communication system. This is an opportunity to be worked on.

Revisit the Vision: The majority of POWERED Accelerator entrepreneurs are tech focused, innovators, and have the habit of going back to product development stage. As a supporting programme, it is important to work with the entrepreneurs in building a road map for their products and inculcate fail-fast attitude. While doing so, we insist them to keep revisiting the reason behind starting the organization. These revisiting conversations help entrepreneurs take the broader picture in view of their impact while they are stuck in day-to-day operations.

Monitoring and Evaluation: Mentoring and accelerator programmes are for improving soft skills and not for immediate tangible outcomes. The impact of these is to be evaluated over

> "What fascinated me about this group was – here is a bunch of women who have chosen to think of projects that are so relevant and imperative for us today and they have a platform, fascinating as it is – POWERED, which is literally powering them to move to the next stage, from passion to actual implementation of business plan. I think there is no stopping these women."
> - **Sanmita Kamat, CEO, Common Purpose**

a period of time. Impact parameters such as carbon footprints reduced, the number of renewable energy watts, and so on and milestones planned by the entrepreneurs should be discussed at a very early stage of the programme so that exact data is captured periodically from entrepreneurs to evaluate the progress. POWERED Accelerator has provided grant support to 13 out of 18 of its portfolio start-ups. To evaluate the grant distribution, we worked with start-ups on quarterly milestones and fund utilization. This created a base for further discussion as we realized the importance of monitoring start-ups on impact parameters. We are currently testing the process with start-ups.

Knowledge Sharing: We believe that the efforts of our programme can be sustainable only if we are able to share our learnings and build knowledge documents for stakeholders to replicate the programme in their context. We are creating case studies, annual reports, toolkits, learning reports, and so on as resources to build on. We are drafting toolkits on topics such as compliance, fundraising, marketing and branding, business and financial modelling, and HR. This is ready to refer material for organizations for their generic needs. We are building open source stakeholders, awards, funding, and so on mapping sheet, which, if maintained, will become a go-to platform for all in the sector.

In addition, participating in national and international forums help the team exchange learnings. For both cohorts and boot camp, we organized demo days, inviting relevant investors, corporates, think tanks, and supporters.

While this gave an opportunity for start-ups to get visibility and a few conversions, it was necessary that these kinds of opportunities should be recreated. We collaborated with an international partner for Open Source Circular Economy Days, which included a few talks and demonstrations. We took this opportunity to showcase one of our relevant start-ups. This initiated international market deals for the start-up and they are now in talks with multiple other countries to sell their products. As a part of supporting the pillar of the ecosystem, we attempt to create such platforms and engage with existing ones.

These women entrepreneurs are an uprising force and can create a snowball effect in the sector. They are unique and so are their ideas and approach. It is all right if they fail over a period. Many start-ups do. What is important is that they exist. It is important that they create an impact, a pathway to be walked on by many others joining them to achieve a rather bigger success of sustainable environment. Moreover, it's important for supporters like us to collaborate and walk along with them beyond conventional methods. EF

"It is exciting to be part of the journey that Indian environmental start-ups have taken and to support them on their approach to utilize the tremendous opportunities of the Indian circular economy market. Thanks to POWERED Accelerator for giving us this experience."

– Sebastian Frisch, CEO, Blackforest Solutions GmbH

Asmita Moon is Program Head – Impact Programs, Zone Startups. She can be reached at asmita@zonestartups.com.

BREAKING GENDER STEREOTYPES FOR SDG 5 THROUGH SUSTAINABLE ENERGY

Women's economic empowerment has been recognized as an important factor that lays out a path towards gender equality, poverty eradication, and inclusive economic growth. It is critical for human society to empower women for an inclusive society, especially from the poorer segments, in order to eradicate poverty in the real sense and bring about more gender equality in livelihoods. This article presents a case study of **SELCO Foundation** focused on scaling up the ecosystem factors that lead to the successful delivery of income-generating assets at the doorstep of the end user.

On a regular day, if you walk into Preeti Joshi's shop, you will see her juggling between handling production and sales of food items, engaging in her catering business, imparting her knowledge on astrology to community members, and even moonlighting as a speaker to local self-help groups that visit her for advice on being a successful entrepreneur. Joshi, 36, is a self-made entrepreneur from Haligal, a small town of over 100 households, in the district of Dharwad, Karnataka.

The untimely death of Joshi's husband led her to start a small home-based catering business to support her two children and aged mother. She manually prepared rotis and vegetables to supply to people working in the locality. Making rotis manually was a very arduous task and she could not afford to hire help either. Milling flour for the same purpose would take over half a day at the milling centre and sometimes an entire day because of 3–4 hours of power cuts daily during working hours and sometimes for a whole day.

Joshi invested in a solar-powered roti-rolling machine and a flour-milling

Joshi using the solar-powered efficient roti-rolling machine

machine was installed at her home, which reduced her production time, increased her income, and reduced her costs considerably. This enabled her to hire women to help her in her business. The technology provided her immediate accessibility and constant reliability. The technology has played an important role in her success as an entrepreneur.

Need for Ecosystem Approach

India's labour market is characterized by gender-based disparities.[1] Wage disparities, lack of access to appropriate technologies, inaccessible asset-based financing for women, gaps in skill and capacity building, all driven by cultural inhibitions caused by defined social structures, do not allow women to take up entrepreneurship. Women in rural, urban, and tribal settings will need a growing appetite for risk to turn their small businesses into successful enterprises and this requires support. For a sustainable energy-based solution to be developed, many factors need to be considered. Keeping the end user in the centre, need-based technologies, appropriate financing, training, capacity and skill building, and policies to scale are required for a solution to be delivered in a self-sustainable manner. These enabling ecosystem factors lead to the successful delivery of income-generating assets at the doorstep of the end user as demonstrated in the cases discussed next.

This allows for end users and communities to not just move out of poverty but also reach a level of social security, such that if there are sudden shocks or stresses (climate change, financial, health crisis, and so on), one is not plummeted back into poverty. These processes have to be the core on which the society needs to prepare relevant programmes and policies.

A typical livelihood solution should be approached as a suite of options for new and existing entrepreneurs,

[1] NSSO (National Sample Survey Office) India Wage Report

An ecosystem map for a small-scale entrepreneur

cooperatives, or hybrid ownership models within various contexts, which include un-electrified, under-electrified, and electrified scenarios. In each of the scenarios, financial savings, removal of drudgery, enhanced productivity, and time efficiency lead to better income opportunities and sustainable growth for rural and tribal livelihoods.

Need-based Decentralized Technologies Powered by Solar, Importance of Asset Ownership, and Exploring Ownership Models

In most traditional livelihoods, women always tend to perform the most drudgery-prone tasks, such as kneading clay in potter communities; cleaning, destoning, and sifting paddy within farming communities; and fanning fire to keep it alight in a blacksmith's workspace. Appropriate technologies such as blunger/pugmill, rice mills, and blacksmith blowers/power hammers can help reduce the day-to-day physical stress, reduce health risks, and allow women to carry out other tasks as well. Puttamma from Hassan district in Karnataka was engaged in the task of fanning the fire in her husband's blacksmith workspace, while he would hammer and shape the tools. They belong to a traditional blacksmith community, where the tasks performed have been passed through generations, including the gender roles. They invested in the blacksmith blower, a simple tool powered by solar energy. This eliminated the need for constantly fanning the fire through the day. After the intervention, Puttamma is now also engaged in crafting the tools herself, which she would never have had the opportunity before. This has given her husband time to engage in the sale of their tools, which has helped increase their income with access to additional markets.

Puttamma engaged in crafting tools at her workspace

Livelihood assets ownership for women entrepreneurs allows the business to grow and increase productivity. In labour productivity, large gender gaps are observed. In urban India, it is 62% compared to men and assets owned 40%. The corresponding ratios for rural India are 44% and 43%, respectively.[2] These technologies, if designed in a decentralized manner, allow for possibilities of individual/community ownership.

Let us take the case of Rosy Louis Dabale. She hails from the remote Agsalkatta village in Dharwad district. Rosy belongs to the Siddhi community, a tribal group whose members have descended from the Bantu people of the East African region. An ASHA worker, Rosy attended a solar workshop. It inspired her to set up the solar-powered decentralized flour mill. The need for an energy solution that

Rosy with her family in her workspace

[2] Basole A. and V. Chandy. 2019. Microenterprises in India: a multidimensional analysis. Global Alliance for Mass Entrepreneurship and Azim Premji University, Bengaluru

was reliable, accessible, and affordable was evident as the area faces 5–6 hours of power cut a day and for days during the monsoon. She also wanted to help the women in her community as they needed to travel 4 km to get their produce milled.

She is now able to mill 20 kg in 2–3 hours and when the demand is high, she mills 42 kg. She is also able to use it in the evenings when power cuts are heavy, as most villagers turn up at that time after finishing other activities. A solar-powered light in her workspace enables her to work comfortably and safely too.

Louis, Rosy's husband, is a farmer who engages in farming activities for one season but would not have any other form of livelihood for the remaining six months in a year. He now helps in running the mill, especially when Rosy is engaged in ASHA duties. He also assists in taking care of the children as the shop is an extension of their house.

Rosy is now eager to develop a market for the milled output and is interested in adding a spice grinding machine as a value add to her business. After starting the business, she also feels more respected and participates in community activities a lot more.

Women also spend a disproportionate amount of time in household chores in comparison to men. Women in India currently spend up to 352 minutes per day on domestic work, 577% more than men (52 minutes) and at least 40% more than women in South Africa and China (the other two BRICS countries for which data are available), according to data from Organisation for Economic Co-operation and Development (OECD).[3] This brings the need for flexibility in their work in a manner where the enterprise can still thrive. Rosy is able to successfully run the mill with her husband, continue her work as an ASHA for her community, manage her household.

[3] Details available at https://www.indiaspend.com/how-unpaid-work-keeps-indias-women-poor-and-unequal/

Preeti Joshi's investment in the flour mill was also very impactful as earlier she had to spend over half a day just getting her produce milled. She feels that the ownership aspect is also important as most mills are centralized and owned by men. She said: "Owning this mill is very liberating. People owning and running the mill business are always men who just stand there all day operating, which we women cannot afford to do. We have hundred other tasks at home to attend to as well."

