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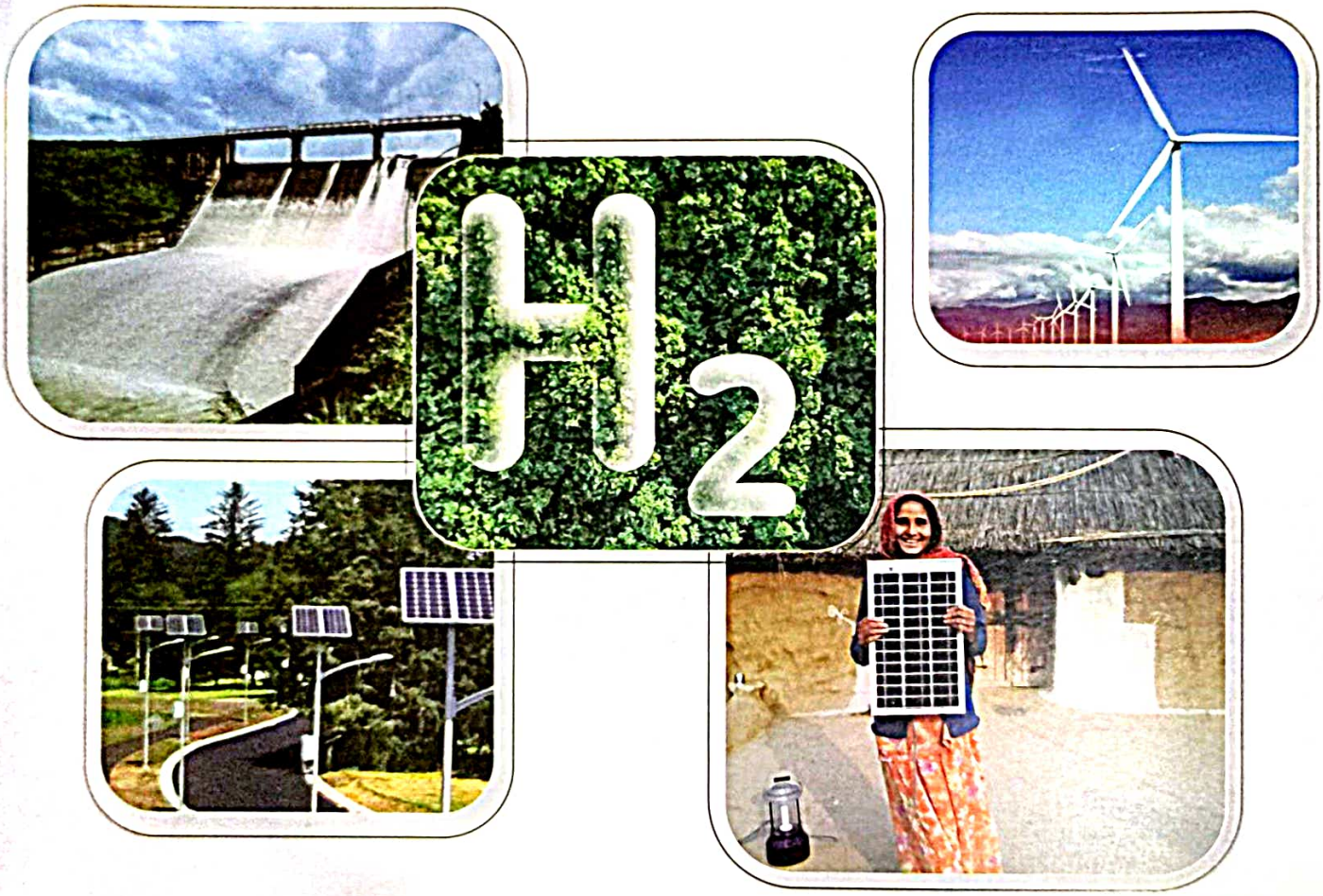

Renewable Resources

Sustainable Development through Renewable Resources

Avinash Mishra
Arunlal K.

Advancements, developments and progress essentially require the consumption of resources and energy. As the pace of urbanisation and commercialisation has been increasing, adopting sustainable approach is inevitable for the very existence of living beings. This realisation has become more visible in the recent decades, and therefore the countries and development agencies have started promoting and insisting the use of renewable resources.

Sustainable Development, as defined in the report of the United Nations World Commission on Environment and Development (1987), chaired by Ms. Gro Harlem Brundtland, is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This vividly emphasises that the consumptive use of resources in achieving the development objectives shall be reasonable and optimum. But since the inception of industrial revolution in the 18th century, the world is in the run for advanced developments and automation. Many of the goods, services and facilities considered luxury less than a decade ago turned out to be today's necessities. The scale, spread and pace of development have literally become boundless and consequently require extensive use of energy and resources. This has posed an inevitable challenge of balancing the spirit of human endeavor to conquer new heights without compromising the fundamental principles of sustainable development. While the improved efficiency in processes could buy time to delay the exhaustion of non-renewable resources, it became obvious that the world needs greener solutions to sustain.

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The critical role of energy in the development activities, and the well-known adverse effects of fossil fuel dependency in worsening the climate change impacts have influenced the use of renewable resources to generate energy. India has been successful in leveraging the natural advantage of harnessing the renewable energy sources to equip sustainable development, and is setting an example. However, our research and development should focus in overcoming the hurdles in making the use of renewables more reliable, affordable and universal.

Energy Sector

Though the use of renewables has scope in various forms and sectors, most often the energy sector is placed at the center-stage. This is primarily due to the fact that energy is the main driver in automation, and in any other fields which demand inputs beyond human efforts. The progress and development targets achieved by the human civilisation rest upon the wide and extensive use of energy in different forms. While discussing the sustainable alternatives, it is largely accepted that choosing an energy strategy inevitably means choosing an environmental strategy. As on today, India is consuming about 9000 billion units of energy for various purposes. About 47 per cent of the total energy is sourced from coal and lignite, 31 per cent from crude oil, about 15 per cent from electricity (hydro, nuclear and other renewable sources) and 8 per cent from natural gas. (Energy Statistics, 2022).

Impact of Fossil Fuels

Other than the never-ending fear of extinction and carbon emission the fossil fuels also pose many strategic and health challenges. The world has witnessed conflicts, and even wars, in attempts to acquire territorial control of the fossil fuel rich regions. In certain other instances, the turbulence in oil supply nations caused distress in oil consumer countries. The recent conflict between Russia and Ukraine has also prompted many countries to explore alternate energy options to fossil fuels. The sources of renewable energy – sun, wind and water – being universal, and not localised as in the case of fossil fuels, would never cause a threat to the world peace.

The 2022 report of the Lancet Countdown on Health and Climate Change: Health at the Mercy of Fossil Fuels says that the changing climate is affecting the spread of infectious diseases, putting populations at higher risk of emerging diseases and co-epidemics; and that coastal waters are becoming more suitable for the transmission of Vibrio pathogens (a major food-borne pathogen that causes life-threatening diseases in humans after the consumption of raw or undercooked seafood). The increasingly extreme weather worsens the stability of global food systems, acting in synergy with other concurrent crises to reverse progress towards hunger eradication.

These facts clearly indicate that the development achieved through burning of fossil fuels cannot be sustainable, and that we have to explore renewable energy options. In view of this, in August 2022, India has updated the Nationally Determined Contributions (NDCs), which embody efforts by each country to reduce national emissions as stipulated in Paris Agreement. As per the updated NDCs, India now stands committed to reduce Emissions Intensity of its GDP by 45 per cent by 2030, from 2005 level and achieve about 50 per cent cumulative electric power installed capacity from non fossil fuel based energy resources by 2030. This demonstrates India's commitment at the highest level for decoupling of economic growth from greenhouse gas emissions.

Renewable Energy

India was a power deficit nation at the time of Independence. The efforts to make India energy-independent have continued for over seven decades, and today, we are a power surplus nation with a total installed electricity capacity of over four lakh Mega Watt (MW). Keeping in mind the sustainable development goals, India's power generation mix is rapidly shifting towards a more significant share of renewable energy. Today, India is the world's third largest producer of renewable energy, with about 42 per cent of our installed electricity capacity coming from non-fossil fuel sources. Source-wise representation of installed

capacity of electricity generation in percentage is presented in Fig 1. Estimated renewable energy potential of India (other than large hydro) is about 1.5 million MW, of which 50 per cent is from solar, 46.7 per cent from wind, and the remaining from small-hydro, biomass and waste to energy.

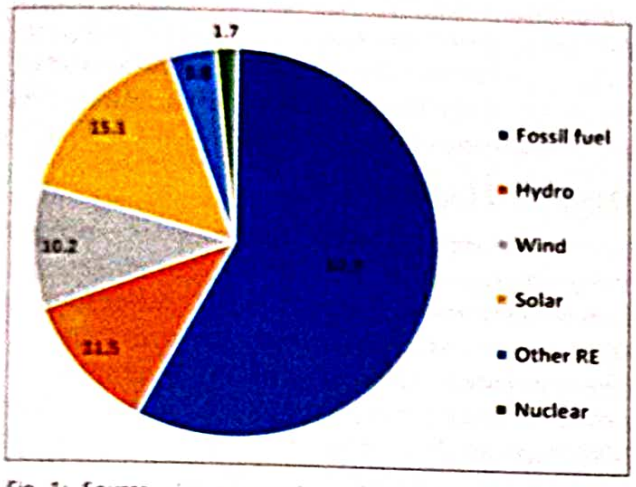

Fig 1: Source-wise generation of electricity in % (Energy Statistics, 2022)

Solar Power

According to the estimates of Ministry of New and Renewable Energy (MNRE) 5000 trillion kwh energy is incident over India's land area every year, with most parts receiving 4-7 kWh per sq. m per day. This is converted to electrical energy through photovoltaic cells. Solar energy has many advantages among which the abundance in supply, ability to generate power on a distributed basis, and ability for capacity addition in short time leads are prominent. Ideally, only a small fraction of the total incident solar energy is required to meet the entire country's power requirement.

The last decade has witnessed surge in the use of solar energy based decentralised and distributed applications. Millions of Indians are now using solar power for lighting, cooking, mobility and other energy needs. The solar power-based cooking has significantly improved the quality of life, especially of rural women and girl children, by reducing the drudgery of long haul of fuel woods and risk of lung and ailments caused by kitchen smoke. Moreover, easy access to power in remote areas have boosted economic activities and employment opportunities, and thus helped in mainstreaming the under-developed zones.

Estimates by National Institute of Solar Energy suggest that covering three per cent of the waste land area with solar photovoltaic modules can generate about 748 GW power. In 2010, Government of India launched National Solar Mission (NSM) with active participation of States to promote sustainable growth while addressing the energy security challenges. This can also contribute significantly to our effort to tackle the challenges of climate change.

Wind Power

The study conducted by National Institute of Wind Energy (NIWE) identified seven states viz. Gujarat, Maharashtra, Rajasthan, Tamil Nadu, Madhya Pradesh, Karnataka and Andhra Pradesh with significant potential for power generation from wind. The wind potential of these 7 seven states at 100 m above ground level (agl) is 293 GW and the potential at 120 m agl is 652 GW. The Government has been promoting wind power projects by incentivising the investments through Accelerated Depreciation Benefit, which allows an investor to claim higher rate of depreciation in wind power infrastructure than that for the general assets. The allowed rate of depreciation was 100 per cent when the scheme was first introduced in 1994 and later rationalised to 80 per cent and to 40 per cent in a phased manner. Government has also introduced waiver of Inter State Transmission System (ISTS) charges for inter-State sale of solar and wind power, for projects to be commissioned by 30 June 2025.

India, having a natural advantage of 7500 km long coast line, has the potential of harnessing offshore wind energy. In 2015, Government of India notified National Offshore Wind Energy Policy with the primary objective of exploring and promoting deployment of offshore wind farms in the Exclusive Economic Zone (EEZ) of the country, including those under Public Private Partnership. The NIWE has identified potential zones for offshore wind energy of 36 GW and 35 GW off the coasts of Gujarat and Tamil Nadu respectively.

Hydropower

Since March 2019 Government of India has been recognising Large Hydro Power Projects (LHPs) including Pumped Storage Projects (PSPs)

having capacity of more than 25 MW as part of renewable energy. Hydro projects with capacity less than 3 MW had already been under the Ministry of New and Renewable Energy since the year 1989 and those with less than 25 MW since 1999. According to the assessment made by Central Electricity Authority (CEA), India has the potential of economically exploitable hydro-power to the tune of 1,48,700 MW. If the probable capacity of pumped storage of 94000 MW and that of about 6700 MW from small, mini and micro hydel projects are considered, India's hydro power potential will be about 2,50,000 MW. However, only less than 30 per cent of this is presently exploited despite having long life, low cost and high efficiency among many other advantages.

Bio Fuels

Ethanol and biodiesel are the two most common types of biofuels in use today. Ethanol is a renewable fuel that can be made from various plant materials, collectively known as "biomass." Government has been implementing Ethanol Blended Petrol (EBP) Programme wherein the Oil Marketing Companies (OMCs) sell petrol blended with 10 per cent ethanol. Biodiesel is a liquid fuel produced from renewable sources, such as new and used vegetable oils and animal fats and is a cleaner-burning replacement for petroleum-based diesel fuel. Presently, biodiesel is produced from imported palm-stearin oil in the country. However, we are phasing it out by using used cooking oil as the feedstock. Since the biomass-based renewable hydrocarbon fuels are nearly identical to the petroleum-based fuels, the transition becomes easier. The National Policy on Biofuels announced in 2018 is aimed at accelerated promotion of biofuels with indicative targets of achieving 20 per cent blending in Petrol and 5 per cent blending in diesel by 2030.

