eNREE

A QUARTERLY ELECTRONIC NEWSLETTER ON RENEWABLE ENERGY AND CLIMATE CHANGE

Volume 18 ■ Issue 3 ■ October–December 2021

Ministry of Environment, Forest and Climate Change, Government of India

The Energy and Resources Institute

Environmental Information System India

www.terienvis.nic.in

Contents

DISASTER RESILIENT CITIES: PROBLEMS AND PROSPECTS AND PLANNING FOR ADAPTATION TO CLIMATE CHANGE

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Abstract

India has been witnessing an unprecedented phase of rapid urbanization. Cities have become magnets for political activities, engines of economy, and attractions of a far better lifestyle. Unfortunately, all the cities in India are following a same pattern of fast and unplanned growth and uncontrolled migration. Consequently, there has been enormous pressure on their physical infrastructure, society, natural environment, and institutional systems. The increased population and their demands have led to urban sprawling – expanding over flood-prone coastlines, areas having loose soil, which are liable to landslides, earthquake fault lines, and wetlands. Thus, catastrophic events such as Chennai floods, landslides in hill towns, earthquakes in NCR, etc. have become common.

Since there is an exodus of people shifting to urban centres, which are high-risk areas, people are more vulnerable to disaster risk and there is a need to focus on strategies for effective disaster management. For preparing cities to effectively respond to pertinent risks and hazards, there is a need to revisit the planning practices adopted so far. Moreover, there is an urgent need to make cities resilient to disasters and understand the challenges in implementing disaster management faced in India. Thus, it is required to propose a framework, a methodology, strategies, and tools and techniques that can be used to improve the resilience factor for Indian cities.

Introduction

Background

We are living in the era of urbanization, wherein large groups of individuals migrate to cities for their benefits. 'Cities inhabit more than half of the world's population by now and this is expected to cross 70% by 2050' (UN 2014). Asian cities are expected to see more than 60% of this increase and 46% of all urban population growth would occur in cities with fewer than 5 lakh inhabitants (Gupta, Mani, Sarkar, *et al.* 2019). This already has huge impact on the environment, natural resources, city systems, and people and thereby increases the risks of disasters. According to the Census data from 1901 to 2011, the number of urban agglomeration/towns and cities has grown from 1827 in 1901 to 7935 in 2011. Population residing in these urban areas has increased from 25.8 million in 1901 to 377 million in 2011, making 31.16% of the total population of the country at present (Gupta, Mani, Sarkar, *et al.* 2019). Some of the reasons of migration to cities include better lifestyle, educational and health facilities, better job market for everyone, connectivity, etc. These urban lands are not only the economic centres but also the areas of challenges pertaining to poverty, migration, incompetent infrastructure, high-density development, ecological deterioration, and exploitation of natural resources.

The urban system has been facing huge crisis due to increased population, their demands, and haphazard growth. These are directing cities to expand over hazard-prone areas such as flood-prone coastlines, areas having loose soil, which are prone to landslides, earthquake fault lines, and wetlands. This rapid, unplanned, and impromptu development has led to the built environment that is susceptible to disasters. Climate change escalates the vulnerability of the urban centres across the globe. To address this, there is a need to adopt sustainable practices while taking into account complex interactions between climate and social and ecological systems. It is widely agreed across nations that climate change is likely to increase the occurrence of natural disasters in the near future. This will not only lead to developmental challenges but also impact communities and livelihoods at the grassroots level. 'Globally, natural catastrophes in 2018 caused 10,400 deaths compared with 13,000 in 2017 and 60,000 in 10 years ended in 2017' (Gupta, Mani, Sarkar, *et al.* 2019).

Disasters, either natural or human-made, bring considerable damage, loss, and devastation to life and property, hitting the entire nation. Mostly, vandalism caused by disasters is indeterminable and ranges with location, governance, climate, and the type of vulnerability. Vulnerability of a city builds on human decisions, governance, attitudes, poverty, and behaviour-forming situations in which hazards could potentially cause destruction or harm. The harm may well be casualties, social and business interruption, and property damage (Kelman, Gaillard, and Lewis 2016). It is the powerlessness of a city and its people to not resist a hazard or know how to respond to it.

Vulnerability depends on numerous factors, and in India, there are various challenges that cause vulnerability of an urban area. These are rapid urbanization, poor or unsatisfactory city planning, unauthorized structures, unfit and improper construction, failure in making and executing strict laws, lack of monitoring of building bye-laws, old building stocks, poor infrastructure and services, insufficient capacity of local government, lack of funding, corruption, unlawful activities, etc. (Malalgoda, Amaratunga, and Haigh 2014; Raj 2015).

Concept of disasters and resilient cities

The United Nations defines disaster as 'a sudden and unfortunate event that disarranges the basic fabric and regular functioning of the society or community.' In other words, it is a serious disruption of the functioning of a society, causing widespread human, material, or environmental losses, which exceed the ability of the affected society to cope using only its own resources (UN-ISDR 2009). Looking at the past catastrophic events in Indian cities, it is clear that urban metabolism in the country is crumbled.

Policymakers, researchers, environmentalists, and urban planners are regularly faced with these challenges of handling disaster events and their impacts. Therefore, they require tools to assess the impacts, and constraints to provide sustainable solutions.

Resilience encourages risk reduction-driven approach from the beginning. However, planning disaster resilient cities is a tortuous process and lay out challenges that existing development would face.

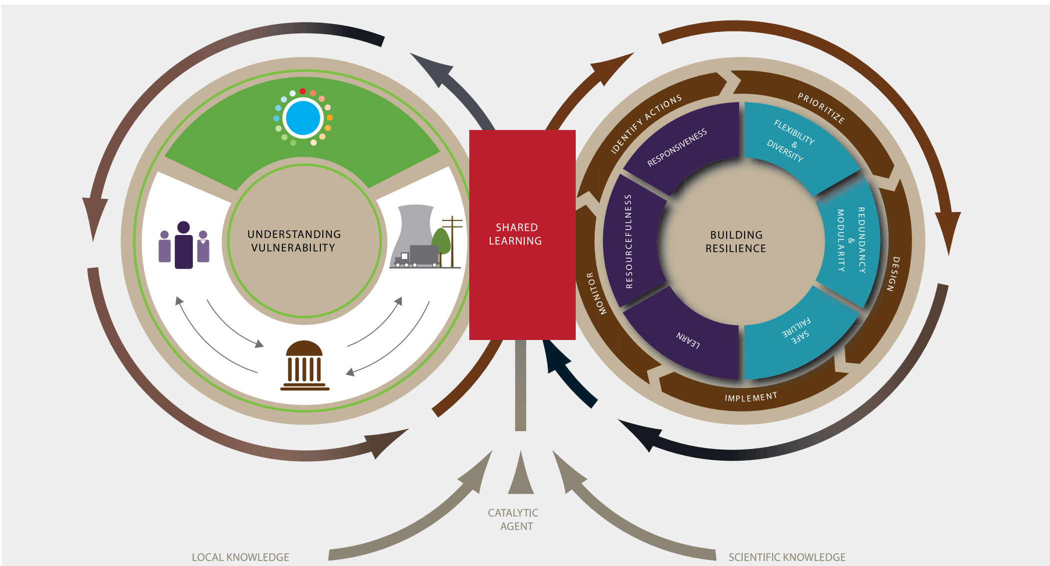

Figure 1: Climate resilience framework

Source: Moench, Tyler, and Lage (2011)