Financial Piece

Women like Rosy and Joshi are a part of self-help groups that help them to open bank accounts and advise them on savings, repayments, and long-term investments. Most women entrepreneurs pointed out that local cooperative banks and MFIs (microfinance institutions) need to be more accessible for women to apply for loans, especially for investing in livelihood assets. Organizations such as SKDRDP, regional rural banks, nationalized banks, NGOs, and MFIs provide financial lending and trainings to particularly vulnerable women. In larger mainstream banks, bankers need to be sensitized and awareness needs to be created towards the importance of renewable energy as well. This can be achieved through organizing training workshops for bankers and handholding support. Pro-women schemes and policies at a central level with interest subvention and easy access to capital subsidies and other benefits will make the transition to formal financing a lot smoother. All the above discussed cases are financed by banks, MFIs, and cooperatives in assistance with NGOs.

Transferring Their Skills to Other Women

Growing a business requires upskilling and capacity building. Seventy-one per cent of the respondents in the IRENA online gender survey, 2018 highlighted that access to training and skill development should be a top priority. Appropriate training for use of technologies can be provided to

Joshi with a self-help group in her workspace

women entrepreneurs by local NGOs, local training centres, and so on. Further training on running a business, business modeling, and cash flow analysis is key to enable the growth of these enterprises. For example, RAPID and SKDRDP, an NGO and MFI, respectively, provide women training for these skills. They also help in demystifying technology by creating awareness about the technology regarding where to procure it, how to use it, and so on.

In India, the proportion of women-owned enterprises that employ three or more workers is a mere 2.7%. The total number of workers employed by women-owned enterprises in 2013–14 was 13.4 million, of which 77% were female, showing a high tendency for women to work with other women.[4] A key element of Preeti Joshi's success was that she was able to provide employment to five other women. She not only transferred her skills and knowledge to these women but was also able to provide employment to them, which is something she takes pride in: "These women had nothing, but their homes and children. The only interaction with the outside world was peeking through their windows and watching their husbands work in fields. Now they have a steady monthly income which brings them dignity. They don't even need to ask their husbands for money if their children want chocolates or other gifts!"

For women-led enterprises to grow, it is vital to ensure that all the pieces of the ecosystem are in place and such models should be replicated not only across India but also in other developing countries with similar context. The need of the hour is to focus on these missing ecosystem factors in order to demonstrate the linkage between sustainable energy and development, signifying the potential of decentralized energy to transform communities.

Conclusion

The focus of SELCO Foundation lies on scaling up the ecosystem factors that lead to the successful delivery of income-generating assets at the doorstep of the end user. In partnership with experts and practitioners, over 65 livelihood technologies and 100 processes have been developed around financial and social models. Forty per cent micro-entrepreneurs have diversified their businesses, particularly shops, by adding services that were not accessible to them and their customers due to lack of energy. Thirty per cent are small-scale vulnerable entrepreneurs who were suffering from opportunity loss due to time-consuming manual processes or unavailability of labour.

Women's economic empowerment has been recognized as an important factor that lays out a path towards gender equality, poverty eradication, and inclusive economic growth. Household chores to raising children are activities that are taken for granted and thus are not assessed in terms of financial remuneration, which has in many ways made many women vulnerable to mental and physical abuse. The status of women gets worse as one goes lower in the financial ladder. The poor, especially women, have to mostly rely on physical labour to earn their livelihood. A combination of household chores, raising children, and physical labour is challenging to the body and mind, rendering many women unemployable for most part of their lives. Today, with climate change creating havoc in the lives of the poor, the women bear most of the consequences. Droughts, floods, crop failures, cyclones, and so on force the poor to rebuild their lives many times in very short periods of time, forcing them to remain in poverty. Women again are the ones responsible for holding the family together.

SELCO recognizes that economic empowerment needs to be complemented by solutions that strengthen the ecosystem for women. SELCO aims to empower women in the sustainable energy sector with a focus on the following:

- Women-led clean energy enterprises
- Women-run small livelihood applications that are run on clean energy
- Women employees at various levels of a clean energy enterprise
- Women in civil society organizations focusing on clean energy awareness and dissemination
- Women innovators in the field of clean energy-based technologies

It is critical for human society to empower women for an inclusive society, especially from the poorer segments, in order to eradicate poverty in the real sense and bring about more gender parity in livelihoods. SELCO Foundation believes that sustainable energy should be used as a catalyst to empower women and alleviate poverty. EF

[4] Basole, A. and V. Chandy. 2019. Microenterprises in India: a multidimensional analysis. Global Alliance for Mass Entrepreneurship and Azim Premji University, Bengaluru

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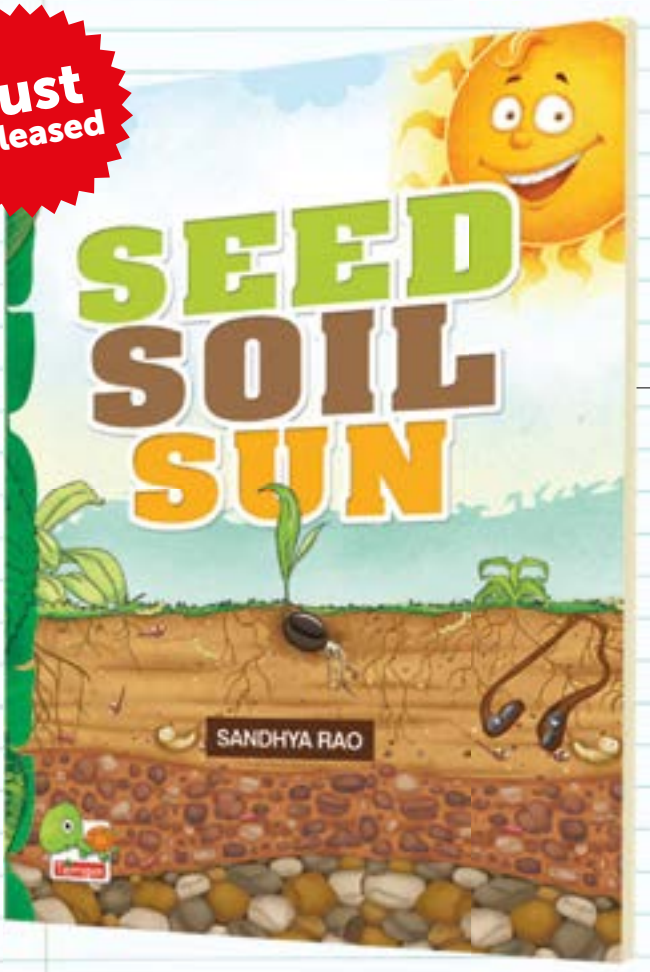

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RENEWABLE ENERGIES

Can the Oceans Play a Role?

While solar, wind, biomass, and other renewable forms are already being tapped across the globe on land, energies that can be harnessed from the vast ocean are yet to move from the research arena to the realm of commercialization. Ocean energy systems have a huge potential but need prototype demonstration for technical viability before we venture into commercialization and cost aspects. In this article, **Purnima Jalihal** talks about technologies for harnessing marine renewable energies.

Introduction

Today fossil fuels are the primary source of energy in the world. Oil, coal, and natural gas dominate the share of the fuels used and are also relatively easy to extract. However, it is also now established that burning of fossil fuels causes air pollution. The current scenario also has climate change and global warming as impending world disasters. They are considered to be a result of the anthropogenic greenhouse gases, with carbon dioxide being the most important. The December 2015 Paris Climate Agreement or COP21 within the United Nations Framework Convention on Climate Change (UNFCCC) aims to reduce the emission of gases that contribute to global warming. The agreement was signed by several countries, but issues still prevail. Some developed countries known to be the major polluters would like to withdraw from the agreement. The less developed countries have larger issues like eradication of poverty and would need financial support to reduce emissions. At subsequent COP meetings, the issues involved were still debated. In such a scenario where consensus is not likely soon, the move towards renewable sources of energy will continue to be slow.

The other reasons for the slow transition to renewables are the technological aspects leading to high costs. Most renewable sources are not baseload sources and their presence varies from region to region around the globe. The design and continuous operation of technological systems and issues in grid integration are challenging. However, today solar and wind energy has been able to overcome the barriers to a large extent. In India also, the targets and mandates set by the government have led to larger penetration of solar PV and onshore wind turbines, which are being extensively installed to meet specified goals.

While solar, wind, biomass, and other renewable forms are already being tapped across the globe on land, energies that can be harnessed from the vast ocean are yet to move from the research arena to the realm of commercialization. The oceans have huge potential for development of new technologies without affecting human settlements or the environment. Hence, the need of the hour is to develop technologies for harnessing marine renewable energies. The four ocean technologies with global potential are wave energy, marine currents, ocean thermal energy conversion (OTEC), and tidal energy. However, tidal energy potential in the Indian context is negligible and currently not being studied.

Wave Energy

The waves we see in the ocean are caused by winds blowing on its surface. Thus, due to the irregular nature of wind, waves are also an irregular phenomenon and their intensities vary with seasons as also the location on the globe. Waves can be as low as 0.5 m to as high as 10–11 m during cyclones.

Wave energy devices extract energy directly from the motion of waves at the surface or from the pressure fluctuations below the surface. Some of the wave energy devices being tried around the world are point absorber, tapered channel, oscillating water column (OWC), and Pelamis.

While waves contain a fair amount of energy, any structure or equipment to be mounted in the open sea needs to resist the forces, to which it is subjected constantly, while generating power. Seawater is also very corrosive, and hence materials used should be suitable for long-term exposure of around 20 years in the sea environment. Thus, the design of wave energy devices is very challenging. In India, the average wave power generation annually is lower than northern latitudes although during the south-west monsoon period (June to August; north-east monsoon season from November to January), the waves can be of very high intensities for a few months.

In India, for nearly two decades, research was carried out with an oscillating water column device at a place called Vizhinjam in Kerala (Ravindran, Jayashankar, Jalihal, *et al*. 1997) (Figure 1). The National Institute of Ocean Technology (NIOT) took over the project from the IIT Madras in 1996. Several power modules were tested and finally the continuously generated power was used to run a reverse osmosis (RO) based desalination plant of 10,000 litres per day capacity (Sharmila, Jalihal, Swamy, *et al*. 2004). This was the first ever self-sustaining system globally where power was generated from the sea to make freshwater out of seawater. However, from the point of view of improving efficiencies by understanding the complex behaviour of pneumatics of OWC, mechanical motions, and hydrodynamics together, the focused is now on smaller floating wave powered devices for remote locations.