Green Hydrogen

Hydrogen is used as an energy source in industry, mobility and thermal applications. It is produced by splitting water through electrolysis using an electric current. When the electricity used for hydrogen generation is sourced from renewable resources, that is without emitting carbon dioxide, it is called green hydrogen. Hon'ble Prime Minister has launched the National Hydrogen Mission on India's 75th Independence Day in 2021. The Mission aims to make India a green hydrogen hub which will help in meeting the target of production of 5 million tonnes of green hydrogen by 2030 and the related development of renewable energy capacity. On 3rd January this year, National Thermal Power Corporation (NTPC) has commissioned India's first green hydrogen blending project in the piped natural gas (PNG) network of NTPC Kawas township, Surat, to supply H2-NG (Hydrogen -Natural Gas) to the households in the township.

Ocean and Geo-thermal

Ocean energy refers to energy derived from Wave Energy, Tidal Energy, and Ocean Thermal Energy Conversion. The technology development in these areas is at research and development stage. The estimated theoretical power potentials for Tidal and Wave energy are 12,455 MW and 41,300 MW respectively. Geothermal Energy is a source of heat stored in the earth's crust, which is manifested on surface as hot springs. In India, Geological Survey of India (GSI) has estimated that a tentative power potential of 10 GW could be extracted from geothermal energy.

Renewable Powered Airport

Cochin International Airport Limited (CIAL) has successfully turned their disadvantage of power deficit to an advantage to become the world's first solar powered airport. The CIAL ventured into the Solar PV sector in early 2013 by installing a 100 kWp solar PV Plant on the roof top of the arrival terminal block. Following this, one MWp solar PV power plant was installed partly on the roof top and partly on the ground in the aircraft maintenance hangar facility. Inspired by the success of the above-mentioned plants, CIAL has decided to set up a larger scale 12MWp solar PV plant in 2015. As on today CIAL has an installed solar power capacity of 50 MWp. CIAL's solar power plants generates 2.0 lakh units of power a day while the daily consumption of power in the airport is about 1.6 lakh units and thus making the airport power positive.

Food Security and Renewables

Ensuring food security is the fundamental pre-requisite for any sort of development. After land, water and energy are the two paramount resources in ensuring food security and thereby

catalysing the human centric development. Ratio of volume of ground water extracted every year to the annual ground water recharge, referred as stage of groundwater development, in the country is 61.6 per cent. The stage of ground water extraction is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where it is more than 100 per cent, which implies that in these states the annual ground water consumption is more than annual extractable ground water resources. In the states of Tamil Nadu, Uttar Pradesh, Karnataka and Union Territories (UTs) of Chandigarh and Puducherry, the stage of ground water extraction is between 60-100 per cent. These trends clearly establish the huge reliance on energy by way of lifting the ground water for irrigation purpose. Moreover, the decline of ground water table leads to the consumption of more energy every year to meet the irrigation requirements. Use of renewables plays a major role in ensuring gains for the water-energy-food nexus. For example, renewable energy based micro irrigation systems, and the reuse of waste water treated in plants powered with renewable energy can significantly contribute to the environment, water & energy saving and in ensuring food security.

Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyan Yojana (PM-KUSUM)

The Government of India approved the PM-KUSUM scheme in 2019 with the objective to provide clean energy to more than 3.5 million farmers and to enhance their income by providing the option to sell the energy generated in excess of their pumping requirement to the power distribution companies (DISCOMs). The scheme has three components viz., (A.) Addition of 10,000 MW of solar capacity through installation of small solar power plants of capacity up to 2 MW; (B.) Installation of 2.0 million standalone solar powered agricultural pumps; and (C.) Solarisation of 1.5 million existing Grid-connected Agriculture Pumps. The States which are dominant ground water users have been implementing the scheme with enthusiasm. Haryana, for example, has installed about 39500 stand-alone pumps, which is close to the number of diesel pumps in the State as per 5th MI census. As of now, 0.8 million stand-alone pumps and 4886 MW small solar plants are sanctioned across the country and are being installed. The scheme has also helped in spreading awareness among farmers about the advantages of using solar pumps.

International Solar Alliance (ISA)

ISA is an international inter-governmental organisation established as a joint effort by India and France in November 2015 on the sidelines of the 21st Conference of Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris. Its objectives are scaling up solar energy, and reducing the cost of solar power generation through aggregation of demand for solar finance, technologies, innovation, research and development, and capacity building. ISA strives to help member countries develop low-carbon growth trajectories, with particular focus on the Least Developed Countries (LDCs) and the Small Island Developing States (SIDS). ISA's partnerships with multilateral development banks (MDBs), development financial institutions (DFIs), private and public sector organisations, civil society and other international institutions is key in this drive. The 'Towards 1000' strategy of ISA aims to mobilise USD 1,000 billion of investments in solar energy solutions by 2030 to provide energy access to 1,000 million people by installing 1,000 GW of solar energy capacity. This would help mitigate global carbon emissions to the tune of 1,000 million tonnes of CO_2 every year. At present, 110 countries are signatories to the ISA Framework Agreement, of which 90 countries have become members by completing the procedure of ratification.

Way Forward

The major hurdle in expanding and popularising the renewable energy sources is its less competitive position in terms of ease of maintenance and useful life as compared to the conventional energy sources. For example, regular cleaning of solar panels, replacing batteries for off

grid-system, extent of area to place solar panels, considerable labor to fix failure in high-mounted wind turbine and the disposal of damaged panels and accessories are a few areas where the science can help. Research and development have to be augmented in the direction of generating more energy with less space. Moreover, there should be an international cooperation, synergy and harmony in tapping the renewable resources by way of exchange of technology, sharing the benefits of advancements in scientific research and space technology, in assessing the global risks and making informed choices. The upcoming G20 summit under India's presidency shall hopefully witness conceptualisation of robust pathways in this direction.

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Powering Growth in Agriculture Sector

Dr. Jagdeep Saxena

The Government has taken a series of steps to empower farmers with renewable energy systems to make them energy self-sufficient, particularly in irrigating their fields. Various sources of renewable energy such as solar, wind, small hydro, biomass and agricultural wastes are being deployed in rural settings for agricultural purpose.

Agriculture is the mainstay of Indian economy despite increasing dominance of manufacturing and services sectors in recent years. It contributes nearly 15 per cent to national GDP and provides livelihood to around two-third of the total working population in the country. Further, agriculture is the primary source of raw materials for some of the major industries such as textile, sugar, food, pharma (mainly Ayurveda) and new age health and fitness products. Recently, agriculture has jumped to the 7th position as net exporter, across the globe. Like other economic sectors, agriculture also demands high energy inputs in many of its activities, mainly irrigation. According to estimates, agriculture consumes nearly 20 per cent of the electricity consumed at national level. Additionally, farmers have installed around nine million diesel pump sets to harvest groundwater for irrigation purpose. Energy consumption at this high level has raised concern in view of the India's commitment to reduce the carbon intensity by less than 40 per cent by 2030 (COP-26). Recently, Government has set a target to make agriculture sector diesel free by 2024. In this context, renewable energy (RE) has emerged as the most viable and sustainable option to address the environmental concerns and meet the targets as envisaged by Government of India. RE also promises to increase income of farmers and saving of precious natural resources, mainly water. The Government has taken a series of steps to empower farmers with RE systems to make them energy self-sufficient, particularly in irrigating their fields. Various sources of renewable energy such as solar, wind, small hydro, biomass and agricultural wastes are being deployed in rural settings for agricultural purpose. To promote the use, deployment and application of RE systems/ devices in agriculture sector, the central

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Ministry of New and Renewable Energy (MNRE) implements various schemes sponsored by Central Government and also facilitates related research, design, development and manufacture. At state level, a network of Renewable Energy Development Agencies actively co-operate and co-ordinate with MNRE to connect with various stakeholders, primarily farmers.

Resources at Work

Biogas is one of the most popular and versatile form of RE deployed extensively in rural India to serve many purposes. Currently, over five million biogas plants of various capacities are operational in the country improving quality of life of villagers. Biogas plants generate the high calorific value (5,000 kcal per cu.m.) gas by decomposition of organic materials such as cattle dung, agricultural wastes, poultry droppings, night soil and municipal wastes. Most commonly, biogas in its raw form is used as clean fuel for cooking, lighting, motive power and generation of electricity. It is also used in diesel engines to substitute diesel up to 80 per cent, however, 100 per cent replacement of diesel may be achieved by using Biogas Engines. The digested slurry from biogas plants, a by-product, is used as a nutrient enriched organic manure for improving crop yield and also maintain soil health. Thus, biogas plants help with waste management, reduce energy costs, improve soil fertility and curb carbon emissions. Proper waste management on farms leads to better cleanliness and hygiene which improves the living conditions and health of the community. The biogas sector has helped generate employment for both skilled and unskilled rural people.

Government of India is promoting installation of biogas plants by providing subsidy through two major schemes:

(a) New National Biogas and Organic Manure Programme (NNBOMP) for biogas plants in size range of 1 cu.m. to 25 cu.m. per day.

(b) Biogas Power Generation (off-grid) and Thermal Energy Application Programme (BPGTP) for setting up biogas plants in the size range of 30 cu.m. to 2500 cu.m. per day. This corresponds to power generation capacity range of 3 kW to 250 kW for thermal energy/cooling applications.

There are four types of basic models and 10 types of designs of biogas plants approved under New National Biogas and Organic Manure Programme (NNBOMP). All approved designs are eligible for financial subsidies and other facilities uniformly across the country. Due to consistent R&D efforts, biogas plant designs are now available from 0.5 cu.m. to 1,000 cu.m. unit size. More or multiples of biogas plants can be installed for achieving higher production depending upon the availability of raw materials. The unit size of industrial and municipal wastes based biogas plants may go up to 15,000 cu.m. to 20,000 cu.m. biogas production per day. Biogas plants installed under BPGTP fulfil the electrical or thermal requirements of the dairy plants, poultry houses and dairy co-operatives. Power is used for milk chilling and other general applications such as pumping, lighting, irrigation and cooking. The surplus biogas/power can be supplied to neighbourhood dwelling units or farms in off-grid mode on payment basis.

Government of India has launched a dedicated GOBARdhan (Galvanising Organic Bio-Agro Resources Dhan) scheme (Swachh Bharat Mission Grameen Phase-2) with twin objectives – to make the villages clean and generate clean power from organic wastes. The scheme also aims to increase income of farmers by converting biodegradable waste into compressed biogas (CBG). Technical and financial assistance under the scheme is attracting entrepreneurs for establishing community based CBG plants in rural areas. CBG is a purified form of biogas (98 per cent purity of methane content) which makes it suitable for use as green and clean fuel for transportation or filling in cylinders at high pressure (250 bar). Scheme is also promoting rural employment and income generation opportunities for rural youth and others. Recently, Asia's largest CBG plant was inaugurated at Sangrur, Punjab with an FDI investment of Rs. 220 crores. The plant currently produces about six tons CBG per day, but soon its capacity will be raised to 10,000 cu.m. by using eight digesters. It will consume 300 tonnes of paddy straw each day which will be sourced from 6 to 8 satellite locations within a 10 km radius of the plant. About 600-650 tons of fermented organic manure will be produced each day as a byproduct. Further, the CBG plant will employ about 400 people directly and nearly 600 people indirectly. CBG plant offers a much needed substitute for burning crop

stubbles which is a serious environmental and health issue. It is claimed that this plant will reduce the burning of stubble on 40,000-45,000 acres of fields, resulting in an annual reduction of 150,000 tonnes of carbon dioxide emissions. This will help India meet its CoP-26 climate change targets of reducing carbon emissions.

Biomass is another potential source of RE in rural India that provides power for household needs and irrigation as well. Biomass materials used for power generation primarily include bagasse, rice husk, straw, crop waste and agricultural residues. A study estimated surplus biomass availability at about 230 million metric tones per annum covering agricultural residues corresponding to a power potential of 28 Giga Watt. MNRE has been implementing biomass power/ cogeneration programs since mid-nineties. Over 800 biomass power and bagasse/ non-bagasse cogeneration projects aggregating to over 10,206 Mega Watt capacity have been so far installed in the country with central financial assistance from Government of India. Power from biomass is generated by installing biomass gasifiers in proximity to the source of raw materials to reduce costs. In Bihar, a gasifier based business model for power generation and distribution uses rice-husk as source material. A series of more than 80 biomass gasifier plants supplies power to nearly 300 villages and hamlets on payment basis. People generally use electricity for household/business lighting, charging of mobile phones and operation of irrigation pumpsets. Irrigation pumps powered by rice-husk electricity are cheaper, long lasting and more eco-friendly than diesel powered pumps. To operate irrigation pumps, the gasifier is connected to a diesel generation and cuts diesel consumption by 70 per cent. Irrigation facility at low cost allows farmers to increase crop intensity and also improves crop yield.