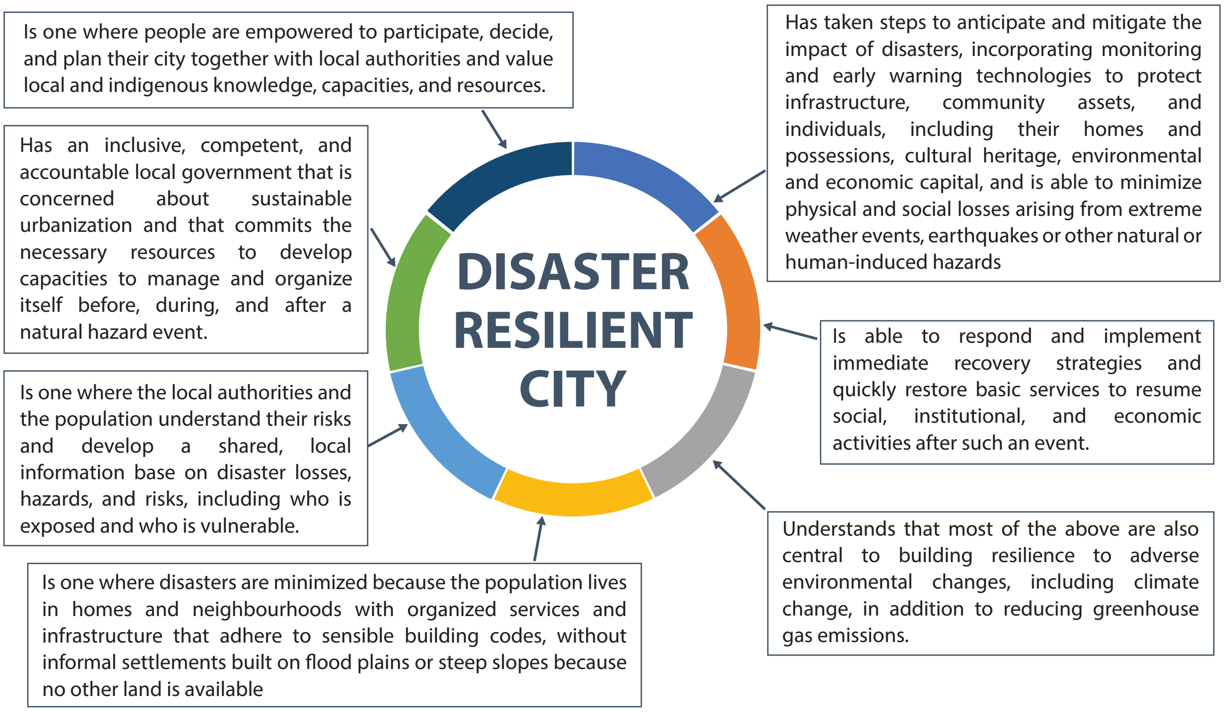

Figure 2: Features of a disaster resilient city

Source: Gupta, Mani, Sarkar, et al. (2019)

Impacts of climate change and induced disasters on cities

The major drivers of climate change leading to disasters and their impacts are given in Figures 3 and 4, respectively.

Challenges Faced by Indian Cities

Despite government efforts, Indian cities face the following barriers in building disaster resilient cities:

Temperature

- Due to extreme temperature, the urban heat island effect experienced by urban centres is likely to worsen.
- UHI will increase the need for cooling and hence there will be an increase in the energy demand which will not just be the case in peak summer months.
- India being a tropical country is more susceptible to climate change and this disbalance due to UHI will have serious implications for energy.
- Extreme temperature and heat waves will impact human health and further increase the risks of heat-related morbidity and mortality cases.

Precipitation

- Extreme precipitation is likely to cause urban flooding in most urban cities with poor sewerage management.
- Lack of proper drainage systems will cause waterlogging and flood-like situations.
- Urban structures are impervious which increases the run-off and worsen any flood-like situation.
- The cities are overcrowded; this increases their vulnerability and they are not able to cope with the damages due to flood.
- Urban areas owing to UHI effects are capable of altering the local air circulation.
- This can lead to both direct (through injuries) and indirect (infections and water/vector-borne diseases) health impacts.

Figure 3: Major drivers of climate change

Source: Gupta, Mani, Sarkar, et al. (2019)

Sector	Probable impacts of climate change disasters
Water supply	▪ Variability in flow of water in perennial and non-perennial rivers will affect water availability ▪ Variability in rainfall will affect groundwater recharge ▪ Reduction in water levels in tanks and dams will be seen due to rise in temperature and variability of precipitation ▪ Scarcity of water will rise over the time and geographically ▪ Water supply systems such as borewells, pumping stations, water treatment plants will get affected due to floods ▪ Springs and rivers will be more seasonal in nature due to variability of rainfall and rise in extreme rainfall events ▪ Groundwater table will fall rapidly in overexploited areas, as recharge of aquifers will reduce due to change in rainfall patterns (more extreme rainfall events leading to high run-off)
Sewerage	▪ Infiltration of floodwaters into sewers creating pollution and impacting health ▪ Pollution of water downstream ▪ Due to high temperature and reduced water supply, reduced flow may choke sewers and early decomposition may take place resulting in deposits in the network ▪ Open sewers may overflow due to heavy rains and threat of epidemic may increase
Sanitation	▪ Pits would get inundated from below due to flooding situations, polluting groundwater and soil ▪ Open defecation would spread faecal matter during flooding causing serious health problems ▪ Silt load carried with floodwater would settle in septic tanks and sometimes there would be backflow of sewage. This would indirectly contribute to waterborne and vector-borne diseases in flooded localities

Figure 4: Sectoral impacts of climate change and disasters in cities

Source: Gupta, Mani, Sarkar, et al. (2019)

i. **Lack of regulatory structure**
In India, there are various government bodies that work directly or indirectly towards disaster management and urban development such as National Institute of Disaster Management, National Disaster Management Authority, State Disaster Management Authority, development authorities, and other government agencies. Various barriers such as lack of defined roles for inter-agency coordination, overlapping responsibilities, and absence of regulations at the local level lead to underperformance of initiatives. Moreover, unwillingness of citizens to approve their building plans before construction, old building stocks, and infrastructure being used without protective measures are other major impediments in India's efforts to secure urban resilience.

ii. **Lack of integrating master plans with appropriate resilient programmes**
Despite cognizant of the fact that each urban area is exposed to different risks and levels of vulnerability, no Indian city has adequate resilience measures in their master plans. The systematic approach of disaster risk reduction (DRR) is not included in every development plan. And if incorporated, then there is no continuous monitoring with changing years and dimensions of town development.

iii. **Lack of political willingness and weak governance**
Due to lack of political willingness and weak governance, there exist outdated zoning plans of major towns in India and unrevised building codes and development regulations. There is unavailability of hazard zonation and vulnerability mapping for numerable towns. The unlawful activities due to corruption add up to the challenges.

iv. **Construction on ecological areas and inadequate urban planning**
In India, owing to growing population and increased density, many urban expansion programmes are planned in ecologically sensitive areas. Thus, high rise buildings on floodable lands, buildings on steep hill slopes, cutting down trees for construction, etc. expose the respective areas to future hazards. Furthermore, lack of cognizance of the impact of construction on the environment increases the risk of hazards. Absence of accurate maps and revised spatial database brings challenges for urban planning decisions.

v. **Unplanned settlements – urban poverty**
Unauthorized structures and unplanned settlements in urban areas are the major resilience challenges of cities. The urban poor with limited access to infrastructure, services, and safe housing

are the most vulnerable population to hazards in cities. Due to the unavailability of affordable housing, often people from the informal sector live in uninhabited areas, mostly along high-risk zones such as landslide prone areas, coastlines, low-lying areas, wetlands, earthquake fault lines, major drainage channels, or other ecological areas.

vi. Lack of information

Insufficient information or knowledge about the hazard risks, vulnerability, initiatives taken by the government and others including UNDP, DRR, building codes, etc. and lack of community engagement make the urban population more vulnerable. The knowledge about disaster management not only helps policymakers, community leaders, practitioners, and organizations, but also public in the event of any emergency.

vii. Limited funds

India being a developing nation and one of the most disaster-prone countries needs a significant amount of funds for emergency preparedness. This includes enforcement of by-laws, materials and technologies for resilient designs, renovations of building stocks and old infrastructure, rehabilitation of urban poor, etc. All these essential services require considerable capital for execution and monitoring. In other words, funding becomes a significant barrier in developing disaster resilient cities in India.

Strategies, Tools, and Recommendations to Strengthen Climate Resilient Capacities

i. Integrated approach

A consolidated approach should be adopted in every development plan, which would incorporate elements of impact assessment, risk reduction, and mitigation plans. The DRR plan, CDMP, and other mitigation measures should also be integrated in the master plan or other development plans of an urban area.

ii. Tools for data mapping

Tools can be employed to visualize causes and effects of disasters in terms of area, frequency, time, and magnitude using high-quality computerized data analysis related to climatology and geography. Software like GIS mapping, remote sensing, and space imageries and their interactive interpretation can be used to integrate various layers of maps including vulnerability assessment map, land use map, density map, socio-economic map, hazard indicator map, infrastructure map, etc. to make accurate decisions.