Figure 1 Wave Energy Plant at Vizhinjam

Figure 2 Backward bent ducted buoy

Towards this end, the NIOT has been working on a floating wave-powered device called backward bent ducted buoy (BBDB) as shown in Figure 2. Extensive computer simulations and laboratory testing have been carried out for determining the hydrodynamic behaviour, mooring loads, and performance of the power module.

Several open sea trials were also conducted where the buoy generated the designed amount of power successfully offshore and it also withstood a cyclone.

The experience was used to further develop a product called the wave powered-navigational buoy (Figure 3). Navigational buoys are required in all ports and harbours and run on solar power. The new buoy developed uses wave energy. After successful trials, it is currently installed in the navigational channel of the Ennore Port in Chennai, where it is additionally giving oceanographic data, thus helping the port with ship movement. The technology has now been transferred to the industry.

Marine Currents

Ocean currents are driven by wind and solar heating of waters near the equator, although some currents result from variation in water density and salinity. Ocean currents are much slower

Figure 3 Wave-powered navigational buoy

compared to wind speeds. However, water is about 835 times denser than wind, and so a smaller water flow can be equivalent to wind with extremely high velocity. Energy can be extracted from such ocean currents using submerged turbines that capture energy by means of hydrodynamic lift and drag forces. Marine hydrokinetic turbines run by using the water velocity. Like waves, water currents change direction and magnitude according to seasonal variations.

Though marine currents are low near the equator, the large Indian coastline makes it more apt to work on marine hydrokinetic turbine using water velocity. As a result of extensive laboratory studies, NIOT recently carried out successful sea trials in Andaman and Nicobar Islands on a small cross-flow hydrokinetic turbine designed and developed in-house. This type of turbine can work in both tidal streams and marine currents in the ocean.

A small turbine was fabricated and it successfully generated the design power output in a seawater channel. Following this success, this turbine underwent rigorous testing in Macpherson Strait in South Andaman. The tests pave the way for scaling up off-grid units for remote coastal locations (Prasad, Nagasamy, and Jalihal 2016).

Figure 4 shows the turbine being tested at Andaman. This success has prompted the scaling up of designs. There are requirements for off-grid units of 1–5 kW rating in some remote coastal locations and islands and such turbines can be useful for these applications.

Ocean Thermal Energy Conversion

The sun warms the surface seawater to an extent that all the energy is captured in a region up to 100 m thickness near the surface. As we go deeper down into the ocean, the water becomes colder. A huge amount of cold water exists at depths of around 1000 m, which is due to accumulation of ice cold water melted from polar regions. The two bodies of warm water from the surface and cold water from the deep can be used to run the OTEC cycle for generating power. Essentially an OTEC device converts a low-grade heat source into electricity using a thermodynamic cycle. For tropical countries like India, OTEC can be a good renewable source since this is a baseload source of energy. The temperature difference exists throughout the year, and hence large amounts of power can be harnessed. However, at present OTEC is still in the testing and sea trial stages in the world because of the underlying challenges. The major components of an OTEC system include the following:

1. Heat exchangers
2. Turbine
3. Seawater pumps
4. Cold water conduit
5. Platform
6. Station keeping and mooring

The first three relate to the process cycle and generally are known in R&D and industry though optimization studies continue in laboratories around the world. However, the other three components, which are offshore based, are the most complex and challenging.

An offshore floating plant needs to be positioned in deep waters with a long conduit hanging vertically down or supported in some configuration to draw cold water continuously from depths of around 1000 m (Jalihal 2005). The conduit has to be designed for loads due to waves and currents and also for installation and deployment scenarios. As the rating becomes larger and larger, the size of the conduit becomes very big and is known to be the single most complex unit in the entire system. Internationally, studies on the conduit are still in progress.

A floating platform needs to be kept in position or at station, or else the cold

Figure 4 Marine current turbine tested at Andaman

water conduit connected to it may start drawing warm water due to vessel drift. Moorings have to be designed to be all weather for this purpose. Current offshore practice has codal requirements for moorings in the oil industry. However, long-term moorings for OTEC are yet to be attempted. In addition, proper data acquisition and control and systematic startup and shutdown procedures are also required.

In 1998, the NIOT under the Ministry of Earth Sciences (MoES) initiated the efforts towards setting up a 1 MW floating OTEC plant in 1000 m water depth about 40 km from the coastal city of Tuticorin in South India (Jalihal, Jayashankar, Nair, *et al*. 1999; Jalihal 2005; Jalihal, Abraham, and Atmanand 2012; Jayashankar, Jalihal, Ravindran, *et al*. 1998). The major challenge was the design of the platform and the cold water pipe. All subsystems were installed on a barge built indigenously. The final configuration of the barge with pipe/mooring is shown in Figure 5.

As part of the commissioning activities, various subsystem qualification tests were carried out onshore as well as in shallow waters. Owing to insufficient offshore infrastructure available in the country, the deployment had to be carried out with serious limitations and the project could not be completed.

Later the same barge was used for mounting desalination equipment and freshwater was first generated in shallow water. The learning was used for setting up desalination plants using thermal gradient successfully. India has the distinction of setting up a low-temperature thermal desalination plant in Kavaratti, Lakshadweep for the first time ever in the world in 2005. The plant is running successfully using ocean thermal gradient even today, generating 100,000 litres per day of potable water. The freshwater generated has had a very positive impact on the health of local islanders. Subsequently two more plants were set

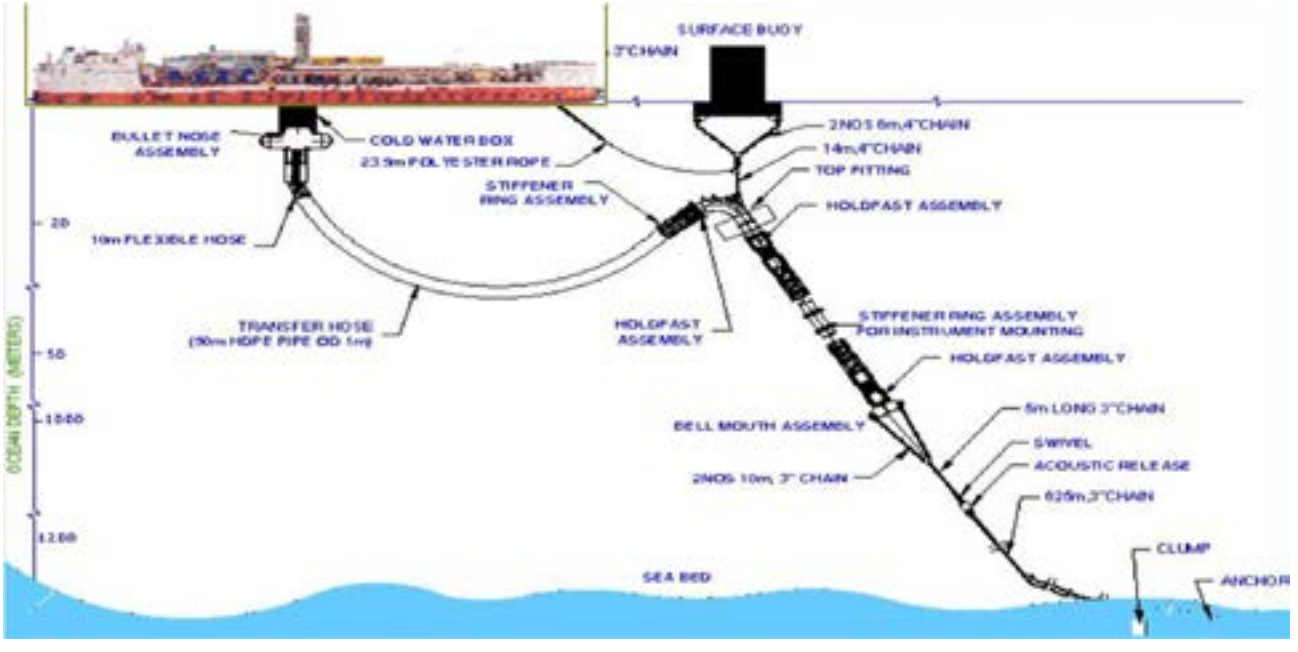

Figure 5 Platform and mooring arrangement of 1 MW OTEC plant

up in the islands of Agatti and Minicoy. A barge mounted desalination plant of capacity 1 million litres per day was also demonstrated offshore on the same barge built for OTEC (Figure 6).

Current Status

Thermal desalination expertise has now been developed with offshore experience for deploying pipes for drawing cold water. NIOT is now scaling up the technology with a large capacity plant of 2 million litres per day being set up at the Tuticorin Thermal Power Station. Efforts are also on now to power desalination using OTEC and such a system is being designed for an island in Lakshadweep. This OTEC powered desalination plant has many more complexities and challenges than before and not only will be a true model of green energy and clean water but will also lay the foundation for scaling up OTEC.

Thus, ocean energy systems have a huge potential but need prototype demonstration for technical viability before we venture into commercialization and cost aspects. The tropical climate and very varied seasonal changes around the year make the technological challenges many, but India needs to focus on these activities for reduction of the carbon footprint as well as ensuring green energy for the future.