Sun at Service

Government of India has made a strong commitment to explore and tap the vast potential of solar energy for driving the development of various economic sectors vis-à-vis meeting the targets of COP-26. Addressing the energy concerns in agriculture sector, a large number of solar devices/ equipments have been developed and deployed that include solar water pumps, solar dryers, solar dusters etc. But PM-KUSUM (Pradhan Mantri Kisan Urja Surkasha Evan Utthaan Mahaabhiyan) scheme, launched in 2019, has emerged as a real game changer for energy security of farming community. PM- KUSUM is one of the largest initiatives of the world to provide clean energy to more than 35 lakh farmers and also enhance their income. The scheme is being implemented through its three components with specific objectives:

Componant A: Decentralised Grid Connected Solar Power Plants (Target- 10,000 MW)

This component intends to make farmer 'URJA DATA' by installing small solar power plant (up to 2 MW capacity) on his barren, fallow, pasture or marshy land, and selling the generated power to electricity Distribution Companies (DISCOMS) on a pre-determined rate. In case of cultivated lands, solar panels may be set up in such a manner that chosen crops may grow under the panels. In addition to individual farmers, cooperatives, panchayats, and Farmer Producer Organisations can also be beneficiary under the scheme. The plant can be installed by the farmer himself or he can provide his land on lease to a developer under a model agreement. The solar plant will be a sustainable source of income for 25 years. A farmer may earn up to Rs. 25,000 per acre per year if the plant is installed by a developer; and up to Rs. 65,000 if he installs the plant by himself by taking soft loan from bank. The Reserve Bank of India has notified this component under priority sector lending that allows competitive rates and soft terms. The Central Government provides financial incentive to DISCOMS for purchase of power from such solar plants. About 73.45 NW cumulative capacity of small solar plants have been installed under this component so far, out of which 48.2 MW has been added during 2022.

Component B: Installation of Standalone Solar Powered Agriculture Pumps (Target-20 lakh)

Under this component, individual farmers can replace their existing diesel pumps with solar pumps through Central Financial Assistance (30 per cent of the benchmark cost) and State Government's subsidy (30 per cent). The remaining 40 percent will be borne by the farmer, but bank finance for 30 per cent is available, so farmer will have to initially pay only 10 per cent of the cost. However, farmers of north-eastern states and hilly states are provided higher central financial assistance up to 50 per cent. Groups of farmers, water user associations

and community/ cluster-based irrigation systems are also eligible for financial assistance. However, priority is given to small and marginal farmers and those farmers who have installed micro irrigation systems. Solar pumps of capacity upto 7.5 HP are allowed in the scheme, however, if a farmer goes for higher capacity solar pump the financial assistance will be limited to 7.5 HP. All solar pumps installed under the scheme will be equipped with remote monitoring systems to facilitate their monitoring on a real time basis. Solar pumps will reduce the irrigation costs of about Rs. 50,000 per year for a 5 HP pump.

Component C: Solarisation of existing Grid connected agriculture pumps (Target – 15 lakh)

Under this component, exclusive power feeders for agricultural purposes will be solarised by installing solar power plants of required capacity. Government of India has earmarked 30 per cent subsidy for this purpose. This will lower the cost of capital and cost of power. The farmer will get day time reliable power for irrigation free of cost or at a tariff as fixed by their respective states. In case where agriculture feeders are not separate, loan for this purpose may be taken from NABARD or other designated financial institutions.

Solar Powered Irrigation

Success Story

- Availability of quality water had always been an issue in Gosaba island of Sunderban region in West Bengal. Farmers were unable to grow Rabi crops. Farm ponds, which harvest rainwater during monsoon, were the only source of water for irrigation in the post-monsoon period. As a solution, solar-powered drip irrigation system was installed in the island. Solar panels were installed near the pond and a nano pump (0.1 HP) was used for lifting water from the pond to a tank (1,000 litre) placed at 2.5 meter height on a platform. During day-time, water get lifted to the tank and the stored water is applied to high-value vegetable crops through drip irrigation by gravity method. The farmer, in whose farm the drip irrigation system was installed, is now able to grow vegetables round the year. There was 20 per cent to 30 per cent more yield; saving of 40 per cent to 60 per cent water; 40 per cent saving of labour; and an increase in the cropping intensity by up to 300 per cent as compared to traditional practices. The economics of the cultivation under solar drip system for an area of 725 sq.m. indicated that the system is quite profitable in terms of gross return, net return and output – input ratio.
- Farmers at Chakhaji Village in Pusa Block, Samastipur, Bihar are reaping benefits of solar-powered irrigation through a successful business model. Solar panels have heralded a new era of improved irrigation, carbon-free air, and increased income for farmers. An entrepreneur at the village has 20 solar panels and irrigates 30 acres for 110 farmers at a charge fixed for hourly supply. A solar powered 5-HP submersible pump provides approximately one lakh litres of water per day on a sunny day, enough to irrigate 20-25 acres of land. Another entrepreneur supplies irrigation water to 50 acres for 100 farmers. In addition to seasonal vegetables, farmers now cultivate high value fruits as well. Solar-powered water is available for eight hours a day, but most farmers make do with just 2-4 hours. Farmers' income has increased substantially.

In addition to day time reliable power and increase in farmer's income, the scheme also has direct employment generation potential. According to estimates, each solar installation creates approximately 24.50 job years per MW. Hence, the scheme is likely to generate employment opportunities equivalent to 7.55 lakh job years for skilled and non-skilled work force. PM-KUSUM will help reduce subsidy required from states for electricity supply to agriculture. It will also help

boost domestic solar manufacturing mainly to make solar cells and solar modules for which we still depend on imports. After complete implementation, the scheme will lead to an annual reduction of 1.38 billion litres in diesel consumption per year, thus, reducing the import bill on account of petroleum products. The scheme will also lead to reducing carbon emissions by as much as 32 million tones per annum.

Among many solar devices/equipments developed so far, solar water pumps are the most popular ones with wide scale adoption across the country. Technically called Solar PV (Photo Voltaic) pumping systems, these are of great utility specifically in low head situations like water lifting from canals, shallow wells and dug wells, farm ponds etc. Solar PV systems can be best used with pressurized systems. Large size solar pumps in a canal command area to irrigate crops with sprinklers. However, small size solar pumps perform excellently of one HP capacity are best suited to irrigate crops from surface water reservoir into green houses, poly houses, and shed net houses for high value vegetable production. Solar PV pumps have a great potential for irrigating high value crops such as pomegranate through drippers. Solar PV duster has been developed with especially designed compatible dusting unit, panel carrier and storage battery. The PV panel is carried over the head which provides shade to the worker and simultaneously charges the battery to run the duster even after sunset. Solar PV sprayer comprises basic PV essentials and a DC motor to operate the pump of the sprayer and sprayer unit. The equipment is mounted on a trolley for easy movement. The solar sprayer is especially useful for safe and effective spray of pesticides for low height field and vegetable crops. Solar driers of various designs and types have been developed for a variety of agricultural produce including fruits, vegetables and cereals. Solar drier is a convenient device to dehydrate vegetables and fruits faster and in a hygienic manner. In a solar tunnel type of drier up to two tonnes of agricultural produce can be dried at a time and the drying time is only 60 percent of that needed for the open sun drying. A tilted type solar drier has been found very effective for drying of a variety of vegetables and fruits in an efficient manner. Conduction and convection type of solar driers have been found very effective in dehydration

of high value crops and horticultural produce. Solar cabinet driers and hybrid solar driers can be used for value addition of the horticultural products before going for tertiary processing. Recently, solar driers have been developed for hygienic drying of fishes and other marine produce. Solar preservators have also been developed for preserving and enhancing shelf life of fruits and vegetables. In this unit, fruits and vegetables can remain fresh for 10 days as against 2-3 days in the normal store. A solar thermal based decentralised milk processing unit has been developed specifically for small dairy plants.

Due to immense potential and scope of renewable energy in agriculture sector, Government is focusing on decentralised RE systems and products. MNRE has recently released a framework (2022) to promote RE based applications that are used for earning livelihoods. A special focus on engaging all stakeholders, skill development and capacity building would scale up RE-based livelihood applications. However, financing for the end-users and enterprises would be critical to enable the adoption of solutions and scale-up of the sector. There has been a visible impact of renewable energy in the Indian agriculture during the last few years. RE based decentralised and distributed applications have benefitted millions of farmers in villages by meeting their energy needs in an environment friendly manner.

Decarbonisation of Transport Sector

Randheer Singh

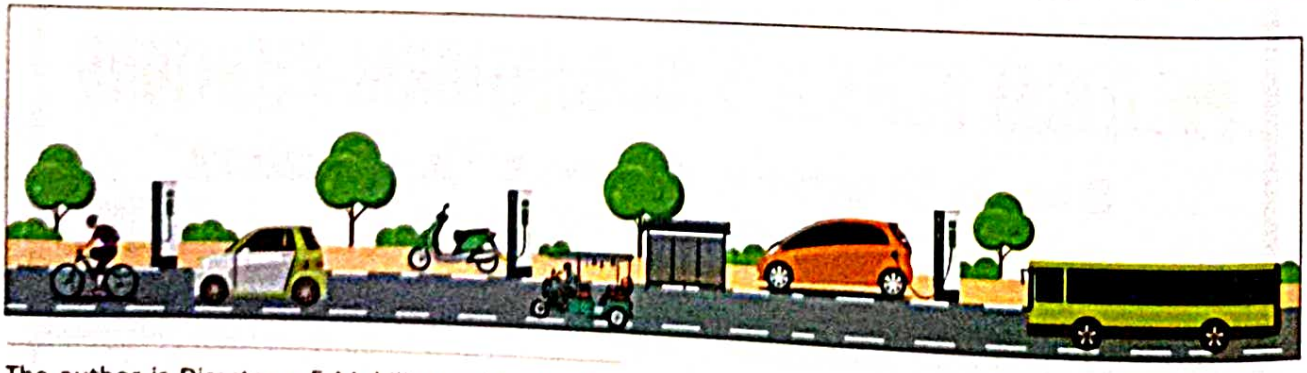
The commitment towards the transition to clean mobility and energy was clarified by Prime Minister Shri Narendra Modi during COP 26 when it was announced that non-fossil fuel-based sources would meet 50 per cent of the country's energy needs by 2030. This will be achieved when solutions will be deployed on multiple fronts. One such critical area is electric vehicle adoption and powering these electric vehicles with renewable energy sources. The Indian government has already committed 7.5 bn USD to three programs (ACC PLI, FAME II, Auto PLI) to facilitate smooth and faster transformation. The programs deal with the manufacturing, supply, and adoption of EVs.

The most critical and pressing issue in front of the world and coming generations is to contain the global temperature rise within 1.5 degrees celcius. Greenhouse gases (GHGs) are the reason for this temperature rise. Therefore, all the mechanisms and sustainable alternatives must be implemented to mitigate the climate risk. Climate change is having profound impacts on India. This includes adverse impacts on agriculture, water resources, forest and biodiversity, health, coastal management, and an increase in temperature. Recently, heat waves have become more common and severe with many cities reporting temperatures above 48 degrees celsius. The decline in agricultural productivity is the significant impact of climate change on India.

Recognising the impact, India is championing climate action – on track to achieve the nationally determined climate goals, mainstream sustainability, and reduce the carbon footprint. The average carbon footprint of a person in India is 0.56 tonnes per year, compared to the global average of four tonnes. India's traditional knowledge, social norms, and daily household practices firmly position it to lead the narrative of addressing climate change through individual behaviours, in the form of mass movements (Jan Andolan), LiFE.

India is focussing on catalyzing, growing, and fuelling the entrepreneurs in the country to create businesses with clean technologies such as hydrogen, electric mobility, batteries, etc. – which has the potential to set the premise for India's growth story and serve as an example for other developing countries. Green technologies are driving sustainable development in India. Such technologies maximise energy efficiency and preserve the environment while saving money[1].

Out of many sectors, including steel, railways, shipping, aviation, energy, road transport, etc., land transport is the one that can be shifted to zero tailpipe emissions mode. In the current context, electric vehicles (EVs) provide this solution and are already much greener than Internal Combustion Engine (ICE) based vehicles. India's transport demand is expected to increase by 2.7 times in over 30 years[2]. EVs are as green as the electricity powering them and the sustainable supply chain of batteries. However, even with the current electricity mix in India, EVs are less polluting than ICE vehicles.