This would help in categorizing different zones of a city based on the development type, land use, and density. Also, this would help in demarcating locations of unauthorized settlement on eco-sensitive/undevelopable areas. The data mapping tool can help urban planners to amalgamate planning decisions with urban risks and vulnerabilities. Micro-zonation planning can also be conducted to demarcate wetlands, watershed areas, earthquake fault lines, and other ecological areas for planning at the micro level.

iii. Integrated impact assessment

Impact assessment tools are essential for decision-making to mainstream disaster risk reduction strategies into urban planning policies. Any developmental activity in areas that are vulnerable to hazards requires not just its cost and benefit analysis but also its impact on the environment. While environment impact assessment (EIA) focuses to predict the possible impact on only the environment, the IIA (i.e., Integrated Impact Assessment) considers the integration of environment concerns along with health, social, and economic aspects.

iv. Upgradation of maps and risk assessments

The base maps and risk assessments of all the urban settlements should be upgraded with the latest data on existing land use, land activities, intensity of development, urban sprawl, structures, and vulnerability to disasters. With rapidly changing dimensions of an urban area, mitigation plans along with the base maps should be updated. Accurate maps and spatial data are vital from the analysis and proposal (for disaster management and urban planning) perspective.

v. Strict rules and development regulations

Strict rules should be imposed for land filling, green or brownfield development, land use deviation in hazardous zones, maintenance of water drainage systems, etc. Also, construction activities should be monitored at regular intervals and DRR building codes and zoning rules should be enforced along with other guidelines.

With the recommendations of strategies and policies, development activities can be restricted in eco-sensitive or high-risk zones of urban areas. And, while the existing development activities in disaster-prone zones may be controlled, evacuation plans can be prepared and public participation can be encouraged.

Land use policies should strengthen development control regulations based on risk management. For policymaking, both risk assessment and cost benefit analysis should be taken into account so that the strategies to upgrade the urban infrastructure can be finalized in detail.

vi. **Planning for economically weaker section**

The majority of unauthorized/slum settlements are located on inhabited, inexpensive, and hazard-prone sites in cities. High population density and poor living conditions further escalate the vulnerability of these people. Thus, such developments in hazard-prone areas need to be identified and regulated by framing strict codes or resettling them to a safer location. Low-income neighbourhoods should be planned from the initial stage of a development project, away from high-risk zones and escape routes should be made available for slum inhabitants.

vii. **Educate communities and associated organizations**

Awareness should be raised among locals about hazard risks and disaster resilience. Community and stakeholders' participation should be made obligatory. Distribution of responsibilities among various organizations and stakeholders should be clearly defined and regular meetings should be conducted to establish proper communication.

Conclusion

The urban system in India is facing huge crisis as the increased pressure of population, their demands, and the impromptu development have made the built environment susceptive to disasters. The repercussions of disasters are highly ruinous when they occur in the urban environment. It is, therefore, essential to enhance urban cities resilience to disasters. A resilient city is developed to absorb and recover from any shock or stress while maintaining the essential functions. Resilience encourages risk reduction-driven approach from the beginning. However, planning disaster resilient cities is a tortuous process and lay out challenges that Indian cities would face. These challenges include lack of regulatory framework and political willingness, unplanned expansion over ecological zones of towns, slum settlements, lack of funds, old buildings stocks and infrastructure, inadequate capacities of local government, etc.

Furthermore, building resilience requires identifying and assessing hazard risks, reducing vulnerability and exposure while expanding resistance, capacity, and catastrophe preparedness. For this, integration of the resilience approach with urban planning becomes essential. By strengthening the policy formulation, implementation, and monitoring, urban resilience can be adopted in India.

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FLOATING SOLAR PHOTOVOLTAIC: A THIRD PILLAR TO SOLAR PV SECTOR?

Introduction

The Energy and Resources Institute (TERI), New Delhi, India, with support from the Energy Transitions Commission (ETC), India, has undertaken a study to analyse data on the potential of the country's medium and large reservoirs to generate energy through floating solar PV (FSPV). The report presents state-wise details of the reservoirs along with the best practice guidelines to develop FSPV projects. The information presented in the report would be useful to stakeholders such as policymakers (MNRE, NITI Aayog, and state governments), project developers, implementing agencies, investors, and finance institutions.

Scope and Approach

Floating solar PV – understanding the need

What is floating solar PV? FSPV, also known as floatovoltaics, is a type of solar PV designed to float on waterbodies such as reservoirs, hydroelectric dams, industrial ponds, water treatment ponds, mining ponds, lakes, and lagoons. In this, solar panels are mounted on a pontoon-based floating structure, which is anchored and moored to remain fixed.

Benefits of floating solar PV

Some of the reported benefits of FSPV are as follows:

- Higher gains in energy production
- Land neutral
- Reduction in water evaporation
- Possibility of sharing existing electrical infrastructure
- Complementary operation with hydroelectric power plants
- Reduction in algae growth
- FSPV as a new source of revenue
- Less soiling loss
- Ease of cleaning
- Easy installation and deployment

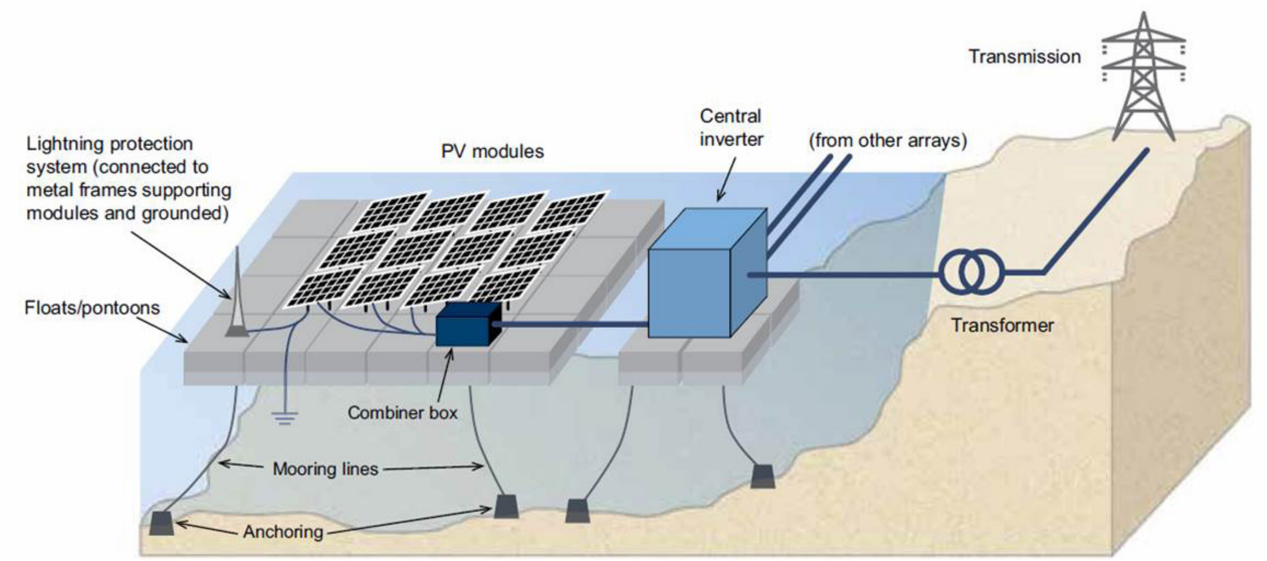

Figure 1: Schematic representation of a typical large-scale FSPV system with its key components

Source: World Bank Group, ESMAP and SERIS. 2019. Where Sun Meets Water: Floating Solar Market Report. Washington, DC: World Bank

Global Market Overview

Global scenario: The technology is currently deployed in more than 35 countries across the entire world, with the majority of installations taking place in Asia, particularly in Japan, China, and South Korea. The total installed capacity now stands at 2535 MWp, which is expected to increase substantially in the coming years and would reach up to 4600 MWp by 2022.

Table: Type of waterbodies on which FSPV is installed in top five leading countries

Country	Waterbody Type	Typical Range of % of Water Surface Area Covered by FSPV Plants	Typical Range of Depth of Waterbody on Which FSPV Plants Are Installed (in Meters)	Typical Range of Water Level Variation (in Meters)
China	Irrigation ponds	10%–30%	3.5–14.1	3.5– 8.0
	Industrial ponds	No information	No information	No information
	Large waterbodies	10%–40%	No information	No information
	Mining ponds	10%–20%	3–12.5	4.8
Japan	Irrigation ponds	10%–70%	1.8–15.1	1.8–15.1
	Industrial ponds	No information	No information	No information
	Water storage reservoirs	15%–86%	3.0–5.0	3.0–5.0
Taiwan	Irrigation ponds	11%–28%	3.6–4.6	2.4–4.6
	Industrial ponds	15%	14	5
	Water storage reservoirs	7%–10%	No information	No information
UK	Irrigation ponds	2% –15%	4.0–18.4	4.0–18.4
	Water treatment plant	48%	10	10

Source: TERI's analysis based on a compilation of publicly available sources

Indian scenario: In India, the FSPV technology is still in its early stages of development. Started in 2015 in the country, a 10-kW FSPV plant was installed in a pond in Rajarhat, Kolkata. Currently, there are over 1700 MW worth of projects in various stages of development and more are in the pipeline, making this emerging market's future highly promising.