Figure 6 View of the barge-mounted desalination plant

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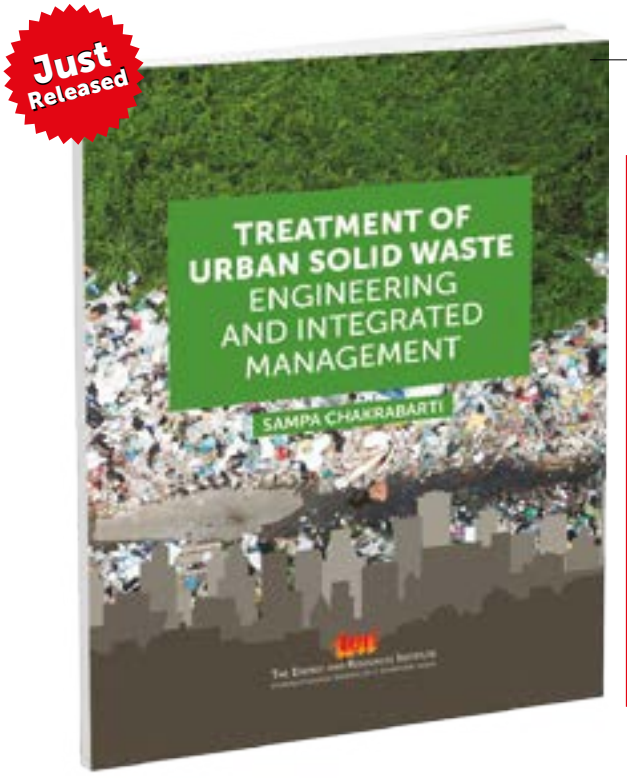
Purnima Jalihal is Head, Energy and Fresh Water, National Institute of Ocean Technology, Chennai. She can be reached at purnima@niot.res.in.

CHALLENGES AND SOLUTIONS OF URBAN SOLID WASTE MANAGEMENT



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ORGANIC PHOTOVOLTAICS

Towards Development of Low-cost Green Solar Cell Technology

Solar power industry is developing rapidly in India. Among the key challenges faced by the solar PV community is to find a balance between manufacturing commercially viable solar panels to meet growing consumer requirements and optimize the manufacturing technology following an environmentally sustainable design. In this article, **Raavi Sai Santosh Kumar** focuses on the development of green solar cells and the possibility to employ eco-friendly green organic molecules in the device fabrication.

The snowballing issue of global warming and its adverse effects suggest that the impact of any new technology on the environment and carbon footprint can no longer be ignored. Renewable energy sources, such as solar, wind, hydro, bioenergy, geothermal, and hydrogen, have received unprecedented interest globally owing to the increasing trend of energy requirement and the need to reduce the reliance on depleting fossil fuel reserves. As per the latest report of International Energy Agency (IEA), the renewable power capacity is set to grow by 50% between 2019 and 2024, led by solar photovoltaics (PV). The installation of solar PV systems on homes, commercial buildings, and industrial facilities is set to increase over the next 5 years, transforming the way electricity is generated and consumed (Figure 1) (IEA 2019). Solar power in India is a fast developing industry. The country's solar installed capacity reached 31.124 GW on 30 September 2019.

To date, there exists a plethora of technologies for solar to electricity conversion. Nevertheless, the most commonly used solar cell panels are based on silicon (Si), whose starting material is quartz. It is the most common form of silica (silicon dioxide), which is refined into elemental silicon. The first step is to refine quartz into metallurgical-grade silicon using giant furnaces. Keeping these furnaces hot requires a lot of energy. The metallurgical-grade silicon is then processed to obtain a purer form called polysilicon. The polysilicon production leads to the generation of a very toxic liquid silicon tetrachloride as a by-product. If it is dumped without further treatment, the silicon tetrachloride reacts with water, releasing hydrochloric acid, acidifying the soil, and emitting harmful fumes. In addition, the extremely potent greenhouse gas sulfur hexafluoride (SF_6) is used to clean the reactors used in silicon production. In its white paper[1] published in 2009, the

[1] "Toward a Just and Sustainable Solar Industry," a Silicon Valley Toxics Coalition White Paper released on 14 January 2009

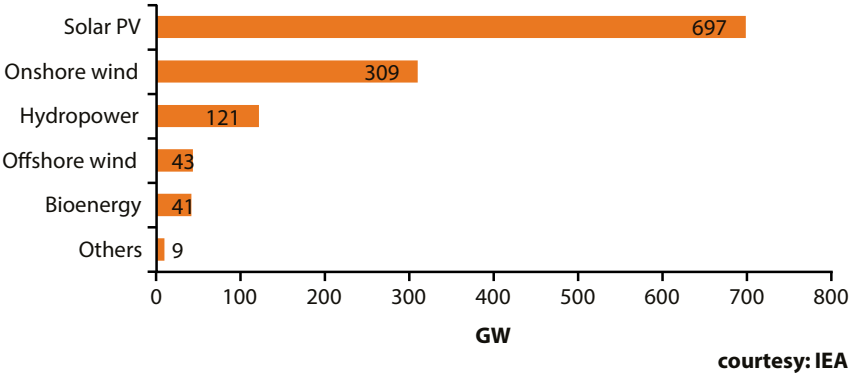

Figure 1 Renewable capacity growth between 2019 and 2024

Source IEA (2019)

Silicon Valley Toxics Coalition (SVTC) highlighted various environmental and health hazards associated with solar panels and suggested a range of actions that could be taken by policy makers, solar panel manufacturers, and consumers for clean and just solar energy. Despite the tremendous success and maturity of silicon solar cell technology, it is limited by the huge fabrication costs. The silicon processing is very expensive. It involves very high temperature methods that leaves a large carbon footprint. Nonetheless, considering the long-term durability and stability of silicon solar cell panels, they are continued to be deployed in installations. There is greater thrust on the development of alternative energy conversion technologies that are eco-friendly and cheaper. For a PV technology to meet the sustainable criteria, it should be economical, there should be abundant resource availability, and its environmental impact is minimum. Organic molecule based solar energy conversion devices have gained a lot of interest as an attractive alternative owing to the possibility of low-cost fabrication procedures, ability to be printed on flexible substrates, engineering at molecular level to tune bandgap and charge transport characteristics, and a potentially less hostile environment bearing (Haining, Boschloo, and Hagfeldt 2018) (Figure 2). These devices include organic (polymer) solar cells, dye-sensitized solar cells (DSSCs), and hybrid solar cells (perovskite solar cell (PSC) and quantum dot solar cells).

DSSCs take its inspiration from nature, almost mimicking the primary process of photosynthesis phenomenon in plants. DSSC consists of three components: (i) a monolayer of dye molecule adsorbed on the mesoporous semiconductor material, (ii) titanium dioxide (TiO_2) deposited on transparent conductive oxide (TCO) like indium tin oxide (ITO), and (iii) liquid electrolyte with excess of electrons. Dye molecules absorb sunlight and get excited. The electrons from the excited dye molecules get injected into the conduction band of TiO_2. The

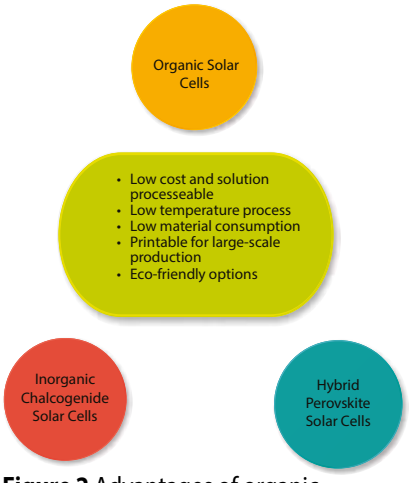

Figure 2 Advantages of organic material-based PV devices

Source Bae, Zhao, Hsieh, et al. (2016)

electrons are transported to the charge collector. After losing its electrons, the dye cation takes electrons from the surrounding electron-rich liquid electrolyte. The counter electrode (CE) typically is a platinum-coated ITO. DSSCs are generally considered eco-friendly to produce than the conventional solar cells because they require little energy to manufacture. Despite the tremendous success of the dye-sensitized solar cell technology with efficiency >13% (Mathew, Yella, Gao, *et al*. 2014) during the last three decades, challenges such as long-term stability for commercialization and overall cell performance and use of expensive platinum-based counter electrodes still exist. The best performing DSSCs use organic solvent-based liquid electrolytes. These liquid electrolytes suffer from various drawbacks, such as high vapour pressure, being toxic and sometimes explosive, and being corrosive to the platinum counter electrodes, thereby limiting long-time stability of devices. In spite of the extensive search for various alternatives to address the above-mentioned issues, one of the most important issues that still remains unresolved in the DSSC community is the contamination of standard aprotic DSSC systems through moisture or water. In this scenario, focus on aqueous DSSCs has taken precedence. Naturally occurring dyes and pigments, most of which are soluble in water, offer cost-effective alternatives; however, the use of natural dyes and pigments as effective sensitizers is yet to reach its potential. In view of being cost-effective and stable in the aqueous environment, an ideal DSSC should consist of inexpensive sensitizer, water-based non-toxic electrolytes, and a platinum-free counter electrode, in line with the true definition of the 'green' photovoltaic device. Recently, a 'green' DSSC was demonstrated by making use of an inexpensive magenta dye, new fuchsin (NF), for the first time, as a photosensitizer, a water-based liquid electrolyte based on Na_2S and aqueous Fe^{3+}/Fe^{2+}, and CoS deposited on C-fabric as the counter electrode. NF dye is also used to make kumkum or vermilion in India. The best device showed photo-conversion efficiency (PCE) of 2.9%, which is among the best obtained with DSSC with other natural photosensitizers with a simple molecular structure (Kokal, Bhattacharya, Cardoso, *et al*. 2019). The search for eco-friendly and inexpensive photosensitizers for aqueous DSSC is still at a nascent stage. NF is an inexpensive dye available off-the-shelf in most supermarkets in India for price of about $2/g from reputed chemical supplier Sigma Aldrich, while a more efficient DSSC N719 costs about $439/g. In terms of price comparison of counter electrodes, the cost of carbon fabric is $0.1/cm^2, while Pt-coated CE costs about $10/cm^2. The KCL solution with Fe^{2+}/Fe^{3+} is very inexpensive and non-toxic. In contrast, the iodide redox electrolyte is known to be corrosive and expensive. Thus, by the choice of cell components for fabrication, a low cost 'green' DSSC based on NF dye with aqueous electrolyte and platinum-free counter electrodes is realized.