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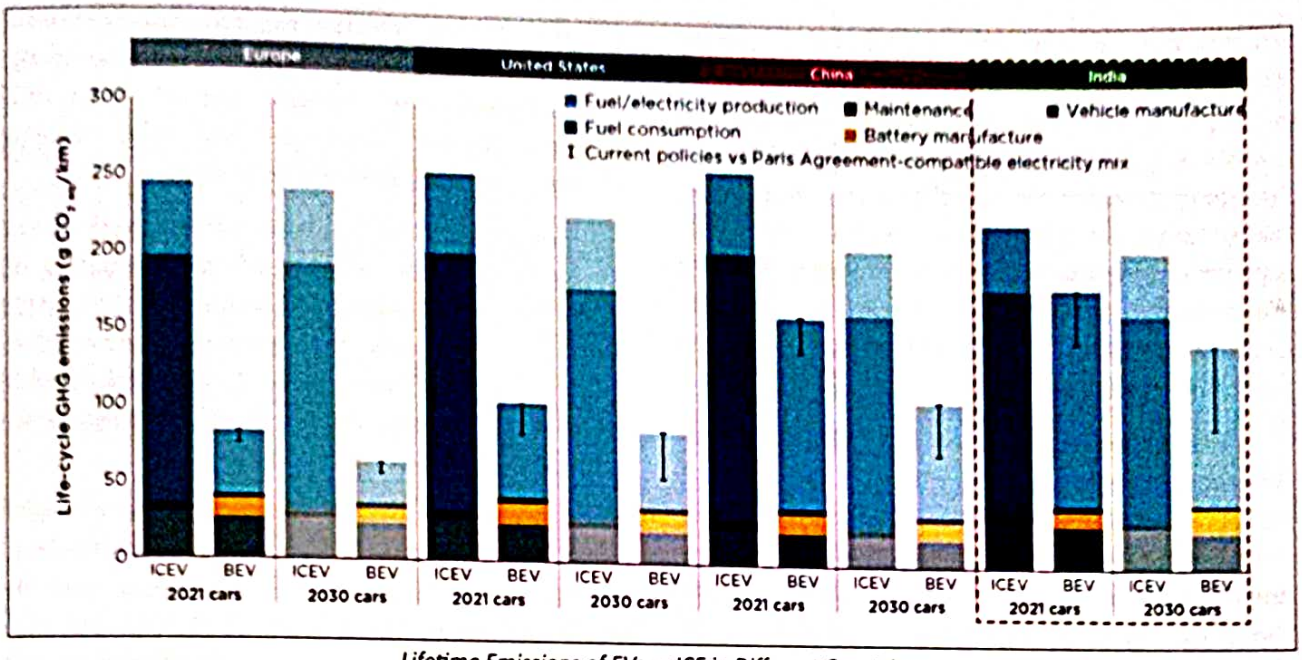


Lifetime Emissions of EVs vs ICE in Different Countries

Lifetime emissions from EVs today are 19-34 per cent lower than ICE cars[3].

Indian automotive market is quite different compared to the majority of the developed world, where four-wheelers dominate personal mobility. Bus transport in India accounts for 38 per cent of passenger km, though its share in overall registered vehicles in India is just around 3.5 per cent. Two-wheeler accounts for 76-80 per cent of the total registered automotive in India. Last-mile connectivity is still a big issue and mainly depends on three-wheelers and sub-seven-meter buses.

Summing up, mass mobility relies on public transport, two-wheelers, and three-wheelers. Therefore, FAME II was focused on these three segments. After the remodelled FAME II was launched in June 2021, the sales have increased by manifolds. Electric two-wheeler sales in June'21 were 4,073 units vs. June'22, when it was 42,260.[4] In parallel, India witnessed the lowest price ever for 5450 electric buses tender (one of the biggest tenders in the world for e-buses). It was on Gross cost contract basis for 5 cities[5]. The lowest price discovered for a 12-meter bus is Rs. 43.49/km, and a 9-m bus is Rs. 39.21/km. This includes the cost of electricity for charging the buses. These rates discovered are 27 per cent less than diesel and 25 per cent less than CNG without subsidy[6].

This paves the way for the electrification of the entire bus market in India (Consolidated and fragmented). Another tender under the National Electric Bus Program for price discovery of 6,465 buses has also been floated on 21st September 2022 by CESL. These buses are Zero tailpipe emission, minimal noise, clutch-free, and low maintenance (few moving parts compared to Internal Combustion Engine/ CNG buses). This will help save on CO_2 emissions, Fossil fuels, and lower noise pollution. The charging infra for city buses shall be located mainly at depots. However, for intercity transport solutions such as opportunity charging and hybrid battery storage models (With fixed and swap battery) need to be explored.

Regarding two wheelers, India is already the biggest manufacturer and most significant market globally. The same legacy is getting carried over to electric two-wheelers also. However, electric two-wheeler vehicle manufacturing is being led by startups and first-time entrants. Traditional players are also now switching to electric models (Albeit very slowly).

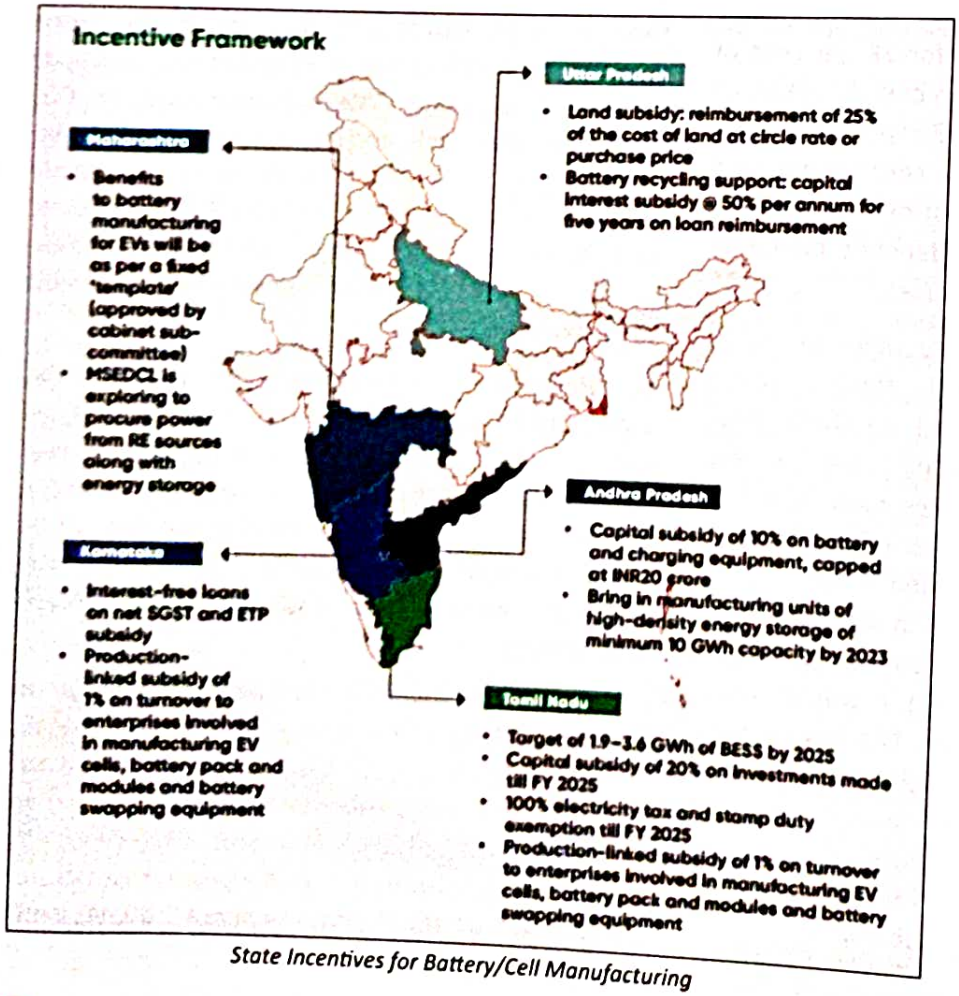
Electric two-wheelers will also see Mobility on Demand (MoD) and Mobility as a Service (MaaS) models to develop. This is because the upfront cost of fixed-battery electric two-wheelers is still higher than ICE vehicles (On a total cost of ownership basis, EVs are cheaper). In terms of the charging infrastructure, electric two-wheelers (Mass segment ~ 80 per cent) will be charged either at home or destination-based

(Offices, parking spots, etc.). In the case of electric two-wheelers engaged in commercial applications or requiring high run, operating models such as battery as a service (Baas) are evolving. The battery swapping provides the benefit of zero downtime, higher range, low price (As you only own the vehicle and the battery is on subscription), freedom from the risk of battery obsolescence, and also higher safety (battery goes back to the OEM-powered charging dock after every use).

The above was in terms of EV adoption. However, India has a chance also to become the global hub of manufacturing for the entire EV Value chain (except raw material mining). Therefore, billion-dollar incentive programs such as the advanced chemistry cell program with an outlay of 2.5 bn USD over five years were rolled out and received an overwhelming response from the industry. Similarly, advanced auto components manufacturing PLI – viz Auto PLI (3.5 bn) is also oversubscribed[7]. This will pave the way for a smooth transition of existing auto parts manufacturing in India and produce global champions. Further, the dominant part of EV (40-50 per cent of EV cost), i.e., cell manufacturing, will get established through this 50 GWh ACC Program[8]. Several states have also rolled out the incentives for battery manufacturing.

Four-wheeler sales have also picked up in H2 2022, primarily because of the availability of affordable EV Models and improved consumer confidence (including the awareness around EVs and technology). This trend will further pick up with the launch of further models in different segments during the Auto Expo in Q1 2023.

India needs to have million-plus fast chargers to cater to the needs of EVs, mainly four-wheelers, cargo three-wheelers, Light commercial vehicles (LCVs), and Buses (Mainly intercity). However, fast chargers are imported into India (Majorly), and only a few players (one or two) are manufacturing locally developed/manufactured fast chargers. India has the potential to lead the manufacturing of fast chargers and become the global hub. Government-led companies such as BHEL / BEL can join hands to develop the local supply chain for chargers manufacturing. Research institutions such as IISc and labs CPRI / CSIR / ARCI can provide further technical support.

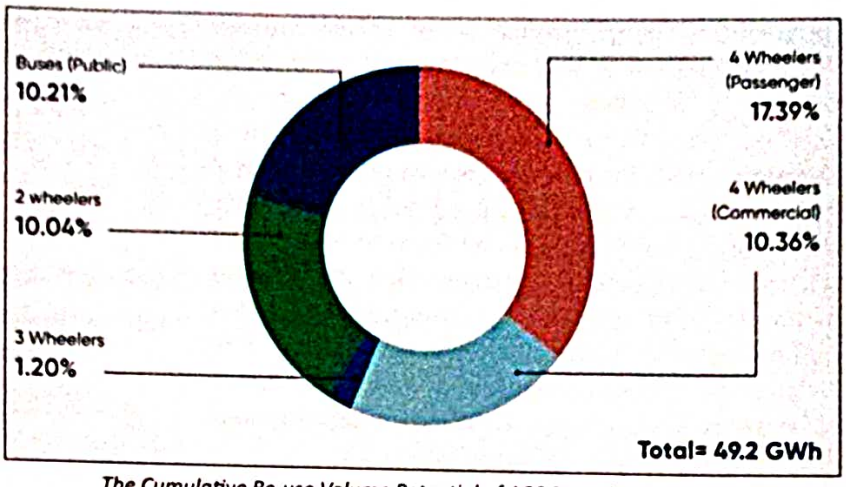


State Incentives for Battery/Cell Manufacturing

The battery swap stations in rural areas will change the EV adoption and Battery storage landscape. It could improve the electricity supply and quality in far-flung areas. For instance, the battery swap station in rural areas can be powered by localised solar power (small setups). These swap stations can serve as micro power grids, which can power the villages/houses in the vicinity and supply the excess power to the grid. All this is in addition to swaps for EVs. Therefore, green power generation and utilisation will increase, and mobility

transformation to cleaner mode will occur.

Another part of India's transition to clean mobility is recycling and refurbishing used batteries. Cumulative potential for advanced chemistry cells in India (2022-2030), the base case is 381.4 GWh for EVs, 36.4 GWh for consumer electronics, 134.6 GWh for grid applications, and 47.3 GWh for Behind the meter application[10]. The cumulative re-use volume potential is 49.2 GWh (2022-2030)[9]. Cumulative recycling volume by 2030 will be around 128 GWh and around 59 GWh will be from EVs alone.



The Cumulative Re-use Volume Potential of ACC Batteries, 2022-2030

India needs a comprehensive mission plan to deal with ACC recycling. This is also important as >95 per cent of the original critical minerals can be recovered from these ACC batteries and reused in cell manufacturing. Many countries have already mandated using recycled minerals in new ACC cells. India needs to take a cue from them.

At the TCO level, light commercial vehicles are getting close. However, the issue is still that traditional players are slow to launch vehicles in this category. We have witnessed German commercial vehicle manufacturers committing (in Germany) to launch the light duty and heavy-duty electric vehicles and develop a dedicated charging network. Most prominent manufacturers (Traton group, Daimler, and Volvo) are coming together and investing in zero-emission commercial vehicle charging infrastructure so that the risks are hedged, and asset utilisation can be improved. A similar approach is required in India, too, wherein the commercial vehicle manufacturers cooperate among themselves and work out the economics. The transition to clean mobility is inevitable. The only question is how soon the organisations will pick it up. A few commercial vehicle start-ups have already launched their offerings in India, challenging the status quo.

States have also provided several fiscal and non-fiscal supports (On top of those provided by the federal government), and already more than 22 states have declared their EV Policies. Even Indian Railways have launched their EV Policy[11]. They not only want to phase out all ICE vehicles used by Indian railways in offices etc., but also to put the charging stations at all electrified railway station parking spaces. This will significantly boost the charging infrastructure availability and help railways achieve their net zero carbon emission by 2030.

Finally, one area which needs much push and would go a long way in transforming the lives of those who can not afford public transport or motorbikes is the electric bicycle. Although the prices of electric bikes are currently high, leasing companies, fleet operators, aggregators, financers, etc., can make it a viable option. The adoption of e-bicycles is rising; even hyper local deliveries are being done worldwide through these. We have seen some startups like Aoki Mobility picking up this space and revolutionise the hyperlocal delivery and last-mile connectivity space.