Cost of floating solar PV plants: Since FSPV technology has just started getting traction, accurate project capital and operating cost data cannot be disclosed in the public domain.

Floating Solar PV as Technology Overview

The typical floating structure supports PV arrays, inverters, combiner boxes, lighting arresters, etc. on a floating bed made of fiber-reinforced plastic or high-density polyethylene or metal structures. The basic integral part of an FSPV plant is solar PV module. The selection of PV modules technology also depends on the space, cost, relative humidity, type of waterbodies, etc.

Some of the criteria for the selection of PV modules are as follows:

- Solar panel performance – power tolerance, efficiency, temperature coefficient especially in high moisture and high humidity conditions
- Solar panel quality – certifications such as ISO 9001
- Solar panel durability – conformance to reliability standards such as IEC 61215 (wind loading)
- Quality assurances by solar panel manufacturer – warranty
- IEC 62804 certification for potential-induced degradation from a solar panel manufacturer
- Solar panel manufacturers' corporate profile and previous experiences

Floating Solar PV – India Potential

India is known to have many human-made reservoirs, which are used for a variety of purposes such as irrigation, hydroelectric, water supply, navigation, etc. As a technology, FSPV is in a nascent stage of development in India. This study identifies about 18,000 km^2 of water surface area across several states and union territories in the country as suitable for the installation of FSPV plants. The overall potential is a strong indication of the extent of the surface area that can be made available for these projects, and even a capacity of around 280 GW is possible.

Potential Environment and Social Impact of Floating Solar PV

As FSPV is in the early stage of development, long-term impacts of deploying large-scale FSPV-based plants on the local environment are poorly known. Some of the impacts of deploying large-scale FSPV plants are as follows:

- Impact on local marine aquaculture due to reduction in sunlight reaching the water surface
- Impact on the fishing pattern
- Impacts of shading of water surface on temperature stratification and dissolved oxygen levels
- Impact on water quality
- Inhibits the breakdown of chemicals by prompting high dissolved organic carbon concentrations, potentially increasing the costs of water treatment
- Impact due to leaching from materials
- Impact due to exposure to electromagnetic fields associated with underwater electrical cables
- Impact on hunting grounds of surface-diving birds
- Impact on habitats of migratory birds
- FSPV could reduce the photodegradation of chemical compounds such as dissolved organic carbon
- A reduction in short-wave solar radiation lowers water temperature and makes stratification less likely
- Insulation of the surface water from the wind will make stratification more likely
- Changes in stratification affect deep water oxygen. A decrease in oxygen level could release pollutants from the lake bed, whereas an increase could inhibit pollutants' release
- Shading from FSPV is likely to reduce toxic cyanobacteria
- FSPV deployment may alter the food web
- Density-driven thermal stratification can occur during the summer months decoupling cool bottom water from warm surface water

Project Design Guidelines of Floating Solar PV

Developing the best practice guidelines for the FSPV sector would help project developers, investors, and policymakers to understand FSPV project development procedures. In a nutshell, significant steps of developing an FSPV project can be understood through the following chart.

Initial Site Assessment	
GIS-based study – Checking historical change in water coverage surface area and finding the permanent area under water surface	Field visit – Site access and pathways, distance from substations of nearby buildings infrastructures, shadow free area, type of waterbody and its current purpose, coverage surface area

Outcome – Optimum surface area identified for FSPV installations and water quality

Bathymetry/hydrography and soil testing	
A contour map showing the elevation of the original waterbody basin geological survey	Soil properties for establishing anchoring and mooring mechanism and feasibility of the project

Outcome - Suitable location for anchoring and mooring, overall viability of the project

Environment and social impact assessment (ESIA)	
Impact of FSPV plant components on local biodiversity, standards for material selections	Decision on minimum surface coverage area for FSPV installations

Outcome – Environmental and social impact assessment report of the project

Project design		
Meteorological data – Solar irradiance, wind direction, wind velocity, wave height and amplitude, water level variations, humidity, ambient temperature, rainfall, etc.	**Current purpose of waterbody** – Seasonal variations of water level, type of waterbody and its purpose	Simulation through softwares (PVSyst, Helioscope, etc.) – Placement of inverters and other components/BOS, cablings, plant capacity, and generation

Outcome – Complete project design layout with applicable standards

Installation and commissioning	
Fixing of anchoring and mooring mechanism	Construction of plant – Launching of platform, fixing of platform with anchoring and mooring

Chart: A flow chart of floating solar PV project design
Source: TERI analysis

Challenges

The FSPV industry is quickly evolving and would soon become a popular alternative to harvesting solar energy. However, currently there is little know-how available for this sector, which poses numerous problems. The following are some of the major issues related to the FSPV:

i. **Technology challenges**
   - Unavailability of FSPV-specific standards/technical guidelines
   - Unavailability of waterbody data
   - FSPV plant components safety and its long-term reliability
   - Absence of local manufacturing
   - Unavailability of bathymetry and other related studies on water

ii. **Environmental and social aspects:** Waterbodies are crucial for human settlements and are often found with abundant aquatic flora and fauna. Fishing, livelihood generation, recreation, social activities, drinking, farming, aquatic life research, and so on rely on waterbodies. The long-term effects of establishing large-scale FSPV plants on the local biodiversity are less known, and there are no published data/studies that can provide proper information in this context.

iii. **Installation challenges**
   - Clearances for FSPV projects: Presently, the guidelines/checklists are only available for ground-based solar PV projects. There is no information on what kinds of clearances are needed in case of FSPV plants.
   - Who owns the waterbody? Waterbodies are generally spread across a large geographical area and often shared among multiple states/departments, making clearance a complex task.
   - Transportation of floating platforms: Waterbodies are frequently found in isolated locations, surrounded by mountain ranges, forest areas, and other obstacles, which makes their access difficult. Transporting floats to remote locations can heavily burden the project's expenditures. Furthermore, establishing float manufacturing units near the project locations could pose challenges, which are determined by the project location and capacity.

iv. **Operation and maintenance challenges:** It is difficult to cope with operation and maintenance concerns in such settings as FSPV plants are located on the water surface rather than land.

v. **Quality:** The floating solar prices have fallen significantly during the past 2 years. While falling prices is a welcome trend, they could also challenge the quality of a project, which can result in impacts on the local biodiversity. Therefore, a protocol needs to be developed to measure the long-term quality of deploying large-scale FSPV plants.

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Renewable Energy

Cochin International Airport Ltd (CIAL) to commission its 1st hydropower project

Cochin International Airport Ltd (CIAL) is venturing into hydropower production, and its first plant will be commissioned by Kerala's chief minister in Kozhikode district. CIAL, the country's first fully solar-powered airport, is expecting an annual power generation of 14 million units through the plant. The plant will be constructed at Arippara near Kozhikode and will be handed to the state electricity board grid in the first week of November. The installed capacity of the world's first fully powered solar energy airport stands at 40 MWp, producing 160,000 units a day against its requirement of 130,000 units. CIAL has also introduced cost-effective high-density polyethene floats using a French technology, upon which 1300 photovoltaic panels were mounted. These panels were laid over two artificial lakes located in the 130-acre golf course of the airport covering one acre and are connected to the state's power grid. It is one of the fastest-growing airports in 2019-20; the turnover of the CIAL was ₹655 crore and the profile was ₹204 crore after tax.

Source: Details available at https://www.hindustantimes.com/india-news/cial-to-commission-its-1st-hydropower-project-101635101042584.html, last accessed on October 25, 2021

GAIL seeks to procure India's largest hydrogen electrolyser

GAIL (India) is in the process of procuring what could be the largest hydrogen electrolyser in India. The electrolyser will outmatch the 5 MW one that NTPC is seeking to set up. It is expected that the 10-MW electrolyser will generate 4.5 tonnes of green hydrogen in a day. Incidentally, the world's largest electrolyser is also of 10 MW. The Fukushima Hydrogen Energy Research Field (FH2R) uses a 20-MW solar array, backed up by renewable power from the grid, to run a 10-MW electrolyser at a site in Namie Town, Fukushima Prefecture, Japan.