Organic (polymer) solar cells function in bulk heterojunction architecture. All organic solar cells consist of a donor (p-type semiconductor) and an acceptor (n-type semiconductor) active layers. At the donor–acceptor (D–A) interface, charges are separated after photoinduced charge transfer from the electron donor to the electron acceptor. A bulk heterojunction solar cell (BHJ-OSC) consists of a bicontinuous network of donor and acceptor domains such that the donor/acceptor interface area is maximized for efficient photo-charge generation. The photoconversion efficiency for this class of OPVs (organic photovoltaics) is the product of quantum efficiency, which is a measure of current generated per photon absorbed, and energy efficiency, which is the fraction of photon energy retained by an extracted charge. This technology holds promise for fabricating lightweight and flexible devices via the low-cost and high-throughput roll-to-roll production process. This has triggered extensive research efforts around the world towards understanding and improving the photo-conversion efficiency of OSCs. The champion BHJ-OSC is reported to have the efficiency >14% for the single-junction binary BHJ cell (Zhang, Qin, Zhu, *et al*. 2018), 16.5% for ternary BHJ system (Li, Wu, Tang, *et al*. 2019), and 17.3% for tandem solar cells (Meng, Zhang, Wan, *et al*. 2018). High-performance polymer solar cells are normally processed with halogenated solvents, which are toxic and hazardous. Now, high power conversion efficiency in bulk heterojunction devices is achieved by using a non-toxic hydrocarbon solvent through an environmentally friendly processing route, yielding OSCs with power conversion efficiencies of up to 11.7% (Zhao, Li, Yang, *et al*. 2016). The novel processing system incorporates the synergistic effects of a hydrocarbon solvent, indicating a method of producing active layers of organic solar cells in an environmentally friendly way. It also provides important scientific insights that will facilitate further improvement in the morphology and performance of organic solar cells.

The class of organometal halide perovskite solar cells has proven to be technologically disruptive. Literature suggests the metal halide perovskite in its three-dimensional form offers the following advantages: strong light absorption, long charge carrier diffusion length, high defect tolerance, and large mobility. Within the first decade of its advent in 2009 with modest photo-conversion efficiency of 3.81%, now the highest certified PCE of a small area (<1 cm^2) of 23.3% is listed in an NREL efficiency chart. This has already crossed the highest certified PCE for thin crystal silicon (21.2%) and polycrystalline silicon (22.3%) solar cells. Efforts are underway to develop tandem architectures to

attain PCEs of approximately 31% and 29.5% for perovskite–Si and perovskite–perovskite tandems, respectively. It was demonstrated that these materials manifest relatively long carrier diffusion lengths of up to 1 µm, which correlates with the efficient overall performance. Perovskites soon demonstrated good compatibility for a wide array of device architectures that include applications with polymers, fullerenes, interfacial layers, and so on. Various methodologies towards highly efficient perovskite solar cells have been reported (Seok, Grätzel, and Park 2018). The most successful and investigated perovskite solar cell is based on methylammonium lead iodide (MAPbI3). However, there are inherent problems associated with PSC that impede long-term device stability and also there is the issue of the toxicity of lead. The chemical stability of perovskites (MAPbX3) is compromised by interactions with oxygen and moisture (Wang, Wright, Elumalai, *et al*. 2016). In the presence of water, it is found that the ionic solid $MAPbX_3$ readily decomposes to PbX_2. When exposed to both light and dry air, the photoactive layers rapidly decompose, yielding methylamine, PbX_2, and X_2 as products. This degradation is demonstrated to be initiated by the reaction of superoxide with the methylammonium moiety of the perovskite absorber. The low power conversion efficiency and stability of these new perovskite materials still pose major hurdles with respect to finding suitable replacements to the lead-based compounds. Concerted efforts are needed to overcome these barriers to make lead-free perovskites the contender for photovoltaic applications (Boix, Agarwala, Koh, *et al*. 2015; Li, Yang, Jiang, *et al*. 2019).

Figure 3 shows that environmental impacts of utility-scale solar energy (USSE) systems may occur at differential rates and magnitudes throughout the lifespan (that is, construction, operation, and decommission) of a USSE power plant, which varies between 25 and 40 years. As USSE systems are on the rise worldwide, an expansion is fuelled by technological advances, policy changes, and the urgent need to reduce both our dependence on carbon-intensive sources of energy and the emission of greenhouse gases to the atmosphere

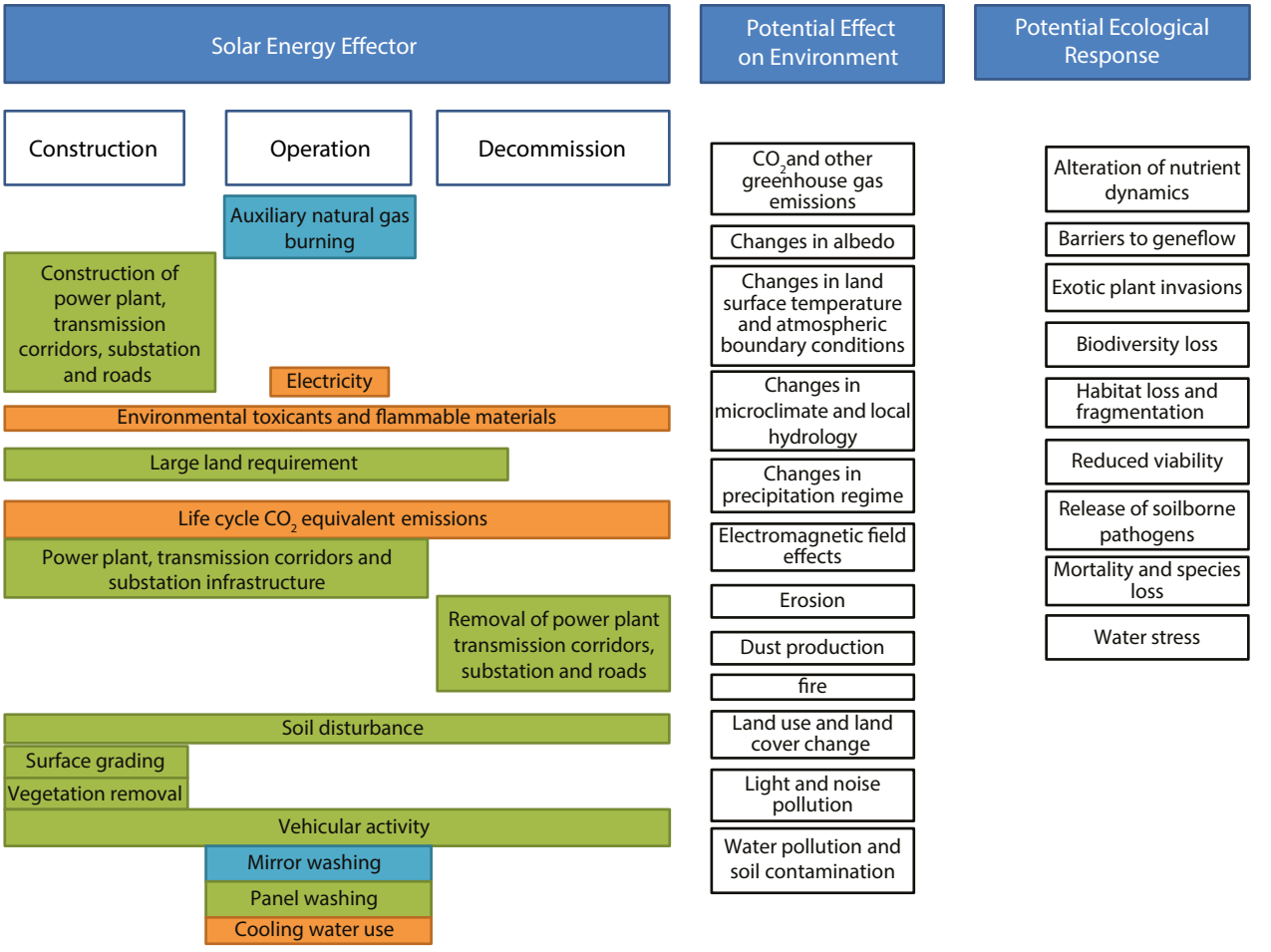

Figure 3 Solar energy effectors for utility-scale solar energy technologies

Source Hernandez, Easter, Murphy-Mariscal, et al. (2014)

(Hernandez, Easter, Murphy-Mariscal, *et al*. 2014).

To summarize, in comparison to most popular silicon-based solar cell devices, OPVs provide an efficient, eco-friendly, and economical alternative. Although technologies such as DSSC and bulk heterojunction solar cells have proven to be less efficient, the possibility to employ eco-friendly 'green' organic molecules in the device fabrication makes them attractive candidates. At the same time, recent advances have been made in the field of lead-free perovskite solar cells with efficiencies comparable to that of single-junction Si solar cells. A focussed effort towards development of 'green' solar cells requires researchers to take a step back and stop running behind achieving the best solar cell efficiencies as sometimes the cost for achieving the best overwhelms the actual motivation behind developing a particular class of solar cell technology, which is to be eco-friendly and inexpensive. Otherwise, why develop another technology when there are silicon solar cells with 40 years of work behind them.

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Raavi Sai Santosh Kumar is Associate Professor, Department of Physics, Indian Institute of Technology Hyderabad. He can be reached at sskraavi@iith.ac.in.

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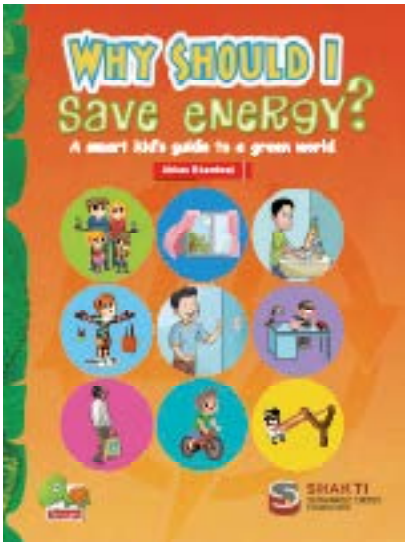

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Table of Contents

About the Author

Abhas Bhardwaj has studied botany and economics. Currently, he works as a market researcher. He has an avid interest in the environment and likes to share his enthusiasm with young minds. In his inimitable style, he likes to approach serious questions with humour.