Since EV is an evolving space, capacity building at all levels, along with upskilling and reskilling, is very important. It all starts with the government officials at the municipal level who interact for things like charging infra, incentives, etc. The sensitisation of the latest guidelines, rules, incentives, etc. should be well communicated through regular training. Next comes the future-ready workforce creation. NITI Aayog is working with IITs to nudge them to start EV-specific courses. More than 15 IITs have already started the courses at the PG level. This has to trickle down to diplomas and other technical and non-technical institutes. At the school level, also (since the large EV market is

for speeds <25km/hr, which can be driven without license), awareness about the benefits and other conditions of cleaner rides needs to be taught. Further, "Shoonya – Zero pollution Mobility" is a consumer and corporate-facing campaign hosted by NITI Aayog. The campaign aims to accelerate the transition of vehicles used for ride-hailing and deliveries into electric vehicles (EVs) by creating awareness and demand for zero-pollution rides and deliveries in Indian cities. The ecosystem it has created by bringing together a dedicated group of industry stakeholders, corporate partners, and consumers can not only

- build awareness around EVs; but also
- create an irreversible demand for zero-pollution deliveries and rides in Indian cities.

India has laid an ambitious outline and policies to direct the country towards a cleaner, greener, and more connected world. The industry is also reciprocating the same, but the speed needs to pick up on all sides, including manufacturing and consumer acceptance.

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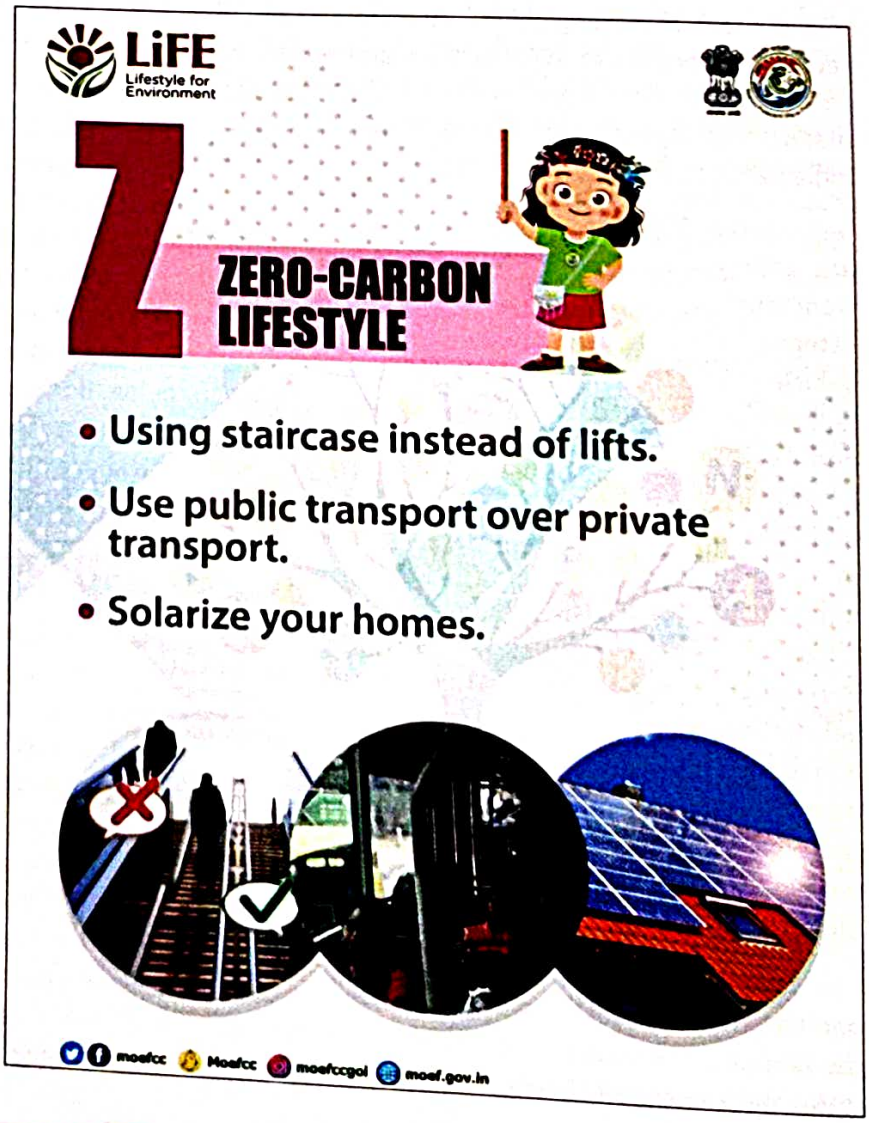

Mitigating Environmental Issues

Ritesh Joshi
Kanchan Puri
Tanuja Puri

Greenhouses gases are generated by burning fossil fuels for energy production which are responsible for global climate change posing great environmental threat. Over 80 percent of India's energy needs are met by three fuels namely coal, oil and solid biomass. As per World Energy Outlook (2021) of International Energy Agency, the current share of India in global primary energy consumption is 6.1 per cent. If the subsidies and impacts of fossil fuels are addressed in energy policies, then the renewable energy technologies could be used more rapidly.

Greenhouses gases are generated by burning fossil fuels for energy production which are responsible for global climate change posing great environmental threat. Environmental problems span a continuously growing range of pollutants, hazards, and ecosystem degradation factors that affect areas ranging from local through regional to global. Literature reveals that energy consumption accounts for 60 per cent of the total greenhouse gas emissions. Talking about the energy consumption in India, as per World Energy Outlook 2021 of International Energy Agency (IEA), the current share of India in global primary energy consumption is 6.1 percent. Over 80 percent of India's energy needs are met by three fuels: coal, oil and solid biomass. [India Energy Outlook, IEA 2021]. In the energy sectors (both for developing and developed countries) widespread use of renewable energy is important for achieving sustainability. After all clean air is basic fundamental human right (World Health Organisation). A transition to cleaner forms of energy has already begun in many countries, with the fast rate of technological innovation and cost reduction. Renewable energy technologies could be

Solar Panels in Uttarakhand

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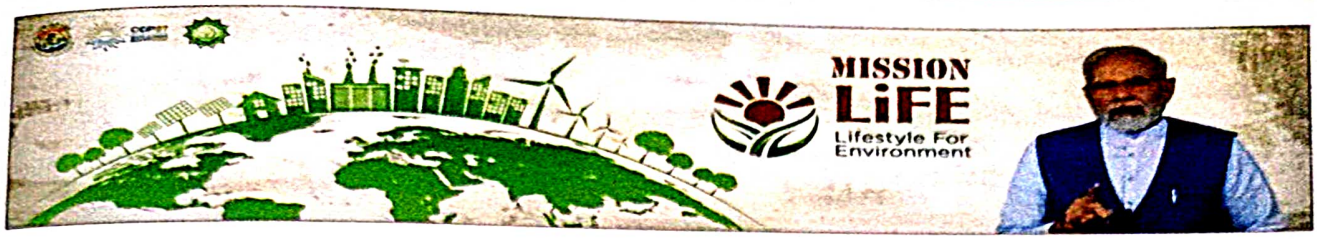


deployed more rapidly if energy policies addressed both the subsidies and impacts of fossil fuels while facilitating more finance for renewable energy projects (www.unep.org).

> The Union Cabinet has given its approval to introduce the Production-Linked Incentive Scheme in High Efficiency Solar PV Modules. Further, the Energy Conservation (Amendment) Bill, 2022 has been passed which focus on the use of non-fossil energy to decarbonise Indian economy. These initiatives will help India achieve targets of Paris Climate Agreement and significantly contributes towards reducing the pollution load and thereby mitigating environmental problems.

In 2008, National Action Plan on Climate Change (NAPCC) was prepared which has eight missions as a multi-pronged, long-term and integrated approach to address climate change. It has overarching policy framework for all climate actions including the expansion of solar energy resources. Subsequently, the states also prepare their respective State Action Plans on Climate Change (SAPCCs) that focus on adaptation interventions. Long-Term Low-Carbon Development Strategy submitted by India under United Nations Framework Convention on Climate Change (UNFCCC) focus on the rational utilisation of national resources with due regard to energy security (www.moef.nic.in). The Paris Agreement in Article 4, states, "All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances." Ministry of Environment, Forest and Climate Change has two central sector schemes that address climate change. The Climate Change Action Plan (CCAP) launched during the 12th Five Year Plan with an outlay of Rs. 290 Cr. to build capacity and support implementation of relevant climate change related actions at the national and State level. Another scheme, the National Adaptation Fund for Climate Change (NAFCC), established in August 2015, with the aim of meeting the cost of climate change adaptation for states and union territories in India which are vulnerable to the impacts of climate change. India at the 26th session of the Conference of the Parties (COP 26) to the UNFCCC held in Glasgow, presented 'Panchamrit' of India's climate action. These were: (1) India will get its non-fossil energy capacity to 500 gigawatt (GW) by 2030, (2) India will meet 50 per cent of its energy requirements from renewable energy by 2030, (3) India will reduce the total projected carbon emissions by one billion tonnes from now onwards till 2030, (4) By 2030, India will reduce the carbon intensity of its economy by less than 45 per cent and (5) By the year 2070, India will achieve the target of Net Zero.

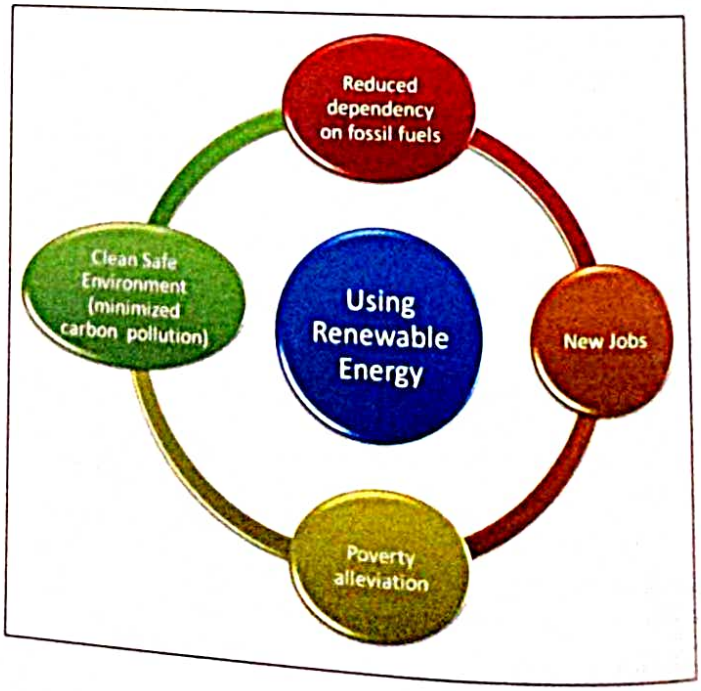
Under the various policy measures taken to fulfil its commitment made in Paris Climate Agreement in 2015 to have 40 per cent of installed power generation capacity from non-fossil fuel sources by 2030, the Government of India also initiated PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Utthan Mahabhiyan) implemented by Ministry of New and Renewable Energy (MNRE). The scheme has three components: Component A: 10,000 MW of Decentralised Ground Mounted Grid Connected Renewable Power Plants of individual plant size up to 2 MW, Component B: Installation of 17.50 lakh standalone Solar Powered Agriculture Pumps of individual pump capacity up to 7.5 HP and Component C: Solarisation of 10 Lakh Grid-connected Agriculture Pumps of individual pump capacity up to 7.5 HP [pmkusum.mnre.gov.in]. The aim is to provide

energy and water security to farmers, enhance their income, de-dieselise the farm sector, and reduce environmental pollution in the process. Also, for setting up of subsidised solar pumps and solar power plants across the country. It is one of the biggest initiatives in the field of transforming India's energy landscapes to provide clean energy to more than 3.5 million farmers across India [Mann ki Baat (Oct 2022), Ministry of Information and Broadcasting].

The Union Cabinet has also given its approval to introduce the Production-Linked Incentive (PLI) Scheme in High Efficiency Solar PV Modules for Enhancing India's Manufacturing Capabilities and Enhancing Exports – AatmaNirbhar Bharat with the scheme outlay as Rs. 24,000 cr, (www.investindia.gov.in). It aims to reduce import dependence in the area of energy sector. The PLI scheme has six objectives which are as follows:

i. To build up solar PV manufacturing capacity of high efficiency modules.
ii. To bring cutting-edge technology to India for manufacturing high efficiency modules. Technologies which yield better module performance will be incentivised.
iii. To promote setting up of integrated plants for better quality control and competitiveness.
iv. To develop ecosystem for sourcing of local material in solar manufacturing.
v. Employment generation and technological self sufficiency.
vi. To encourage sustainable manufacturing practices and adoption of circular economy approaches.

It has 14 key sectors to create national manufacturing champions and also to create 60 lakh new jobs during next five years. Green Energy Corridors is another programme implemented by MNRE in the country to promote renewable energy sources, to create intra-state transmission system for renewable energy projects. Central financial assistance is provided to set up transmission infrastructure for evacuation of Power from Renewable Energy projects. Recently, Hon'ble Prime Minister of India declared Modhera, a village in the Mehsana district of Gujarat as India's first solar-powered village. Conversion to a clean, renewable energy source is not only enabling the villagers to run more electrical household gadgets to make life comfortable, without worrying about the electricity bill but also becoming a source of income for them (UN News). The solarisation of the Modhera Sun Temple and town happened through partnership between the Central and State governments. It involved integrating the village with a Battery Energy Storage System (BESS) at Sujjanpura in Mehsana, about 6 km away from the Sun Temple. More than 1,300 rooftop solar systems have been installed on houses for power generation. While day time power comes from the solar panels, at night it is supplied from the BESS. Villagers at the ground level have realised the benefits and have not only reduced their electricity bills but have also expanded their scope of work with the help of solar power.