A larger 24-MW hydrogen electrolyser is being developed at the Leuna Chemical Complex in Germany. French oil major Total and utility Engie have also announced plans for 40-MW electrolyser to solar power in southern France. That plant is slated to be operational in 2024.

Source: Details available at https://www.business-standard.com/article/companies/gail-seeks-to-procure-india-s-largest-hydrogen-electrolyser-121102101207_1.html, last accessed on October 22, 2021

Climate Change

New climate vulnerability index finds Assam and Andhra most at risk, Kerala least

Assam, Andhra Pradesh, Maharashtra, Karnataka, and Bihar are the most vulnerable to extreme climate events such as floods, droughts, and cyclones in India, according to a Climate Vulnerability Index released by the Council on Energy, Environment and Water (CEEW). As per the index, overall 27 Indian states and union territories are vulnerable to extreme climate events, which often disrupt the local economy and displace weaker communities.

The report 'Mapping India's Climate Vulnerability – A District-level Assessment', supported by the India Climate Collaborative and EdelGive Foundation, has analysed 640 districts in India and found that 463 of these are vulnerable to extreme floods, droughts, and cyclones.

Source: Details available at https://indianexpress.com/article/india/new-climate-vulnerability-index-finds-assam-and-andhra-most-at-risk-kerala-least-7591307/, last accessed on October 26, 2021

Making methane from CO_2 – carbon capture grows more affordable

In their ongoing effort to make carbon capture more affordable, researchers at the Department of Energy's Pacific Northwest National Laboratory (PNNL) have developed a method to convert captured CO_2 into methane, the primary component of natural gas. By streamlining a long-standing process in which CO_2 is converted into methane, the researchers' new method reduces the materials needed to run the reaction, the energy needed to fuel it, and, ultimately, the selling price of the gas.

A key chemical player known as EEMPA makes the process possible. EEMPA is a PNNL-developed solvent that snatches CO_2 from power plant flue gas, binding the greenhouse gas so it can be converted into useful chemicals.

Earlier this year, PNNL researchers revealed that using EEMPA in power plants could slash the price of carbon capture to 19% lower than standard industry costs – the lowest documented price of carbon capture. Now, in a study published in the journal *ChemSusChem*, the team reveals a new incentive – in cheaper natural gas – to further drive down costs.

When compared to the conventional method of methane conversion, the new process requires an initial investment that costs 32% less. Operation and maintenance costs are 35% cheaper, bringing the selling price of synthetic natural gas down by 12%.

Methane's role in carbon capture

Different methods for converting CO_2 into methane have long been known. However, most processes rely on high temperatures and are often too expensive for a widespread commercial use. In addition to geologic production, methane can be produced from renewable or recycled CO_2 sources and can be used as fuel or as an H_2 energy carrier. "Though it is a greenhouse gas and requires careful supply chain management, methane has many applications, ranging from household use to industrial processes," said a lead author and PNNL chemist.

Source: Details available at http://https//www.sciencedaily.com/releases/2021/09/210903095311.html, last accessed on October 5, 2021

Transforming 'sewer gas' into clean hydrogen fuel

Scientists have found a new chemical process to turn a stinky, toxic gas into a clean-burning fuel. The process, detailed recently in the American Chemical Society journal *ACS Sustainable Chemical Engineering*, turns hydrogen sulfide – more commonly called 'sewer gas' – into hydrogen fuel. Hydrogen sulfide is emitted from manure piles and sewer pipes and is a key by-product of industrial activities including refining oil and gas and producing paper and mining. The process detailed in this study uses relatively little energy and cheap material – the chemical iron sulfide with a trace amount of molybdenum as an additive. In addition to smells like rotten eggs, hydrogen sulfide is highly toxic, corrodes pipes and harms the health of people who encounter it.

'Hydrogen sulfide is one of the most harmful gases in the industry and to the environment. And, because the gas is so harmful, a number of researchers want to turn hydrogen sulfide into something that is not so harmful, preferably valuable," said a co-author of the study and research associate in chemical and biomolecular engineering at The Ohio State University.

The study is built on previous work by the same research group using a process called chemical looping, which involves adding metal oxide particles in high-pressure reactors to burn fuels without direct contact between air and fuel. The team first used chemical looping on coal and shale gas to convert fossil fuels into electricity without emitting CO_2 into the atmosphere. The initial process used iron oxide to break down the fossil fuels.

Source: Details available at http://https//www.sciencedaily.com/releases/2021/09/210909162226.htm, last accessed on October 5, 2021

Renewable Energy

An optimization study on a typical renewable microgrid energy system with energy storage

Graça Gomes, J., H. J. XU, Q. Yang, and C. Y. Zhao. 2021

Energy 234: 121210

This study proposes a novel optimization model that sizes the most cost-efficient renewable power capacity mix of an autonomous microgrid supported by storage technologies. The proposed algorithm considers operational, technical, and land-use constraints. The problem was formulated using linear programming, tested and scrutinized with sets of historical weather, load demand, and installation prices data, and modelled hour-by-hour. The method was applied to Corvo, an island in the Azores archipelago, Portugal. The results obtained exhibit that the proposed approach provides the optimal configuration of the renewable-based microgrid with an LCOE (levelized cost of electricity) of 0.21 €/kWh, a value lower than a diesel-based alternative, while ensuring minimum land area occupation. Furthermore, this study also presents a sensitivity analysis to examine the effect of variables on the LCOE and present cost of the system. It shows that the developed optimal sizing model can improve electricity planning and facilitate energy transition in distributed power systems.

Optimization and sizing of SPV/wind hybrid renewable energy system: a techno-economic and social perspective

K. Faizan A., N. Pal, and S. H. Saeed. 2021

Energy 233: 121114

This study intends to develop a rural hybrid renewable energy system and examines its techno-financial and social viability for rural sites in northern India. This work analyses the performance of the solar photovoltaic-wind hybrid renewable energy system for a residential load demand of 51.54 kWh/day with 11.51 kW peak in a stand-alone application. In this paper, a nine parameter-based multi-target optimization and sizing scheme was executed by the HOMER PRO software. This work sequentially addresses the techno-economic and socio-environmental indicators for an optimization analysis. The specification of the technical and financial fields was availed from local markets in India. Seven feasible combinations of different resources were analysed for designing parameters and the optimized combination was selected by a multi-criteria analysis. The solar photovoltaic-wind-diesel generator-battery storage was found to be the best combination for consistent power supply. The net present cost and the cost of energy were obtained as $0.179 and $31,439, respectively. Sensitivity analysis was performed for macro-economic factors and components cost to obtain better opportunity. Moreover, the technical and commercial viability of the proposed system was assured by a robustness check for satisfying the consumer demand.

Does transitioning towards renewable energy accelerate economic growth? An analysis of sectoral growth for a dynamic panel of countries

Doytch, N. and S. Narayan. 2021

Energy 235: 121290

This study examines the impact of non-renewable and renewable energy consumption on economic growth, differentiating between manufacturing and services growth. The study derived the empirical model from an endogenous growth framework with an expanding variety of intermediate capital goods embedding non-renewable and renewable energy inputs. Controlling for well-established growth determinants, the study estimates the effects of non-renewable and renewable energy consumption, differentiated by the type of use – industrial, residential, and total final energy consumption – on manufacturing and services growth. It was found that renewable energy enhances growth in high-growth sectors, that is, the services sector in high-income economies and the manufacturing sector in middle-income economies. In the case of high-income countries, renewable energy is a complement to non-renewables, whereas in the case of middle-income countries the two are substitutes to each other. The growth effects are primarily due to industrial energy consumption. Based on the findings, the study proposes that an effective renewable energy incentives policy for middle-income countries should be directed at manufacturing enterprises, and in high-income countries, these incentives should be directed at the services sector.