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WORLD SUSTAINABLE DEVELOPMENT SUMMIT 2020

World Sustainable Development Summit (WSDS), the annual flagship event of TERI (The Energy and Resources Institute), was held from 29 to 31 January 2020. The theme of the 2020 edition of the Summit was 'Towards 2030: Making the Decade Count'. It was inaugurated on 29 January 2020 by Mr Prakash Javadekar, Hon'ble Minister of Environment, Forest and Climate Change. In his inaugural address, Mr Prakash Javadekar expressed his satisfaction over India's role in sustainable consumption and emphasized on the urgent need to change lifestyles as stated in the preamble of the Paris Agreement. He highlighted the achievement of India in the field of sustainable development, including an increase in the green cover. Mr Javadekar also inaugurated the first edition of IFAT Delhi – North India's trade fair for water, sewage, solid waste and recycling. In his welcome address, Mr Nitin Desai, Chairman, TERI, emphasized on the need for practical expression of the term 'sustainable development' in order to integrate the agendas of development and environmental protection. TERI felicitated Professor Jeffrey D. Sachs with the Sustainable Development Leadership Award (SDLA) 2020 for his work in the field of sustainable development. In his address, Professor Sachs highlighted the importance of shifting from the current politics of power to the politics of problem solving. In his welcome address, Dr Ajay Mathur, Director General, TERI, stressed on the need to assess the present situation and take necessary steps to achieve the 17 SDGs. He also highlighted the importance of fostering new partnerships and strengthening the existing ones. Dr Mathur welcomed the Summit delegates to the first edition of a joint venture with IFAT Delhi, focusing on technological innovations in the sector of water and waste management solutions. Dr Annapurna Vancheswaran, Senior Director, TERI, in her concluding remarks thanked the Summit partners and delegates across sectors for their presence and participation in the deliberations.

This year, WSDS hosted 20 distinct thematic tracks, deliberating on an array of sustainable development

issues and solutions. These thematic tracks were populated by experts and key practitioners from respective fields and covered a variety of topics. The major themes of the Summit included mobility, water, industry and energy transition, air pollution, green finance, and blue economy. In addition, plenary sessions were held, a key one being with Dr Ajay Mathur, Lord Adair Turner, Chairman of the Energy Transitions Commission, and Mr Jairam Ramesh, Hon'ble Member of Parliament, on the overarching theme 'Towards 2030 Goals: Making the Decade Count'.

The final day of the Summit kicked off with the launch of a report by McKinsey & Company on 'Climate Risk and Response: Physical Hazards and Socioeconomic Impacts'. The session was chaired by Dr Ajay Mathur, Director General, TERI, who was in conversation with Mr Rajat Gupta, Senior Partner, McKinsey & Company.

In his keynote address, Mr Gupta began by emphasizing on the need for such a report by drawing attention towards the global climate crisis. The report tries to link climatic models with economic projections by taking into consideration specific cases.

The valedictory session was graced by Mr Jayant Sinha, Hon'ble Member of Parliament, who, in his address, introduced the 'farm-to-green frontier' development model. Mr Nicholas Stern, IG Patel Professor of Economics and Government, Co-Director of the India Observatory, and Chair of the Grantham Research Institute at LSE, in his remarks stressed that change is possible through rapid technological advancement, international agreements, and collective efforts from youth. Dr Ajay Mathur concluded the Summit by reminiscing about the beginning of WSDS's journey and mentioned the new partnerships that WSDS has formed over the years. Dr Mathur thanked the 21 key partners of WSDS 2020 for their invaluable contribution to the Summit's success. In his closing remarks, Dr Mathur expressed his gratitude to IFAT Delhi, TERI colleagues, and everyone associated with the successful completion of WSDS 2020. EF

GENDER MAINSTREAMING IN ENERGY SECTOR

Concerted actions are required at multiple levels of policymaking, implementation, budgeting, and monitoring to promote equal participation of women in the energy sector. Gender- sensitive policies and practices are necessary to create opportunities for women across energy value chains, including at workplace and marketplace. **Suhela Khan**, Country Programme Manager - WeEmpower Asia at UN Women, in conversation with **TCA Avni** for Energy Future talks about enhancing women's access to sustainable energy and developing their leadership and entrepreneurial skills in renewable energy.

Men and women are impacted by lack of access to affordable energy in different ways – could you tell us a little more about this and about how policy and programmes can be more gender sensitive?

Women and men have different energy needs stemming from their varied roles at homes, communities, and workplaces. In most developing countries, women to a large extent are responsible for household and community energy provision. They are commonly responsible for providing lighting, heating, and cooking in households and tend to oversee the smaller, daily household energy transactions. Moreover, they assign different attributes to the same product or service that impact their decisions. For example, a UN Women's study on assessing women's demand and willingness to pay for renewable energy products and services, supported by DFID, found that safety, reliability, affordability, and absence of pollution were the drivers for female-headed households to purchase renewable energy products. For male-headed households, low electricity bill and absence of pollution were the key drivers for renewable energy product purchase. Gender responsive energy policies must recognize women's gender-specific needs and demands and translate these insights into targeted initiatives to support women's economic empowerment in the decentralized sustainable energy sector.

While several international agreements such as UN's Sustainable Energy for All (SEforALL) initiative, 2015 Paris Agreement on climate change, and Sustainable Development Goals (SDGs) recognize that a just energy transition cannot be secured without inclusion of women, majority of the renewable energy policies across countries remain gender blind. This is largely because the energy sector is dominated by men at all levels. Women occupy only 4% of the chair positions on the World Energy Council (WEC) and 18% of the secretary positions. Only 10% of energy ministries are headed by women and they make up less than 22% of the energy labor force.

For policies and programmes to be gender responsive, there is a need to integrate a gender perspective throughout all their phases from design, planning, formulation, and adoption to monitoring. This entails recognition and identification of gender energy needs and gaps, enabling women's participation in decision-making processes and taking transformative actions to address gender gaps. There is a need for disaggregated data and evidence to bolster the understanding among policymakers about different energy needs of women and men. Tools and strategies of gender audits and gender responsive budgeting can bring nuanced perspectives on gender issues and gender gaps in existing policies and programmes. Furthermore, to link policy change to practice, awareness-raising initiatives are critical that address discriminatory social and cultural norms that define and promulgate the energy sector as a 'male' field and hinders women's participation.

Do urban and rural women face different types of challenges in energy access? Do you feel enough attention is given to this difference? Is there a need to formulate policy differently to address these?

Yes, rural–urban disparities do create different challenges for women in energy access. For example, compared to women in urban areas, women in rural areas face a lack of access to modern fuels and improved stoves. This poses severe health risks and enhances women's drudgery and time spent in unpaid work, specifically in fuel collection, cooking, and food preparation, limiting their participation in economic activities. The challenges of reliable energy are more pronounced in rural areas that have implications on domestic and productive activities as well as on service provisioning that impacts women the most. For example, health centres, schools, and water supply systems are key economic and women's advancement enablers. When health centres are connected with modern energy services, they are better able to address women's sexual and reproductive health needs; access to energy services at streets and schools enables girls' and women's safety and mobility for education and productive activities. Ensuring that school, health centres, and water supply systems are electrified is a precondition to address the energy poverty of women and enable them to seize new income opportunities created by sustainable energy access. More emphasis is needed on interaction among these different stakeholders for solutions that look at the entire ecosystem. Gender responsive budgeting can be promoted to ensure resources are allocated to increase access of sustainable energy solutions in health, education, and water supply. Options to encourage schools, health centres, and water supply to source their sustainable energy technologies from women entrepreneurs may be explored. This could provide women entrepreneurs with 'anchor clients', that is, clients that provide a regular source of revenue, which will be extremely valuable in increasing their access to finance.

Can you talk about 'Women's Entrepreneurship for Sustainable Energy Programme' and how women can become active participants in the transition to renewable energy?

Women are not only the primary energy users and managers, but they are huge market as consumers too. Interventions that have tapped the potential of women as consumers and entrepreneurs, in the demand and supply side provisioning of renewable energy, throughout the globe, have shown remarkable outcomes. For example, the Solar Sister Initiative, which invests in women solar entrepreneurs, has grown from 2 to 1250 entrepreneurs

in 5 years.[1] Women's engagement in the supply chains, particularly in retail and marketing, has a potential to reach out to the unreached, while creating income generating opportunities for them. TERI's own experience in Lighting a Billion Lives initiative in India that worked initially with men as entrepreneurs demonstrated that they could not get into every home and increasingly women entrepreneurs were entering the field. Furthermore, even when entrepreneurs were men, they were selling largely to women.[2]

Likewise, many leading players in India working with rural communities for entrepreneurship in renewable energy, with whom we interacted for developing the implementation road map of the Women's Entrepreneurship for Sustainable Energy Programme, found that women entrepreneurs outperformed men in areas where relationship building was involved, such as opening bank accounts or filling loan paperwork; rural communities were more candid to women entrepreneurs and women play a central role in supply chain as trusted users and promoters of household and energy products.
The Women's Entrepreneurship for Sustainable Energy Programme aims at enhancing women's access to sustainable energy and developing leadership and entrepreneurial skills in renewable energy. The Programme in collaboration with the Department of New and Renewable Energy, Government of Madhya Pradesh has invested in strengthening women managed institutions, such as Anganwadi centres. The pilot project enabled off-grid energy access at Anganwadi centres for improved working conditions and services rendered. These solar powered Anganwadi centres with lighting, cooling, and mobile charging facilities can host a range of basic services and activities lacking in an underserved community, including providing safe spaces for women's livelihood and community-based activities in the evening hours. The project created a cadre of trained women Anganwadi workers in the management and maintenance of installed solar systems. Another intervention is around employing new age clean solar dehydration technology and creating necessary backward and forward linkages in enabling small and marginal women farmers dry and sell agricultural and fish products in Maharashtra and Odisha. The intervention will create a cadre of women entrepreneurs embedded in the dried and processed food value chain through effectively leveraging clean technology while building there technical and entrepreneurial skills. Women's access to dehydrated food products round the year will strengthen household's food security, resulting in positive nutritional outcomes for women and girls.

Could you talk about the role of different stakeholders – governments, civil society, corporates, etc.?
Government has a crucial role to play in ensuring that gender is mainstreamed within energy policies and programmes and that women are not seen as mere beneficiaries but as active agents of change. Civil society's role in removing barriers to skills, information, and social norms is critical towards strengthening women's role as leaders and active players in energy value chains. Moreover, they are a key constituency for engagement in strategic policy dialogue. At UN Women, together with partner civil society organizations, we have demonstrated models integrating gender into livelihoods that focused on addressing issues of women's identity as citizens and economic actors, leadership and decision-making, as well as violence with bearing on their economic empowerment. Corporate sector is an important driver of women's economic empowerment. Through gender sensitive policies and practices, they can expand opportunities for women across energy value chains, including at workplace and marketplace.