In Uttar Pradesh, a target of producing 22,000 MW electricity from solar energy in the next five years has been set viz. 14,000 MW from Solar Park, 4500 MW from Solar Rooftop Residential, 1500 MW from Solar Rooftop Non-Residential and 2000 MW under PM Kusum Yojana. The new Solar Policy will give subsidy for solar power pumps for running tubewells and other agricultural purposes. There is exemption for solar plants from obtaining environmental clearance, grid connected solar PV projects from obtaining consent and NOC for installation and operation under pollution control rules. The solar energy sector is a true representation of an AatmaNirbhar Bharat. Renewable energy technologies need to be strengthened by education and training programs (knowledge awareness). Further, the Energy Conservation (Amendment) Bill, 2022 has been passed which focus on the use of non-fossil energy (biomass, ethanol, green hydrogen) to decarbonise Indian economy. It will also allow carbon credit trading. These initiatives will help India achieve targets of Paris Climate Agreement and significantly contributes towards reducing the pollution load and thereby mitigating environmental problems. It will also have bearing on the targets set in Global Biodiversity Framework under the COP-15 of Convention on Biological Diversity to protect the world's biodiversity.

Public Awareness About Renewable Energy Sources

Debabrata Samanta
Nitish Nigam

The power sector, worldwide, is experiencing a transition from fossil-fuel-based power to clean energy power, based on renewable sources. In this transition, making people aware of clean energy for use and adoption plays a crucial role.

Energy services are essential in all societies to provide for basic human needs (such as lighting, cooking, space comfort, mobility, and communication) and support productive processes that promote economic development. However, since the 1850s, the use of fossil fuels (coal, oil, and gas) has increased globally and has come to dominate the energy supply, which has caused a steep rise in greenhouse gas (GHG) emissions. In 2019, it contributed 34 per cent of the total GHG emissions (IPCC, 2022). In order to effectively optimise energy structures, balance supply, and demand discrepancies, and safeguard the environment, renewable energy is a crucial part of the energy supply. Subsequently, meeting the climate goals of the Paris Agreement requires the rapid global transformation of the energy system; there has been a shift to utilise renewable energy sources to mitigate environmental crises resulting from a changing climate. Implementing renewable energy technologies has gained popularity as a strategy for reducing GHG emissions and mitigating the effects of climate change in both developed and developing nations (Suman, 2021).

> The promotion of renewable energy use has two parts; in one, the people are made aware of the benefits of using renewable energy sources, and in another, the commitments of government and other institutions towards decarbonisation of energy sources through strong policy and financial investment support.

Nearly, 80 per cent of the world's population resides in nations that are net importers of fossil fuels, making them susceptible to geopolitical shocks (United Nations, n.d.). For example, the recent Russia-Ukraine war profoundly impacted global energy markets, as acknowledged by the International Energy Agency (IEA) in the World Energy Outlook 2022. Consequently, the global energy market experienced price volatility, supply shortages, security issues, and economic uncertainty, as Russia is the world's major producer and exporter of oil and natural gas (IEA, 2022b). In light of this, IEA reports that it could accelerate the transition towards green energy. Consequently, the shift towards renewable energy has the potential to make countries self-sufficient in terms of energy security. Considering its possibility to decarbonise the energy system and ensure self-sufficiency, recent years have seen a rise in interest in clean energy as various economies and nations seek to reduce their reliance on highly polluting fossil fuels. The "Agenda 2030" calls for a path to end extreme poverty, fight inequality and injustice, and protect the planet. In line with this, target 7.2 of Sustainable Development Goal 7 (SDG 7) calls for a substantial increase in the share of renewable energy in the global energy mix by the year 2030 to ensure access to affordable, reliable, sustainable and modern energy for all (United Nations, 2015).

Renewable Energy: Concept and Implications

Renewable energy sources can be defined as energy sources that are not depleted with their use. In other words, they are able to be replenished from their respective sources, such as the water resources used to generate hydroelectric power. Renewable energy, as defined by the United Nations (UN) is energy derived from natural sources, which are replenished at a higher rate than consumed. Common renewable energy sources include

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solar, wind, geothermal, hydropower, ocean, and bioenergy. Solar energy generation utilises the sun's energy to provide thermal energy through solar thermal systems and electrical energy through solar photovoltaic (PV) and concentrating solar power (CSP) systems. Wind energy uses large wind turbines located on land (onshore) or in sea or freshwater (offshore) to capture the kinetic energy of moving air. Geothermal energy makes use of the accessible thermal energy from the earth's interior. Hydropower utilises the potential energy of water flowing from higher to lower elevations. Ocean energy is derived from technologies that utilise the kinetic and thermal energy of seawater, such as waves and currents, to generate electricity or heat. Bioenergy is derived from a variety of organic materials known as biomass, such as wood, charcoal, manure, and agricultural crops for liquid biofuels.

Renewable energy is also referred to as clean energy as it does not produce pollution, and they also have a low carbon footprint and emit fewer GHGs in comparison with conventional fossil fuels energy sources. The IEA reports that in 2021, renewable energy sources contributed 28 per cent of the total energy generation worldwide, while coal was used to generate 36.3 per cent. Furthermore, renewable energy sources are expected to account for over 90 per cent of global electricity expansion over the next five years, surpassing coal to become the largest source of global electricity by early 2025 (IEA, 2022a). China, the European Union, the United States, and India are primarily responsible for the surge in the share of renewable energy sources in the next five years due to their policy responses and market reforms pertaining to green energy. The Economic Survey 2021-22 reports that renewable energy contributes to approximately 10.7 per cent of India's power generation, followed by coal. The transition from conventional to green energy has experienced the fastest rate of growth among all large economies, with renewable energy capacity increasing by 2.9 times and solar energy expanding by over 18 times (Government of India, 2022).

Public Awareness Related to Renewable Energy: Concept, Implications and Determinants

To be able to mitigate the negative impact of climate change and adopt renewable energy sources, individuals, households, communities, organisations, government, and other stakeholders

must be engaged at relevant scales. In this context, a substantial body of research on the environmental impact of economic development often assumes that the emergence of environmental awareness is correlated with affluence. Studies have found that public understanding, communication, and knowledge concerning climate actions positively impact public engagement (Bohensky et al., 2016). Along the same line, public concern for environmental threats also has been heightened as by the risk signals mediated through personal experience. Furthermore, public awareness is argued to be the most important factor influencing environmental actions (Chukwuma,1998).

Public awareness can be defined as the improvement of the public understanding of environmental issues with various aims, including building environmental awareness and getting public, financial and/or scientific support for solving issues (Public Awareness, n.d.). In the context of renewable energy, public awareness refers to the level of understanding and knowledge that members of a society have about renewable energy sources and technologies. It can be seen as a measure of how well-informed the public is about renewable energy, and it can be influenced by various factors such as media coverage, public education campaigns, and personal experiences.

Public awareness of renewable energy encompasses information, attitudes, and behaviours related to consuming energy services that have a beneficial impact on the sustainability of the environment (Suki et al., 2016). Public awareness plays a vital role in shaping individuals' decisions towards certain things, such as consumer behaviour towards the adoption of clean technologies (Mustafa et al., 2022). Additionally, it is found that public awareness is being influenced by socio-demographic factors such as age, educational level, social status, environmental concerns, recycling knowledge, public behaviour and the willingness to accept. To meet emission targets, the promotion of renewable energy is crucial. In this context, public awareness can help in promoting the involvement of citizens in the decision-making processes that shape energy policies. By raising awareness about renewable energy options, individuals can be motivated to engage in activities such as supporting policy measures that promote the deployment of renewable energy, investing in renewable energy technologies, and advocating for change, which can help to bring about positive changes in energy policies and practices.

Increasing general public awareness of the adverse environmental impacts of fossil fuel use and of the potential provided by renewable energy sources will contribute to the realisation and expansion of renewable energy investments. The level of awareness and knowledge of different renewable energy sources may vary from inter-region or inter-country. The population's knowledge and opportunities related to renewable energy sources and their willingness to adopt them, depend on several factors. In developed countries, a section of people thinks that the use of renewable energy is an effective solution in combating the negative effect of climate change, and companies should emphasise the use of renewable sources. It is also pointed out that as cost-effectiveness is one of the most important motivating factors, and social acceptance can be achieved by the returns following a positive cost-benefit calculation (Zoellner et al., 2008). Studies found six basic factors affecting the adoption of renewable energy, these are gender, age, education of the head of the household and education in general, occupation and interest in the environment, in technology, or in engineering; and consciousness about environmental behaviour of people (Szakály et al., 2021).

Renewable energy awareness policies are intended to promote the usage of renewable energy sources while also increasing public understanding of their benefits. This can be accomplished through a variety of approaches, such as education and outreach campaigns, financial incentives, and rules requiring the usage of renewable energy. For instance, Norway, which uses 92 percent of its power from renewable power sources, has implemented several policy initiatives to promote renewable energy consumption. It includes the development of Centres for Environment-Friendly Energy Research (FME) in the year 2008 and Green Conversion Package-Green Research Platform in the year 2021. FME aims to develop expertise and foster innovation by focusing on long-term research in specific areas of environmentally friendly energy. Further, Green Platform's purpose is to promote green growth and a sustainable corporate community (IEA, n.d.).

Awareness Related to Renewable Energy: Role of Institution

Increasing public awareness and knowledge will inspire more people to use renewable energy technology and will help people change their conventions and beliefs about these sources. People can be made aware of the advantages of renewable energy, including its potential to lower greenhouse gas emissions, enhance air quality, and lessen dependency on fossil fuels. By raising public awareness, government decision-makers may be more likely to give renewable energy top priority, resulting in more laws and regulations that encourage the development of the renewable energy sector. Increasing public knowledge of renewable energy can accelerate the transition to a cleaner, more sustainable energy system when taken as a whole. Taken together, public awareness relating to renewable energy sources can help people to understand the benefit of renewable energy sources and can be instrumental in the adoption of renewable energy use.

In a world of rapid change, technologies are also changing very rapidly to cater needs of people as well as to make the growth process more sustainable. With Renewable energy, security and sustainability have become other major priorities for both customers and energy providers. The

deployment of sustainable/renewable energy sources is crucial to a healthy relationship between society and the environment. Renewable energy is also providing clean and cheap options for people that live in a friendly and healthy environment. In recent years, despite the COVID-19 crisis, annual growth in renewable investments has been projected at around 5 per cent in 2020, barely behind the trend of recent years (IEA, 2020). The largest capacity growth in the coming years is found to be in the field of solar energy, followed by wind, hydropower, and bioenergy. With regard to countries/regions, the largest growth is expected in China, followed by the European Union (EU) and India (IEA, 2019). In the current energy market structure, the government promotes the production and adoption of renewable systems. Most of these cases, these supports take the form of financial, institutional, or educational. For example, Costa Rica, a country which uses almost 99 per cent of its power from renewable sources, has invested highly in hydropower and non-hydro renewables (www.wri.org). It is argued that, to reach long-term policy targets related to renewable energy, the long-term continuity of policy support is crucial, along with financial, legal, administrative, technological, and cognitive frameworks. As policy consistency has been identified as a significant challenge for renewable energy sources (White et al., 2013). Along with financial and institutional support, making people aware of these non-conventional plays an instrumental role in the adoption of renewable energy by people. Finding a compromise and balance between private and public interests is argued to be one of the cornerstones of sustainable development.

Renewable Energy Promotion: The Indian Context

To promote the use of renewable energy sources, an exclusive institution, the Department of Non-Conventional Energy Sources (DNES), was created in the Ministry of Energy in the year 1982. In 1992, the Department was upgraded into a separate Ministry of Non-Conventional Energy Sources (MNES) in 1992 and was re-named as Ministry of New and Renewable Energy (MNRE) in October 2006. The Ministry is being supported by five institutes, namely, (i) National Institute of Solar Energy (NISE), (ii) National Institute of Wind Energy (NIWE); (iii) Sardar Swarn Singh National Institute of Bio Energy (SSS-NIBE) (iv) Indian Renewable Energy Development Agency (IREDA); and (v) Solar Energy Corporation of India (SECI). This institute provides technical and R&D support to the Ministry. Among them, IREDA, a Non-Banking Financial Institution under the administrative control of this Ministry, provides term loans for renewable energy and energy efficiency projects. IREDA, a Non-Banking Financial Institution under the administrative control of this Ministry, provides term loans for renewable energy and energy efficiency projects. Indian Institute of Technology, Roorkee, provides technical support for small hydropower development.

To enhance efficiency and responsiveness to people and to make people aware, the Ministry has brought out a Citizens'/Clients' Charter (CCC), incorporating its mission, main services/transactions and commitment to its clients and the people of India in general. It also aims at addressing problems of the interface between the Ministry and its Clients/ Citizens and also continuously improving the quality of public services for the people at large to make them responsive to their needs and wishes.

Policy and Guidelines

As per the Annual Report of 2021-22, a comprehensive policy framework on Renewable Energy Research and Technology Development Programme is in place to support Research and Development in the new and renewable energy sector, including associating and supporting Research and Development earned out by the industry for market development. Ministry provides up to 100 per cent financial support to Government/non-profit research organisations/ NGOs and up to 50 to 70 per cent to industry. The Budget allotted for Renewable Energy Research and Technology Development (RE-RTD) Programme is Rs. 228 crores for FY 2021-22 to 2025-26. The policy framework provides guidelines for project identification, formulation, monitoring, appraisal, approval, and financial support.