Climate Change

Analysis of the emergent climate change mitigation technologies

Panepinto, D., V. A. Riggio, and M. Zanetti. 2021

International Journal of Environmental Research and Public Health 18(13): 6767

Climate change mitigation refers to efforts to reduce or prevent greenhouse gases (GHGs) emission. Mitigation can mean using new technologies and renewable energy, making older equipment more energy efficient, or changing management practices or consumer behaviour. The mitigation technologies reduce or absorb GHGs and, in particular, the CO_2 present in the atmosphere. The CO_2 is a persistent atmospheric gas. It seems increasingly likely that concentrations of CO_2 and other GHGs in the atmosphere will overshoot the 450 ppm CO_2 target. The target is widely seen as the upper limit of concentrations consistent with limiting the increase in global mean temperature from pre-industrial levels to around 2 °C. To stay well below the 2 °C target as per the Paris Agreement, it is necessary that low (or better zero) emissions are opted and a quantity of CO_2 is absorbed from the atmosphere, by 2070, equal to 10 Gt/y. Further, to absorb CO_2 equal to 10 Gt/y, it is necessary to implement the negative emission technologies. The aim of this work is to perform a detailed overview of the main mitigation technologies currently available and, in particular, an analysis of an emergent negative emission technology – the microalgae massive cultivation for CO_2 biofixation.

Scenario-based hydrological modeling for designing climate-resilient coastal water resource management measures: lessons from Brahmani River, Odisha, Eastern India

Kumar, P., R. Dasgupta, S. Dhyani, R. Kadaverugu, B. A. Johnson, S. Hashimoto, N. Sahu, R. Avtar, O. Saito, S. Chakraborty, and B. K. Mishra. 2021

Sustainability 13(11): 6339

Widespread urban expansion around the world combined with rapid demographic and climatic changes has resulted in serious pollution issues in many coastal waterbodies. To mitigate these impacts (e.g., local land-use or climate change adaptation policies), coastal management strategies based on research methodologies that incorporate participatory approaches along with computer simulation modelling tools can be formed. One such research methodology is 'Participatory Coastal Land-Use Management' (PCLM) approach, which consists of three major steps: (a) a participatory approach to find key drivers responsible for the water quality deterioration, (b) a scenario analysis using different computer simulation modelling tools for impact assessment, and (c) using these scientific evidences for developing adaptation and mitigation measures. In this study, a PCLM approach was applied in the Kendrapara district of India (focusing on the Brahmani River basin) to evaluate the current status and predict its future conditions. It is a rapidly urbanizing area on the country's east coast. The participatory approach included key informant interviews to determine key drivers of water quality degradation. This served as an input for scenario analysis and hydrological simulation in the next step. Future river water quality (biochemical oxygen demand [BOD] and total coliform [Tot. coli] as important parameters) was simulated using the water evaluation and planning tool. In this regard, a different plausible future scenario (to 2050) was considered and diverse drivers and pressures (i.e., population growth, land-use change, and climate change) were incorporated. Water samples (collected in 2018) indicated that the Brahmani River in this district was already moderately to extremely polluted in comparison to the desirable water quality (Class B). Also, modelling results indicated that the river water quality is likely to further deteriorate by 2050 under all of the considered scenarios. Demographic changes emerged as the major driver affecting the future water quality deterioration (68% and 69% for BOD and Tot. coli, respectively). In contrast, climate change had the lowest impact on the river's water quality (12% and 13% for BOD and Tot. coli, respectively), although the impact was not negligible.

Scientific evidence to understand the impacts of changes in future can help in developing diverse plausible coastal zone management approaches for ensuring sustainable management of water resources in the region.

GREEN SKILL DEVELOPMENT PROGRAMME ON SUSTAIN AND ENHANCE TECHNICAL KNOWLEDGE IN SOLAR ENERGY SYSTEMS

Green skills contribute to preserve and restore the natural environment for a sustainable future. These skills lead to jobs that protect ecosystems and biodiversity, increase efficiency in energy consumption, and minimize waste and pollution. In line with the Skill India Mission of the Hon'ble Prime Minister, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, utilizing the vast network and expertise of Environment Information System (ENVIS) Hubs/Resource Partners (RPs), has taken up an initiative, titled 'Green Skill Development Programme (GSDP)'. This is a skill development programme in the environment and forest sector, which enables India's youth to earn gainful employment and/or self-employment.

Under this scheme, TERI ENVIS RP conducted a programme titled 'Sustain and Enhance Technical Knowledge in Solar Energy Systems' in Aurangabad, Bihar for 240 hours or 36 days from February 22 to March 27, 2021. Under this programme, the unemployed youth including 10th and 12th dropouts and ITI-qualified candidates are provided an opportunity to learn about solar energy technologies. The course intends to make the participants self-reliant and employable so that they can earn a decent living. The following are the objectives of the training programme:

- Help in understanding and assessing the market needs and skills required to start a career in this field
- Inculcate a step-by-step understanding of the methodology to design a grid-connected photovoltaic (PV) system
- Help in identifying different types of solar devices, assessment of power, and customization of solar systems along with providing information related to their importance
- Help in acquiring a basic understanding of actual project implementation and design principles of the solar PV

Selection of the area: TERI has conducted a number of energy access projects in Bihar (majorly in Purnea and Gaya districts), wherein solar charging stations, solar home systems, and forced draft improved cookstoves were disseminated. The GSDP training programme in Bihar was conducted in association with Bihar Rural Livelihoods Promotion Society (BRLPS), Government of Bihar. BRLPS works towards integrated sustainable development in rural areas by empowering poor women and making them self-reliant. Recently, TERI commenced a clean energy access programme in Aurangabad, Bihar, in which Integrated Domestic Energy Systems (IDES) were also distributed. The programme engages the trained participants as solar energy entrepreneurs.

Selection of the candidates: The training programme was advertised well in advance in local newspapers, targeting nearby district of Aurangabad, Bihar. Through both online and offline modes, 85 students applied (majorly female applicants) for the training. The applicants included 10th/12th dropouts, ITI pass, graduates, and postgraduate, among others who showed keen interest to be trained on the solar energy systems during the interview. The interview was conducted at District Project Coordination Unit (DPCU), JEEViKA, Aurangabad, Bihar. The selection process was divided into two stages: direct interview and verification of certificates and experience. The interview panel consisted of Mr Sanjeev Kumar, Solar Energy Expert, TERI, Mr Rajeev Ranjan, Manager Communication and Social Development, JEEViKA, Aurangabad, and Mr Gaurav Pandey, Energy Consultant, BRLPS, Gaya.

Figure 1: Interview session conducted in Aurangabad

About the training: The training programme was inaugurated on February 22, 2021 in Aurangabad. Mr Manish Pandey, Fellow & Area Convenor, TERI and Mr Pawan Kumar, District Project Manager, BRLPS, Aurangabad graced the occasion. The participants were informed about the purpose and mode of GSDP training during the ceremony. Motivational speeches by the guests on the urgent need of capable and skilled manpower in the solar energy sector were appreciated by the participants. This half-day session witnessed the launch and distribution of the training course module among the participants.

गांव में सोलर लाइट लगाने के लिए प्रशिक्षण हुआ प्रारंभ

प्रशिक्षण में शामिल जीविका दीदी। • हिन्दुस्तान

औरंगाबाद | हिन्दुस्तान प्रतिनिधि

गांव-गांव तक सोलर लाइट और सोलर उत्पादों को पहुंचाने के लिए बनी योजना के तहत बुधवार को जिला मुख्यालय में प्रशिक्षण कार्यक्रम का आयोजन किया गया। भारत सरकार के स्किल इंडिया मिशन के तहत केन्द्रीय पर्यावरण, वन और जलवायु परिवर्तन मंत्रालय के हरित कौशल विकास कार्यक्रम के अन्तर्गत द एनर्जी एंड रिसोर्सेज इंस्टिट्यूट (टेरी), एनवायर्नमेंटल इनफार्मेशन सिस्टम, रिसोर्स पार्टनर के द्वारा एक निजी होटल में नक्सल प्रभावित और सुदूर ग्रामीण इलाकों से आए युवाओं के लिए सौर ऊर्जा और प्रौद्योगिकी प्रणालियों के तकनीकी ज्ञान को बढ़ाने हेतु छह सप्ताह का आवासीय प्रशिक्षण 22 फरवरी को शुरू किया गया है। यह प्रशिक्षण आगामी 27 मार्च तक चलेगा।

टेरी के क्षेत्रीय प्रबंधक संजीव कुमार ने बताया कि ग्रामीण क्षेत्रों में रोजगार के अवसर पैदा होंगे वहीं गांव में सौर ऊर्जा उत्पादन की दिशा में भी एक कारगर पहल होगी। टेरी द्वारा चलाए जा रहे इस प्रशिक्षण कार्यक्रम में साक्षात्कार के माध्यम से कुल 30 प्रतिभागियों का चयन किया गया है।