Thank you for taking the time to have this discussion with us. To end, could you tell us a little about future directions?
While it is heartening to see the recognition of close interconnection between gender and energy issues globally as is reflected in Sustainable Development Goals as well as Paris Agreement, concerted actions are required at multiple levels of policymaking, implementation, budgeting, and monitoring to promote equal participation of women in the energy sector. EF

[1] Details available at http://www.icrw.org/sites/default/files/publications/Invisible-market-energy-agricultural-technologies-women's-economic-advancement_0.pdf

[2] Details available at http://www.business-standard.com/article/news-ians/number-of-women-entrepreneurs-in-rural-solar-projects-rising-116040300364_1.html

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Energy Conversion and Management, Volume 203, 1 January 2020, 112235

Manpreet Kaur, Manoj Kumar, Sarita Sachdeva, and S. K. Puri

This study is based on 'waste to energy'concept, wherein the potential of almond crop residues (that is, almond shells) was investigated for biofuel production via different bioprocesses. Three routes, namely, A1 representing hythane production through two-stage anaerobic digestion (TSAD), A2 representing ethanolic fermentation, and A3 representing coupled ethanol and hythane production, were evaluated for maximizing energy recovery. Results showed that in route A1, increased $H_2/(H_2 + CH_4)$ ratio (0.53) resulted in inappropriate hythane composition, which was attributed to higher hydrogen yield of 236.6 L/kg chemical oxygen demand removed (CODr) and lower methane production (203.9 L/kg CODr) in the route. In route A2, sole ethanol production led to much lower carbon conversion efficiency (25.7%) and energy yield (6173.1 kJ/kg CODr), which questions the feasibility and efficiency of this process. However, in route A3, coupled ethanol and hythane production led to increased substrate degradation (91.3%) and higher carbon conversion efficiency (75.1%), resulting in enhanced energy recovery (22156.6 kJ/kg CODr) as compared to A1 route (13573.6 kJ/kg CODr). The stable $H_2/(H_2 + CH_4)$ ratio of 0.29 obtained in route A3 makes this pathway most suitable for efficient co-production of both biofuels. Further, linking of biochemical conversion process with thermochemical process, that is, pyrolysis, to produce biochar from almond shell residues could be seen as an effective strategy for waste management and for enhancing the economic viability of the process. EF

Clean Gaseous Fuel Application in Diesel Engine: A Sustainable Option for Rural Electrification in India

Renewable and Sustainable Energy Reviews, Volume 117, January 2020, 109485

S. Das, D. Kashyap, P. Kalita, V. Kulkarni, and Y. Itaya

In this study, biogas (BG) and producer gas (PG) based CI engine technology for remote electricity generation in India has been reviewed. It is focused on conceptualizing the influence of these gaseous fuels in CI engine as the secondary fuel under dual fuel (DF) mode with diesel/biodiesel as the pilot fuel. The effects of various operating parameters on the performance, combustion, and emission characteristics have been reviewed. It is evident from the study that induction of gaseous fuel declines the engine performance to some extent; however, emission characteristics are reported to be enhanced. However, changes in the operating conditions have immense scope in the improvement of the engine performance. The study develops a clear understanding on the possibilities of these gases to be used as a primary source for generating rural electricity. An exhaustive review is also carried out on various electricity generating units in India powered by BG and PG individually. This study provides a complete insight into pros and cons associated with such power generating units and their socio-economic impacts on rural livelihood. EF

A Review on Technical, Applications and Economic Aspect of Packed Bed Solar Thermal Energy Storage System

Journal of Energy Storage, Volume 27, February 2020, 101046

Abhishek Gautam and R. P. Saini

The development of renewable energy technologies provides a significant solution to deal with the energy crisis along with resolving environment-related issues. Solar energy is one of the emerging technologies that has been established as an effective alternative to fossil fuels and is an eco-friendly source for the sustainable development of society throughout the globe. Its rapid growth is dealing with many technical barriers such as low efficiency, fluctuations in energy supply, and economic hindrances. The intermittent nature of solar energy is also one of the major causes of fluctuations in energy supply, which can be rectified by installing the storage unit with solar

thermal systems. Packed bed storage system is an option for solar thermal systems to store energy during its availability and supply that stored energy at the time of requirement. This study is about technical characteristics and economic feasibility of various applications of the solar thermal system for different temperature ranges. The packed bed storage system and its working principle and design aspects are discussed, followed by its heat transfer fluid and packing element. The various factors affecting the heat transfer within a packed bed are described. The factors affecting thermal losses and pressure drop are also discussed. The review also examines the various applications of the packed bed storage system for various temperature ranges and their economic aspects. EF

Thermal and Kinetic Analysis of Diverse Biomass Fuels under Different Reaction Environment: A Way Forward to Renewable Energy Sources

Energy Conversion and Management, Volume 203, 1 January 2020, 112266
Farooq Sher, Sania Z. Iqbal, Hao Liu, Muhammad Imran, and Colin E. Snape

This study investigates the thermal and kinetic analysis of six diverse biomass fuels in order to provide valuable information for power and energy generation. Pyrolytic, combustion, and kinetic analyses of barley straw, miscanthus, waste wood, wheat straw, short rotation coppicing (SRC) willow, and wood pellet were carried out by non-isothermal thermogravimetric analyser (TGA), differential thermogravimetric (DTG), and differential scanning calorimetry (DSC) techniques. Biomass fuels were thermally degraded under N_2, air, CO_2, and the selected oxy-fuel (ratio of 30% O_2 and 70% CO_2) reaction environments. The thermal degradation under inert N_2 and CO_2 atmospheres showed an almost identical rate of weight loss (R), reactivity (RM × 103), and activation energy (Ea) profiles. Similar profiles for R, RM, and Ea were observed for the environments under air (ratio of 21% O_2 and 79% N_2) and the oxy-fuel combustion. Results indicated that the thermal decomposition rate for biomass fuels in an oxidizing condition was faster than in an inert atmosphere; a favourable effect on thermal degradation of biomass fuels was observed when the oxygen content increased from 21% to 30%. Higher activation energies with lower reactivity were observed for the biomass fuels that have low cellulosic contents as compared to the other fuels. Regression analysis confirmed that the reaction order 0.5 modelled fitted well for all biomass samples. All these findings will provide valuable information and promote the advancement of future researches in this field. EF

Experimental and Analytic Study of a Hybrid Solar/Biomass Rural Heating System

Energy, Volume 190, 1 January 2020, 116392
Xinghui Zhang, Jiaojiao Yang, Yi Fan, Xudong Zhao, Ruimiao Yan, Juan Zhao, and Steve Myers

This paper presents a dedicated analytical and experimental study of a hybrid solar/biomass space heating system incorporating a micro-channel solar thermal panels-array, a biomass boiler, and a dedicated control algorithm. The annual energy performance of the hybrid system was investigated using a professional building energy simulation program (EnergyPlus), which can predict the heat load profile of house, the ratio of energy usage from solar/biomass sources, and the primary energy/exergy efficiencies. The thermal efficiency of the solar thermal panels-array is in the range of 60–70%. The heat storage water tank has a heat conversion factor in the range of 0.94–0.98. The heat load index per unit area is 46.86 W/m^2 and the cumulative heating energy consumption with 100 m^2 house is 24.3 GJ during a heating season. The total annual energy demand of the solar/biomass heating system is around 35.91 GJ, of which the sun provides 63.31% and biomass provides 36.69%. The primary energy and exergy efficiencies of the solar/biomass rural heating system are 67.66% and 16.17%, respectively. However, when the total input electrical exergy is traced back to its primary energy source (that is, a coal-fired power plant), the exergy efficiency falls from 23.14% to 7.27%. Compared to the traditional primary energy supply system, the energy conversion effect and the effective utilization degree of the solar/biomass heating system are relatively higher. EF

GREEN AND EFFICIENT POWER TO EVERY HOUSEHOLD

Cygni Energy is an IIT Madras incubated start-up founded by Venkat Rajaraman in 2014 with the aim of providing green and efficient power to every household. Cygni Energy in association with the Indian Institute of Technology Madras has developed 48V inverterless DC technology. The Solar DC Inverterless system, consisting of DC solar generation, the DC powerline, DC appliances, and battery, is a landmark innovation with the potential to be rapidly deployed in every home and office in India as well as in homes across the world. The efficiency of the system eliminates the typical conversion losses by 40–45% associated with the traditional AC devices and contributes to building energy security.

It transforms the lives of ordinary citizens by providing them reliable power supply, energy-efficient appliances, and lower cost of electricity all at the same time. The DSIR certified R&D lab at Cygni gives the necessary traction to the innovation by catering to the requirements of society. The product variants are positioned to ensure universal energy access by particularly focusing on the marginalized section. Our product not only caters to homes that lack access to power but is also capable of running urban homes and even businesses.

In the tribal areas and remote geographical locations of India, the power eludes households and mainstream development remains a distant dream. And households often fall into the viciousness of poverty. The transformative effect of energy access has been proven to improve the life standard of the people by enabling longer hours of work. Children can now study in a well-lit and ventilated home environment, as well as energy access is creating new job opportunities through rural entrepreneurship. An affirmative step to bring the marginalized section to the mainstream was envisaged and envisioned through the revolutionary DC technology. Our solar solutions ensured energy access a reality to the remote terrains.

Our core product is Cygni Integrated Battery Inverterless System (IBIS). It comes with an integrated Li-ion battery replacing the older lead-acid batteries, making the system both compact and efficient.

The energy efficiency is achieved because we prevent multiple AC-DC conversion that occurs during the normal operation of any equipment. Most energy-efficient appliances at homes such as LED lights, fans, and even your electronics run on DC power. The solar energy generated and the power backup in batteries are again DC power. Using an inverter and adaptors makes this conversion at each level and even the best of equipment has an efficiency of nearly 85% and with multiplier effect even with just 2 conversion wastes about 28% (about 72% efficiency, which is 85% of 85% energy) of energy. We utilize this by a single large AC-DC conversion at source.

The IBIS system provides connectivity via both Bluetooth and GPRS and real-time consumption can be viewed by mobile app or through the energy management system. Our product line enables the use of energy-efficient DC appliances such as BLDC fans and LED lights. Typically, homes have two distinct lines – 5A and 15A. Our vision is to convert the 5A line into a DC line and keep the high power appliances such as dishwasher and air conditioner (which are typically on a 15A line) intact.