Special Schemes

There are specific schemes to promote renewable energy in India. National Solar Mission is one of the most important scheme of Government of India, being implemented by the Ministry of New and Renewable Energy. National Solar Mission aims to increase the share of solar energy in the total energy mix. The cumulative targets under the mission for Grid Connected Solar Power Projects

consist of 40 GW Grid connected Rooftop projects and 60 GW large and medium size land-based solar power projects. The combined target is now set at 100 GW. The total investment in setting up 100 GW will be around Rs.6,00,000 crore. The Pradhan Mantri Kishan Urja Suraksha evam Utthan Mahabhiyaan (PM-KUSUM) is another important scheme in this regard. The scheme aims to add solar capacity of 30,800 MW by 2022. The scheme by 2026 targets to install 10,000 MW of solar capacity through small Solar Power Plants, install 20 lakh standalone Solar Powered Agriculture Pumps, and Solarise 15 Lakh Grid-connected Agriculture Pumps. The National Mission on Strategic Knowledge for Climate Change is another initiative to make people aware. The scheme seeks to build a knowledge system that would inform and support national action for ecologically sustainable development.

Conclusion

The persistent use of fossil fuels has caused a steep rise in greenhouse gas emissions. Renewable energy, which is a crucial part of the energy supply, has emerged as an efficient energy supply to optimise energy structures, balance supply and demand discrepancies, and safeguard the environment. Price volatility and supply shortages have shaken the market of energy, especially, fossil fuel energy, post Russia-Ukraine war. However, it appears as a turning point in the transition towards more renewable energy use. Renewable energy sources are energy sources that do not get depleted with use and are derived from natural sources, which are replenished at a higher rate than consumed. Common renewable energy sources include solar, wind, geothermal, hydropower, ocean, and bioenergy. To be able to mitigate the negative impact of climate change and adopt renewable energy sources, individuals, households, communities, organisations, government, and other stakeholders must be engaged at relevant scales. Considering the possibility of decarbonising the energy system and ensuring self-sufficiency, recent years have seen a rise in interest in and promotion of clean, renewable energy. Renewable energy awareness policies are intended to promote the usage of renewable energy sources while also increasing public understanding of their benefits. This can be accomplished through a variety of approaches, such as education and outreach campaigns, financial incentives, and rules requiring the usage of renewable energy. These

aspects also fulfil conditions for the Paris agreement as well as the sustainable development goal. The promotion of renewable energy use has two parts; in one, the people are made aware of the benefits of using renewable energy sources, and in another, the commitments of government and other institutions towards decarbonisation of energy sources through strong policy and financial investment support.

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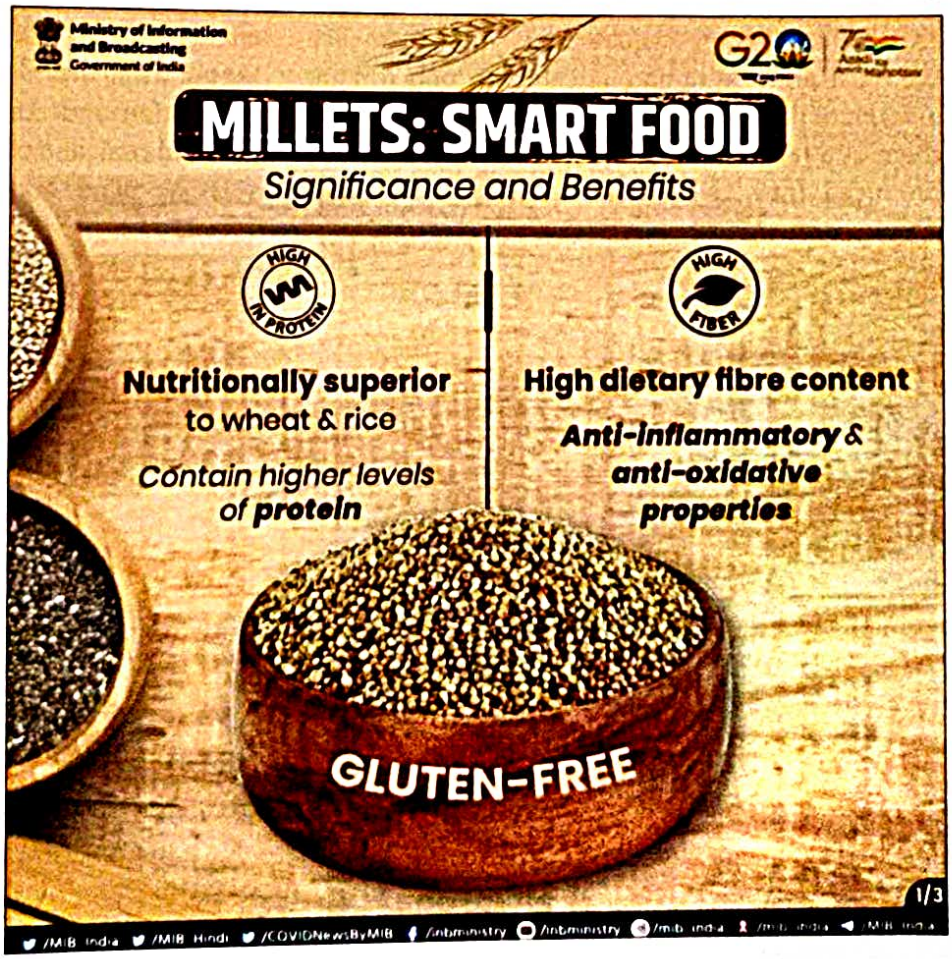


Transition to Clean Energy

Irtif Lone

Increasing the proportion of renewable energy sources in India's total energy mix is both a great opportunity and a requirement as the country seeks to fulfil the demands of its constantly expanding population and economy. The nation is exploring greener means of meeting its energy needs.

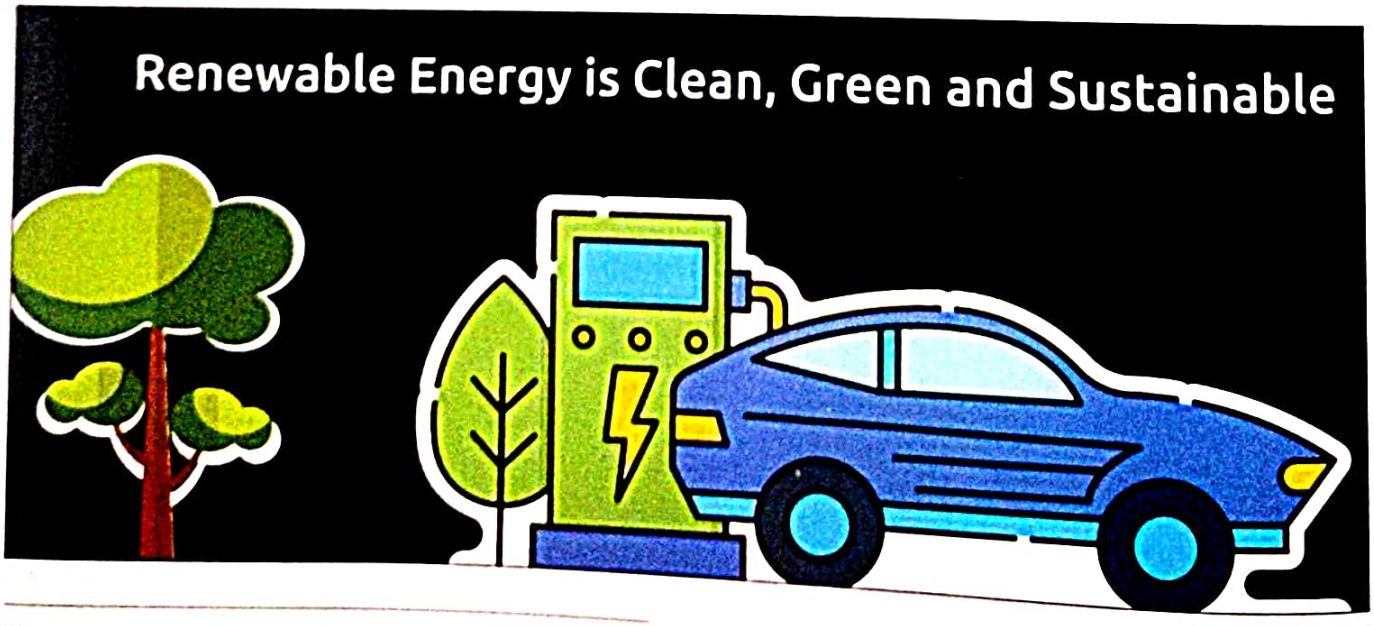
The ever-increasing need for energy for both human and economic growth has coincided with an increase in the variety of sources that may be used to generate energy. However, most of the energy is derived from fossil fuels. The generation and use of these energy resources are the primary contributors to the release of greenhouse gases all around the planet. Since, emissions of greenhouse gases are one of the primary causes of climate change, nations all over the globe are making concerted efforts to transition to cleaner forms of energy by altering the processes by which energy is generated.

At this time, we rely almost exclusively on fossil fuels to heat and power our houses as well as fuel our vehicles. The usage of coal, oil, and natural gas to fulfil our energy requirements may seem like the most practical option, but there is only a finite amount of these fuels on the planet. We are utilising them at a rate that is far faster than they are being produced. They are eventually going to be depleted.

India's future energy security depends on the renewable energy sector expanding, and it is crucial to draw attention to the critical responsibilities that may be performed when using energy sources that are not connected to the grid. Energy access in rural India and lowering fossil fuel usage are two major challenges to achieving long-term energy security in the country, and it is imperative that policymakers take up the challenge of expanding the renewable energy industry and outline the path to do so.

Clean Energy

The term "energy transition" refers to the change that is taking place in the global energy sector away from fossil-based systems of energy production and consumption, such as oil, natural gas, and coal, and toward renewable energy sources such as wind and solar, as well as lithium-ion



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batteries. The sun, the wind, the water, the heat of the earth, and plants are all examples of sources of energy that can be regenerated naturally and are used to produce renewable energy.

At this time, we rely almost exclusively on fossil fuels to heat and power our houses as well as fuel our vehicles. The usage of coal, oil, and natural gas to fulfil our energy requirements may seem like the most practical option, but there is only a finite amount of these fuels on the planet. We are utilising them at a rate that is far faster than they are being produced. They are eventually going to be depleted.

The use of renewable energy sources is preferable for the health of the environment, regardless of whether or not we have an infinite supply of fossil fuels. Renewable energy technologies are called "clean" or "green" since they generate very few pollutants, if any. However, the combustion of fossil fuels releases greenhouse gases into the atmosphere, which trap the sun's heat and contribute to global warming. Climate experts are nearly unanimous in their conclusion that the earth's average temperature has increased over the last century. If this pattern continues, there will be an increase in sea levels, and experts estimate that there will be an increase in the frequency of floods, heat waves, droughts, and other types of extreme weather events.

Energy Scenario

In the recent past, India's energy sectors have embraced two new major developments. The first achievement is that India has been successful in recent years in connecting hundreds of millions of its residents to the nation's electrical grid, which has contributed to an increase in the material well-being of a very large number of people. Second, India has recognised the game-changing potential of renewable energy and solar in particular. The rise of India's renewable energy industry has been quite remarkable.

As a result of steadily increasing earnings and generally better living conditions, India has risen to the position of the world's third-largest consumer of energy. Since 2000, energy consumption has increased by a factor of two, with coal, oil, and solid biomass still supplying 80 per cent of the demand.

Coal, oil, and biomass are the primary sources that contribute to India's ability to meet its energy demands. Together, these sources have reliably satisfied more than 80 per cent of India's overall energy consumption. Coal's dominance as an energy source is supported by its strong position in power production and as a commercial fuel (especially heavy industries such as iron and steel).

In the year 2000, coal met 33 per cent of India's primary energy needs; in the present day, it fulfils 44 per cent of that requirement. Coal has played a significant role in the expansion of India's economy; nevertheless, it is also one of the factors that have led to a decline in air quality and an increase in the country's emissions of greenhouse gases. Traditional biomass was India's second-most important energy source in 2000, accounting for a quarter of the major energy mix. Traditional biofuels include fuelwood, animal waste, and charcoal. Since then, energy consumption as a whole has doubled, while the share of conventional biomass in the total energy mix has progressively declined, reaching 12 per cent in 2019. This drop is mostly due to the improved availability of contemporary cooking fuels, especially LPG.

The increase in automobile ownership as well as road travel has increased oil consumption across the country. Transport energy consumption climbed 3.5 times since 2000 while building demand grew 40 per cent due to increasing appliance ownership and the availability of contemporary cooking fuels. Urbanisation and rising affluence have also led to an increased usage of residential appliances, driving up electricity consumption and outpacing total energy demand. The industry's usage of electric motors and other machines has further increased power demand.

India has made great progress in electricity access in recent years through the Saubhagya scheme, and government data indicate that more than 99 per cent of households were connected to electricity in 2019. There are, however, continuing problems with the quality and reliability of electricity access for connected households and with access for non-household customers: studies found that less than 80 per cent of institutional customers, 65 per cent of small businesses, and 50 per cent of agricultural customers had been connected to the grid as of 2018 (Bali, Vermani, and Mishra, 2020; Dayal, 2019).