क्षेत्रीय संयोजक मनीष पांडेय ने प्रतिभागियों का उत्साहवर्धन करते हुए विस्तृत रूप से सौर ऊर्जा प्रणालियों के बारे में बताया एवं सभी प्रतिभागियों को इस प्रशिक्षण से ज्ञान अर्जित कर सोलर एनर्जी में सर्विस के माध्यम से उद्यमिता विकास करके स्वरोजगार के लिए प्रेरित किया। बताया कि आज के दौर में सोलर के क्षेत्र में दक्ष एवं कुशल कामगारों के लिए बहुत अवसर है। इस अवसर पर जीविका के जिला परियोजना प्रबंधक पवन कुमार एवं रंजय राय, गौरव पांडेय मौजूद थे।

जीविका दीदियों को गांवों में सोलर लाइट लगाने के लिए दिया प्रशिक्षण

सिटी रिपोर्टर | औरंगाबाद सदर

प्रशिक्षण में शामिल अधिकारी व प्रशिक्षणार्थी।

बिहार के आम बजट में गांव-गांव तक सोलर लाइट और सोलर उत्पादों को पहुंचाने के लिए इस बार विस्तृत चर्चा की गई है। इसी कड़ी में टेरी ने जीविका दीदियों को प्रशिक्षित करने का कार्यक्रम प्रारंभ किया है। द एनर्जी एंड रिसोर्सेज इंस्टिट्यूट (टेरी)- एनवायर्नमेंटल इनफार्मेशन सिस्टम (एनविस) रिसोर्स पार्टनर द्वारा शहर के एक निजी होटल में युवाओं को प्रशिक्षण दिया जा रहा है। छह सप्ताह का आवासीय प्रशिक्षण 22 फरवरी को शुरू किया गया है। जो 27 मार्च तक चलेगा। इस बारे में जानकारी देते हुए टेरी के क्षेत्रीय प्रबंधक संजीव कुमार ने बताया कि इससे जहां ग्रामीण क्षेत्रों में रोजगार का अवसर पैदा होंगे। वहीं गांव में सौर ऊर्जा उत्पादन की दिशा में भी एक कारगर पहल होगी। टेरी द्वारा चलाए जा रहे इस प्रशिक्षण कार्यक्रम में साक्षात्कार के माध्यम से कुल 30 प्रतिभागियों का चयन किया गया है। टेरी के क्षेत्रीय संयोजक मनीष पाण्डेय ने प्रतिभागियों का उत्साहवर्धन करते हुए विस्तृत रूप से सौर ऊर्जा प्रणालियों के बारे में बताया एवं सभी प्रतिभागियों को इस प्रशिक्षण से ज्ञान अर्जित कर सोलर एनर्जी में सर्विस के माध्यम से स्वरोजगार के लिए प्रेरित किया। उन्होंने यह भी बताया कि आज के दौर में सोलर के क्षेत्र में दक्ष एवं कुशल कामगारों के लिए बहुत अवसर है। इस मौके पर जीविका के जिला परियोजना प्रबंधक पवन कुमार, रणंजय राय, गौरव पाण्डेय सहित कई लोग मौजूद रहे।

Figure 2: Media coverage of the inaugural session

The training programme was spread over 6 weeks, which comprised 50 sessions (23 theoretical and 27 practical). Along with this, more practical sessions to strengthen participants' technical skills and field visits to provide them exposure to solar projects and solar power plant installation were organized. The technology exposure (detailed repairing and maintenance) included solar water heating, solar street light, solar power plant, solar home light, solar lantern, improved biomass cookstove, solar drinking water, solar pumping, etc. Technical experts from TERI, experts in banking, GST taxation, computer for basic training, and industry experts from UTL Energy, Gaya, Sunlight Solar, Dhanbad, Jai Vaishnavi Agency, Bokaro, Shailesh Entreprises, Nawada, etc. were engaged in all practical sessions. Besides, a master trainer from Purnea, Gaya, Bihar also took a session on various aspects of solar entrepreneurship and after-sales services.

Figure 3: Training sessions

During the programme, special emphasis was given on hands-on training with practical exposure to the participants to make them understand about the practical difficulties they would face after the end of the course. A working model was placed at the training venue, which enabled the students to operate all solar and electrical equipment connections and understand their functioning practically.

Installation of solar PV power plant: As per the mandate of the training programme, a 1-kW solar PV power plant was procured and installed at a premises of Cluster-Level Federation (CLF) in Dev block, Aurangabad district (10 km from Aurangabad). The location was selected with support of JEEViKA. CLF is a community-level institution, which is committed to improve the livelihood of the members of self-help groups and village organizations. The most important part of the training was to engage all the participants in the installation of the solar power plant and the training room's wiring. The participants did the job of technicians under the supervision of experts from TERI and the solar vendor.

Figure 4: Installation of 1-kW mini grid by students

Assessment of the students: To understand the impact of the sessions and gauge the involvement of the participants, regular assessments were conducted by subject experts. These included weekly theoretical and practical assessments and a final assessment.

Valedictory session and certificate distribution: The programme concluded on a positive note as every participant was happy, enthusiastic, and optimistic. The valedictory session of the programme was successfully conducted at Maa Laxmi Hotel, Aurangabad, Bihar on March 27, 2021. The session was graced by Mr Pawan Kumar, District Project Manager, JEEViKA, Aurangabad, Mr Rajeev Kumar, Manager Communication & Social Development, JEEViKA, Aurangaad, Mr Sanjeev Kumar, State Field Manager, TERI, and Mr Arun Kumar, Assistant Field Coordinator, TERI. During the session, intensive interaction between participants and experts took place to evaluate the participants' learning and skills.

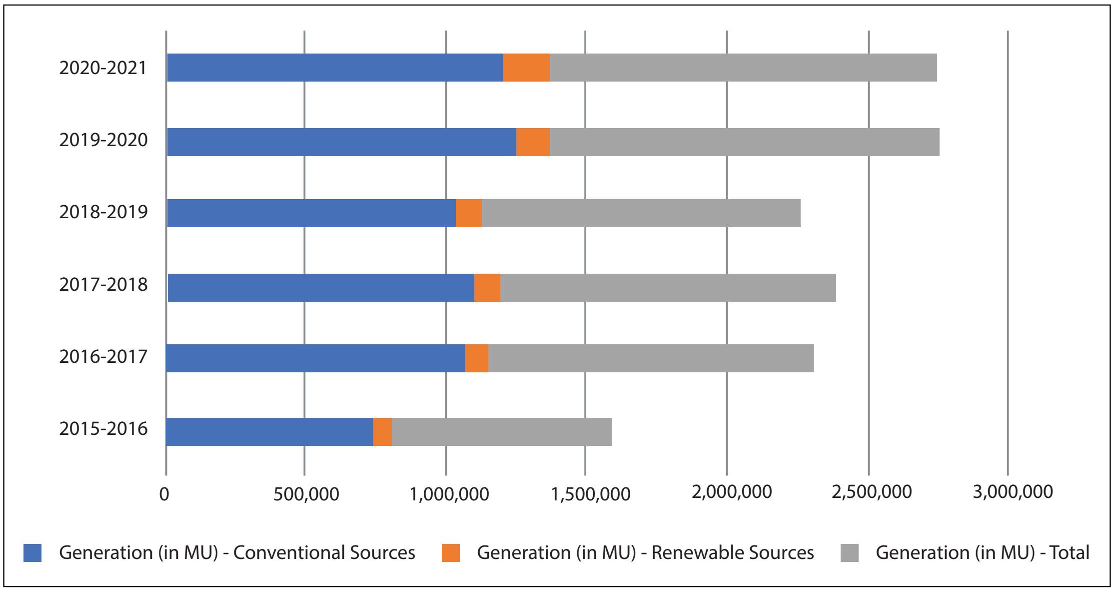
Figure 5: Certificate distribution ceremony during valedictory session

Strategies adopted for placements: The aim of the course was to make the students self-reliant so that they can earn a decent living by providing services, becoming entrepreneurs or master trainers, etc. Some of the steps taken in this direction are as follows:

- A brochure comprising candidates' profiles and a brief overview of GSDP was prepared to be distributed to various solar industries.
- Mass distribution of the brochure was done to ensure the maximum outreach.