Technical Specifications of the Products

The IBIS 500 includes the following: (a) Up to 1.25 kWh Li-ion battery, (b) AC-DC converter DPAU 500 (ensures a maximum load of 500 W), (c) solar panels up to 500 Wp, and (d) dual input – solar and grid (optional).

Special Features of the Product

- Technology collaboration with IIT Madras
- BIS Certified IS 16711:2017
- Provision for solar, battery, and grid (AC) inputs
- Solar interface for connecting up to 500 W of solar panels

Variant Specification	IBIS Off grid	IBIS Lite	IBIS Standard	IBIS Pro	IBIS Duo
Solar panel capacity	125 Wp/200 Wp recommended	125 Wp/200 Wp recommended	125 Wp/200 Wp recommended	Up to 500 Wp	Up to 500 Wp
Battery pack capacity (usable)	1 kWH	0.5 kWH	0.5 kWH	1 kWH	1 kWH
Total load limit	250 W	150 W	150 W	500 W	500W (includes 500VA AC output)
Nominal output voltage	48V DC	48V DC	48V DC	48V DC	48V DC and 230V AC
Input sources	Only solar	Only solar	Solar + Grid (150 W)	Solar + Grid (500 W)	Solar + Grid (500 W)
AC output	No	No	No	No	Yes
Approx. Weight	18 kg	13 kg	13.5 kg	20 kg	22 kg
Preferred application	Off grid homes	Off grid homes	Near off grid homes	Grid-connected homes	Grid-connected homes and small offices

- » Battery interface for connecting up to 2 kWh of battery
- » Single-home/multi-home design
- » Online DC energy metering and advance remote monitoring
- » Smart DC short circuit protection
- » Advance Bluetooth Low Energy 4.0v interface

Solar inverterless 48 V DC controller comes with the following variants: Inverterless Off-grid, Inverterless Lite, Inverterless Standard, Inverterless Pro, and Inverterless Duo.

All the inverterless controllers come with remote monitoring features: 48V DC appliances include LED light bulb, mixer, DC-powered 21"/24"TV, DC desert cooler, ceiling fan, computer, cell phone charger/socket, tube light, induction stove, freezer, power loom, and water pump.

Rural productive appliances are moving towards in a big way to DC and Cygni is planning to play a significant role in that market. The price of our products ranges from ₹20,000 to ₹100,000, which changes based on the bundle of appliances that we provide to the customers. This is typically about 40% cheaper than the traditional solar AC system.

Our Projects

With the help of IIT Madras and Rural Electrification Corporation Limited (REC), Ministry of Power, Cygni Energy has successfully implemented installations in remote rural areas of Jammu and Kashmir, Assam, Manipur, and Rajasthan, with overall installations across the country being over 45,000. These IBIS systems currently operate in hostile weather conditions of high humidity in Assam, low temperature in J&K, and high temperature in Rajasthan.

The seamless integration of IBIS, grid, and solar designed to function in the local weather conditions is ensuring uninterrupted power supply to households. Our products have made remarkable improvement in the living standard of villagers and in savings for our urban customers.

Since our customers are majorly in hard-to-reach rural areas and rough terrains, to handle the challenge of post-installation service, we have a dedicated onsite and online support team for quick serving and all products come with built-in GSM/GPRS, which enables remote monitoring even in such rural areas.

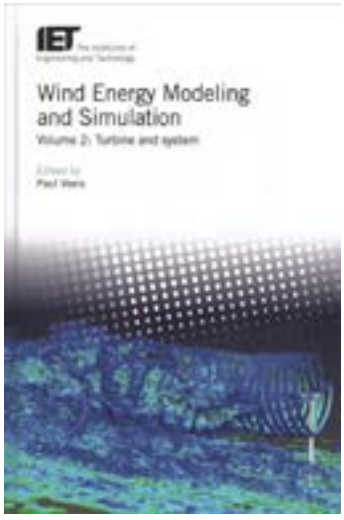
Awards Won

Cygni Energy is the first company to be a part of Startup India campaign, 2015 for its innovative technology. Cygni Energy has won several accolades, such as ASSOCHAM award for Most Innovative SME Company at 6th SME Excellence Awards – 2018, Best Emerging SME Award Dun & Bradstreet India & RBL Bank SME Business Excellence Awards 2017, Millennium Alliance Round 5 Award, CII 19th National Award for Excellence in Energy Management, Best Rural Electrification Projects by Industry during ISGF Innovation Award, and so on. EF

Founder and CEO Venkat Rajaraman

Wind Energy Modeling and Simulation: Turbine and System, Volume 2

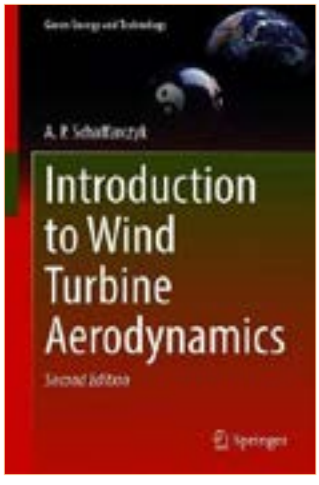
In order to optimize the yield of wind power from existing and future wind plants, the entire breadth of the system of a plant, from the wind field to turbine components, needs to be modelled in the design process. The modelling and simulation approaches used in each subsystem as well as the system-wide solution methods to optimize across subsystem boundaries are described. Chapters are written by technical experts in each field, describing the current state-of-the-art in modelling and simulation for wind plant design. This comprehensive, two-volume research reference provides long-lasting insight into the methods that will need to be developed for the technology to advance into its next generation. Volume 2 covers turbine-level aerodynamics, aeroelasticity, electrical systems, wind turbine control, offshore foundations, system optimization, and grid modelling. EF



Editor: Paul Veers
Publisher: The Institution of Engineering and Technology
Year: 2020

Introduction to Wind Turbine Aerodynamics

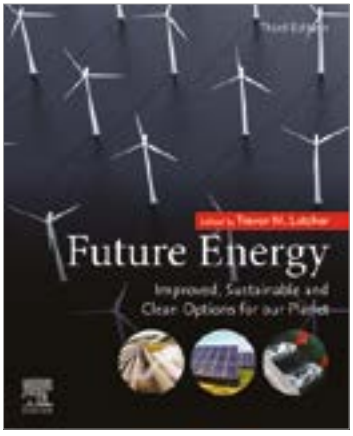
This book offers an introduction to the topic for professionals and students with a diverse range of backgrounds. *Introduction to Wind Turbine Aerodynamics* is a self-contained textbook that shows how to progress from the basics of fluid mechanics to modern wind turbine blade design. It presents the fundamentals of fluid dynamics and inflow conditions, as well as extensive information on theories describing the aerodynamics of wind turbines. After examining a number of related experiments, the book applies the lessons learned to blade design. EF



Author: A. P. Schaffarczyk
Publisher: Springer
Year: 2020 (2nd edition)

Future Energy: Improved, Sustainable and Clean Options for Our Planet

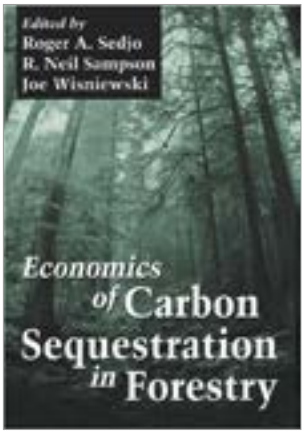
This book provides scientists and decision-makers with the knowledge they need to understand the relative importance and magnitude of various energy production methods in order to make the energy decisions necessary for sustaining development and dealing with climate change. The third edition examines the present energy situation and extrapolates to future scenarios related to global warming and the increase of carbon dioxide and other greenhouse gases in the atmosphere. EF



Editor: Trevor M. Letcher
Publisher: Elsevier
Year: 2020 (3rd edition)

Economics of Carbon Sequestration in Forestry

Since the 1992 Earth Summit, there have been increased efforts on an international scale to address global climate change. Reducing the increased levels of CO_2 and other greenhouse gases, which are believed to be contributing to this climatic change, will require major effort on the part of the world's governments. This means that the environmental, economic, social, and political consequences of climate change must be understood and that strategies to mitigate climate change must also address these issues. The workshop detailed in this book concentrated on how economic principles and analysis could contribute to the planning of forestry projects aimed at effecting terrestrial carbon balances. More than 30 international scientists came together for one week near Stockholm, Sweden and divided into working groups charged with addressing a specific issue and preparing a paper within this time frame. EF



Editors: Roger A. Sedjo, R. Neil Sampson, Joe Wisniewski
Publisher: CRC Press
Year: 2019

RENEWABLE ENERGY AT A GLANCE

Ministry of New and Renewable Energy			
Programme/Scheme-wise Physical Progress in 2019-20 & Cumulative up to December 2019			
Sector	**FY- 2019-20**		**Cumulative Achievements (as on 29 February 2020)**
	Target	**Achievements (April-February 2020)**	
I. GRID-INTERACTIVE POWER (CAPACITY IN MWp)			
Wind Power	3000.00	2043.28	37669.25
Solar Power - Ground Mounted	7500.00	5596.40	31980.70
Solar Power - Rooftop	1000.00	628.59	2424.94
Small Hydro Power	50.00	90.00	4683.16
Biomass (Bagasse) Cogeneration	150.00	83.00	9186.50
Biomass (non-bagasse) Cogeneration)/ Captive Power	100.00	0.00	674.81
Waste to Power	2.00	1.50	139.80
Total	**11802.00**	**8442.77**	**86759.16**
II. OFF-GRID/CAPTIVE POWER (CAPACITY IN MW_{EQ})			
Waste to Energy	10.00	12.41	191.13
SPV Systems	400.00	54.86	970.47
Total	**410.00**	**67.27**	**1161.60**
III. OTHER RENEWABLE TECHNOLOGIES (CAPACITY IN NOS.)			
Biogas Plants	0.76	0.20	50.92

Source: www.mnre.gov.in

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Contact details

Gitesh Sinha
Email: gitesh.sinha@teri.res.in
<Extn 2710>

Sanjeev Sharma
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