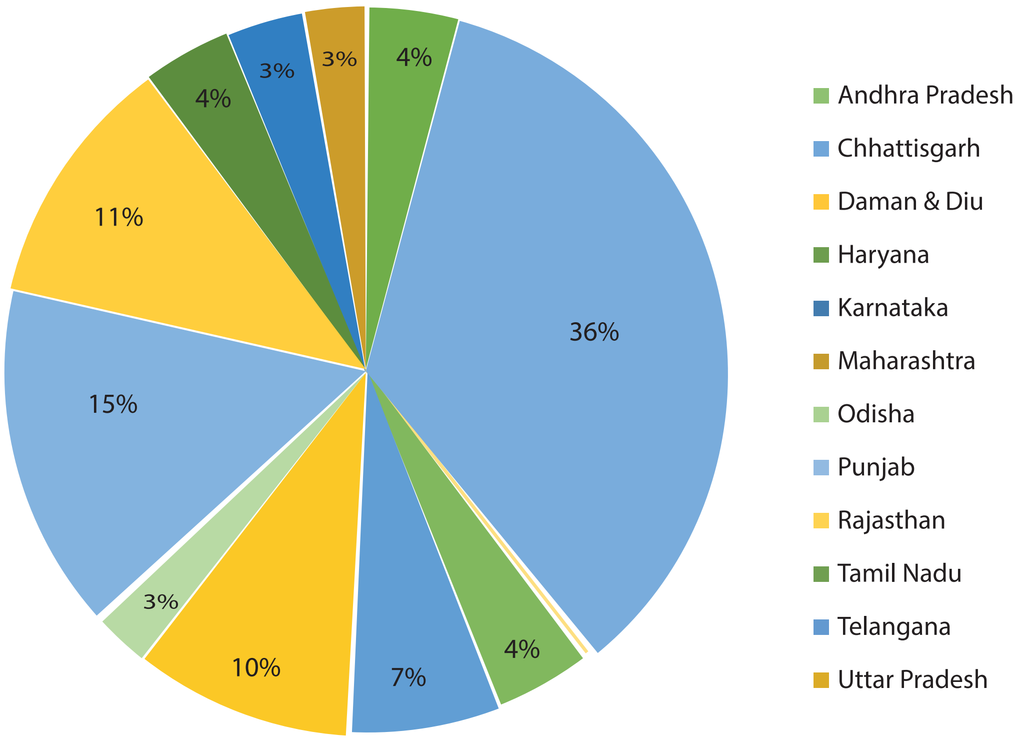
Figure 6: Brochure for the placement of the students

1. Year-wise power generation in India through both conventional and renewable sources in India (2015-2016 to 2020-2021)



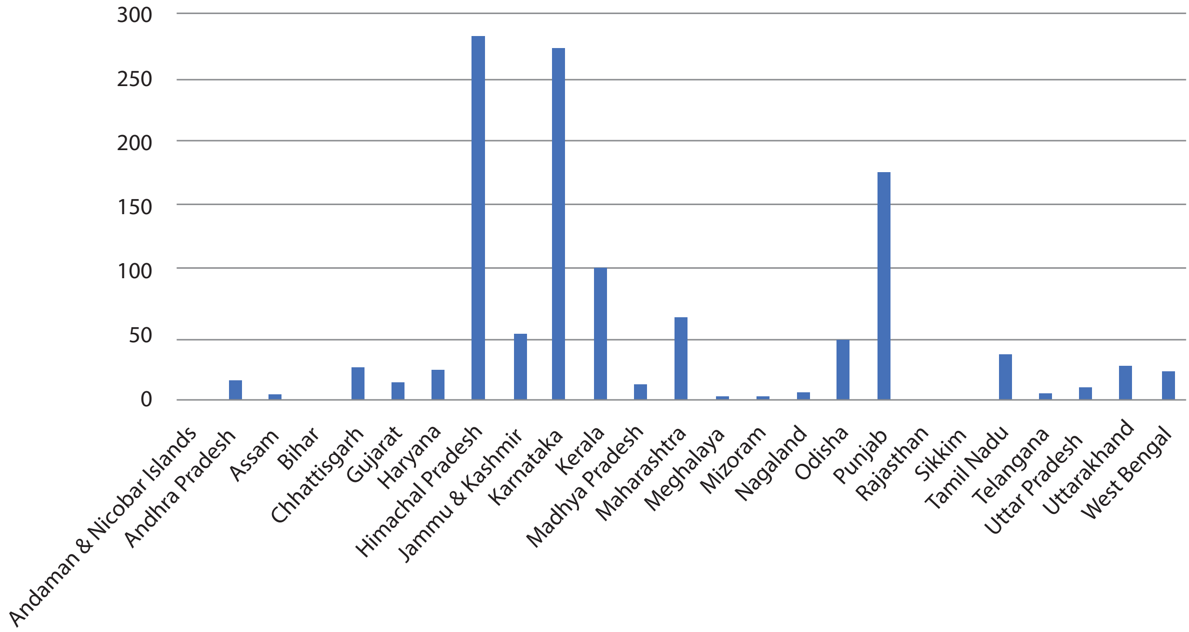
Source: Details available at www.indiastat.com, last accessed on September 29, 2021

2. State-wise renewable energy generation from biomass projects in India (July 2021)



Source: Details available at www.indiastat.com, last accessed on September 29, 2021

3. State-wise renewable energy generation from small hydro projects in India (July 2021)

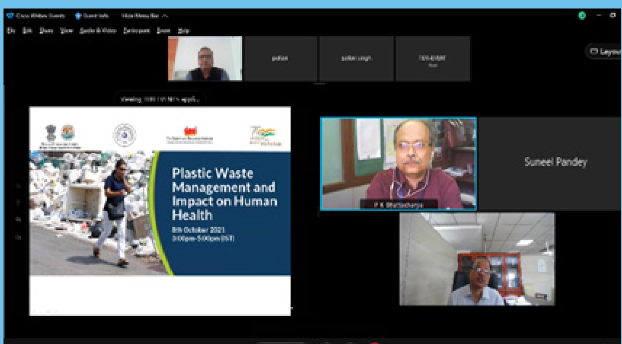


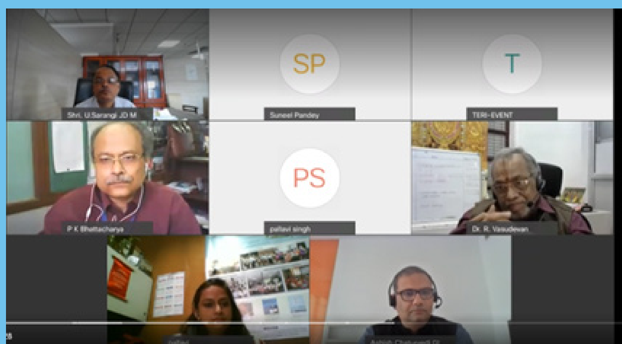
Source: Details available at www.indiastat.com, last accessed on September 29, 2021

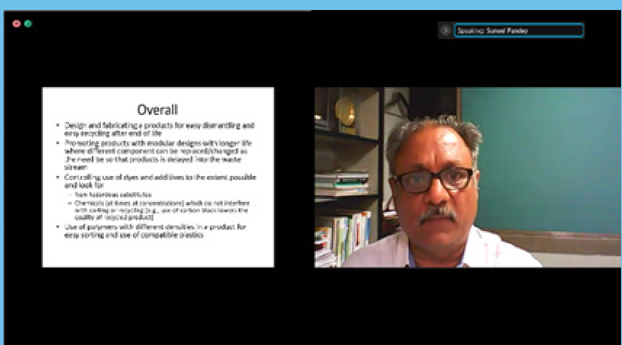
TERI ENVIS RESEARCH PARTNER'S KEY HIGHLIGHTS

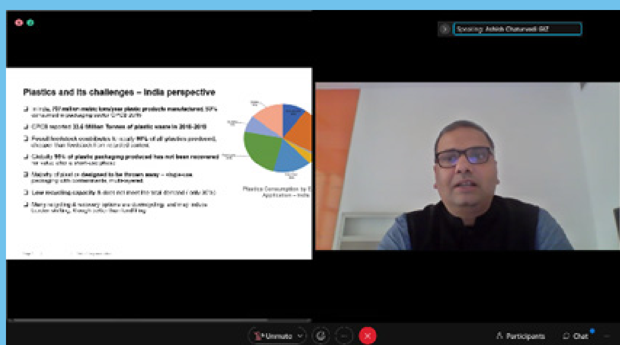
TERI ENVIS Resource Partner's Highlights

Glimpses of a webinar on 'Plastic Waste Management and Impact on Human Health' held on September 8, 2021.









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