Future of the Energy Sector

Within the next two decades, according to the reports published by the International Energy Agency, solar power is projected to see spectacular development in India, eventually equalling the amount of coal in the mix of power generation in India. At the moment, solar energy is responsible for less than 4 per cent of India's total electricity output, whereas coal is responsible for close to 70 per cent. This remarkable about-face is being driven by India's policy ambitions, most notably the target to reach 450 GW of renewable capacity by 2030. Solar power, along with other forms of generation technology and energy storage, is encouraged to be combined in order to provide a "round-the-clock" supply, which is one of the driving forces behind the growth of renewable energy projects on a utility scale.

In India's power industry, the emergence of renewable energy sources has been a key success story. Wind and solar photovoltaic electricity currently account for 7 per cent of total output, which is twice as much as their proportion in 2014. In some Indian states with an abundance of renewable resources, such as solar and wind, the two resources together account for up to 15 per cent of the total electricity generation. Nevertheless, there are still major structural, legislative, and institutional impediments that might hamper further expansion, and the level of success has been variable among the many forms of renewable technology. Congestion on the grid, concerns regarding the development of grid infrastructure, and the weak financial status of many state distribution businesses are some of the challenges that need to be addressed and overcome.

The rise of residential rooftop solar has lagged behind that of utility-scale installations due to higher pricing and a scarcity of financing options that are favourable to consumers. This is owing to the fact that it is more difficult to secure financing for rooftop solar installation projects. Rooftop solar panels supplied a total energy of 40 GW toward the 100 GW total, making them the single largest contributor.

The annual growth rate of India's demand for electricity is 4.7 per cent, which is approximately double the pace of overall growth in the demand for energy. Because of the widespread use of home appliances, the proportion of total energy consumption that is met by electricity is expected to increase from the current 20 per cent to approximately 50 per cent by the year 2040. Electrification of India's energy infrastructure is a major factor in rising demand; power is being used more often in industries that benefit from a steady supply of low-temperature heat, and steel production is more dependent on electricity. Both of these trends are driven by significant increases in the consumption of electricity. Increased adoption of electric vehicles, particularly two-and three-wheeled vehicles, makes it possible for electricity to make headway in the transportation industry.

Solar photovoltaic (PV) projects are now the most cost-effective technique for generating new power in India, and they are also among the most cost-effective methods worldwide. This is because solar energy has a lower cost per watt than other forms of renewable energy. However, in order to accurately evaluate the competitiveness of solar photovoltaics (PV) in India, one needs to look at a number of other factors in addition to the pricing of the technology itself.

Hydro-Power

India has close to one hundred hydropower facilities, in addition to nine pumped storage installations. In 2019, it achieved 50 gigawatts of potential hydropower capacity, moving it past Japan to take fifth place on the list of the world's highest prospective hydropower capacities. However, hydropower's contribution to the overall mix of sources used to generate electricity has been steadily declining over the last few decades and now accounts for just around 10 per cent of total output. The potential for pumped storage in India is approximately 90 GW, and there are 63 sites that have been identified and recognised in national energy regulations for the significant grid services they provide.

Sustainable Development Goals

In recent years, India has made significant strides in accomplishing the United Nations Sustainable Development Goals (UN SDGs). The realisation of the Sustainable Development Goals (SDGs) pertaining to energy carries with it the possibility of accelerating the attainment of other SDGs as well, such as those pertaining to public health, education, water and sanitation, all of which are frequently hampered by a lack of dependable access to electricity and poor air quality.

A number of the Sustainable Development Goals (SDGs) depend on air quality improvements to be achieved. Increasing household access to clean energy would reduce household pollution, increasing the share of renewable energy would result in a long-term decrease in power sector pollution, increasing energy efficiency would reduce air pollutant concentrations throughout the energy economy, and expanding access to environmentally friendly transportation would improve the quality of the air in cities as a whole. Reduced greenhouse gas emissions are a direct side benefit of air pollution control policies.

A number of significant private players have also upped their commitment to the development of sustainable energy. Reliance Industries has announced a net-zero target for the year 2035, and other energy supply companies have also committed to setting these goals. Other energy supply companies, such as Tata Group, Adani Transmission, Suzlon, and Essar Oil and Gas, have committed to set emissions reduction goals under the Declaration of the Private Sector on Climate Change. Within the next five years, automotive businesses in India expect to spend around 500 million dollars in support of the adoption of electric vehicles.

Investments in Energy Sector

No matter how the energy sector in India advances from this point forward, the scale of the country's energy investment requirements is immense, notably in the power and end-use industries. Between 2014 and 2019, there was approximately a 55 per cent increase in the amount of money invested in renewable energy, and there is still a significant amount of enthusiasm in investing, as seen by the high number of solar PV bids.

To meet the requirements for lowering emissions in industry, which includes the steel, cement, chemical, and manufacturing sectors, the energy intensity of production will need to be cut by almost a quarter over the course of the next decade. The expenditures that would be required to make this a reality would mostly concentrate on improving efficiencies, but they would also include money for the direct use of renewable sources, such as bioenergy and solar thermal power.

India to lead the Global Energy Sector

The role that India plays in international energy politics is already significant, and it is expected that this position will take on an increasingly important function in the years to come.

Between 2019 and 2040, India will have the highest rise in energy demand of any country, accounting for about one-quarter of the total global increase. India is the world's second-largest contributor to the increase in the usage of renewable energy sources, after only China. India, which is currently a major player in solar photovoltaics (PV), will take on a similar role in battery storage, attracting more than a third of global investment between 2019 and 2040. India's power system will grow larger than the European Union's by 2040, and it will be the world's third-largest in terms of electrical generation. Furthermore, India's installed renewable energy capacity will be thirty per cent greater than that of the United States.

To capitalise on India's position as a leader in the deployment of battery storage and other clean energy technologies, as well as a country with a large and growing domestic market, the government intends to capture a larger share of this demand through domestic production. However, this goal raises worries about whether there will be sufficient supplies of necessary minerals. India's policymakers will have the critical responsibility of managing the risks and geopolitical hazards connected with these increasingly crucial value chains. This is an area in which international collaboration, as with other aspects of energy security, may play a critical role in the management of these risks and hazards.

India will soon become one of the world's largest marketplaces for a range of renewable energy technologies, making it an important target for technology businesses that are looking to grow. By the year 2040, the solar PV module, wind turbine, lithium-ion battery, and water electrolyzer businesses in India are expected to generate a combined annual revenue of over $ 40 billion. The annual demand for lithium-ion batteries in 2040 will be equivalent to more than 20 times the capacity of the largest gigafactory that exists today. India is responsible for a sizeable share of the global market for each product: around 10 per cent of the market for lithium-ion batteries, 15 per cent of the market

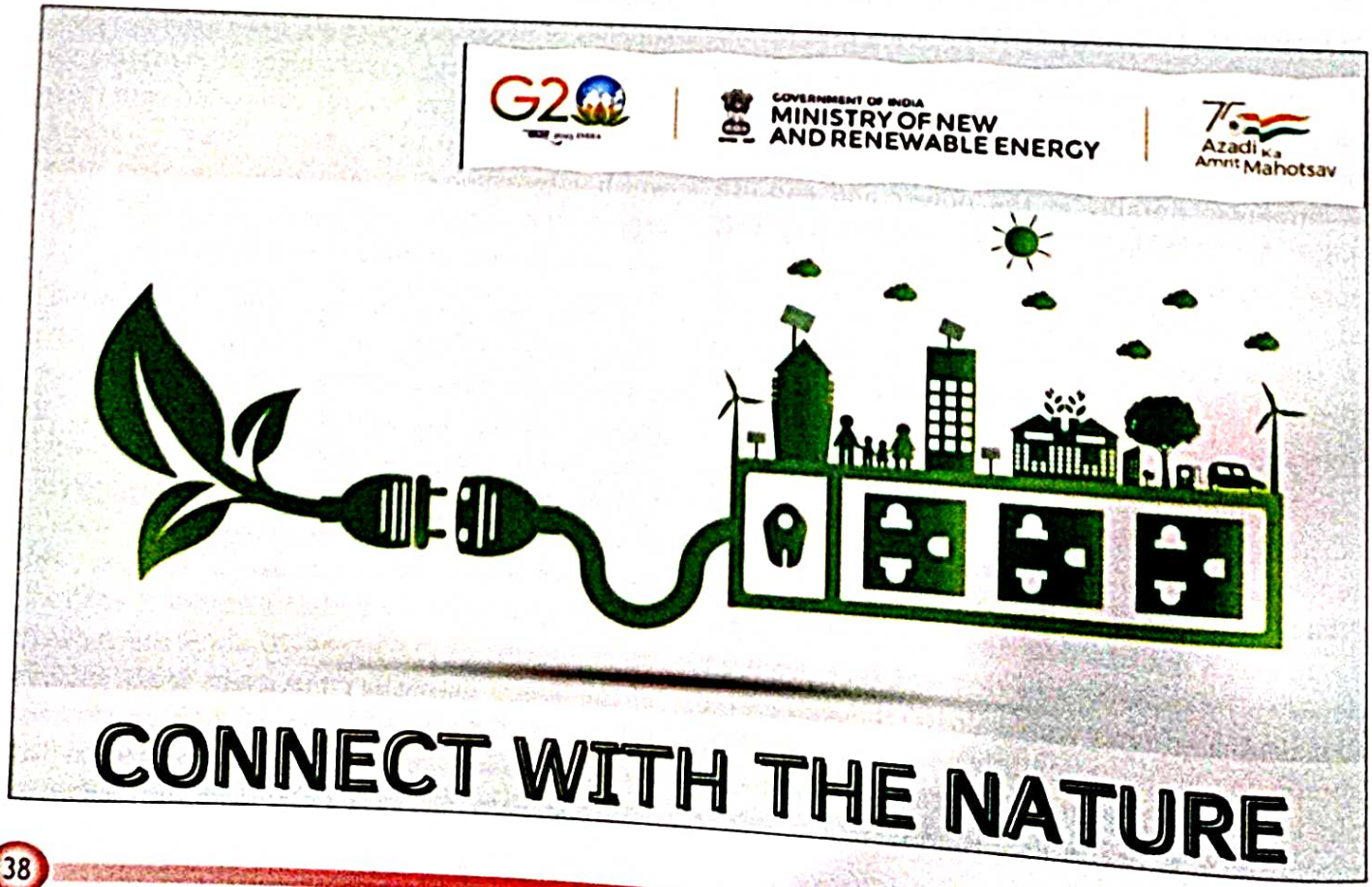
for wind turbines, and 30 per cent of the market for solar photovoltaics.

With a total yearly trade volume of over $ 3 billion, India is now a net importer of goods such as solar photovoltaics (PV) and batteries. The solar photovoltaic (PV) cell and module production facilities in India have had difficulty operating with high capacity factors and competing with imports, notably those coming from China. It is possible that local production would be able to satisfy a greater share of demand, which would be in line with the policy aim of the government to increase domestic manufacturing. The Advanced Chemistry Cell and Battery Gigafactory plan developed by NITI Aayog offers financial incentives to companies who want to construct battery cell plants. In addition, the first plant in India to produce anodes for lithium-ion batteries was recently commissioned in the state of Karnataka.

The Future is Clean Energy

The size of India and its innovative potential will have an effect on the worldwide technology for sustainable energy. Public financing for research and development in the field of energy has increased to a total of $ 670 million in 2019, however, this figure is still relatively low in comparison to that of other major nations. Energy businesses from around the world are placing their bets on India's innovative spirit and commercial potential. The development of renewable energy technologies in India would benefit from a well-planned strategy. The position that India has in the technological value chain will define the countries with which it trades, the patterns of those trades, and the locations of industrial investments.

In order to make the necessary technological changes for energy transitions, India should examine current best practices for prioritising technologies and encouraging public and private innovation in the relevant fields. To a large extent, this will determine India's next move. Multilateral undertakings and international collaborations based on foreign expertise that bolster local capacities are likely to be beneficial. New connections between industry and academic institutions may also improve information exchange. Having access to enough funding is also crucial, and there has to be an exploration into how international financial institutions might aid in the development of pre-commercial energy technologies. Clean energy markets will likely remain unpredictable and reliant on modest margins. PV cell and module manufacturing is a highly competitive market. Many companies have collapsed because they didn't upgrade their assets.



Renewable Energy Transforming Rural Women

Mousumi Kabiraj
Prachi Singhal

Renewable energy has been a boon for women in rural India – whether by ensuring safety through solar-powered streetlights, reducing drudgery by replacing thigh-reeling techniques in the textile industry, generating jobs through self-help groups that connect people to the electricity grid or simply allowing more time for education and skill development. RE can be transformative for India's economy, agriculture, job market, and especially for women. We are just unlocking the potential on our path to net zero.

Renewable energy is transforming the lives of rural women in India and has the potential to do much more. At the Conference of the Parties (CoP) in Egypt in 2022, India announced that it plans to invest heavily in renewable energy, aiming to achieve about 50 per cent of electricity from non-fossil fuel-based energy resources by 2030. In rural India, renewable energy can drive energy availability in previously unconnected areas, generate jobs, enable social transformation and accelerate economic growth.

For women, renewable energy is a boon. Several initiatives have been taken by the Indian government, especially by the Ministry of New and Renewable Energy (MNRE), to bring out policies that leverage renewable energy (RE) as a change-maker in rural women's lives.

"With the [Women in Renewable Energy] initiative within the ministry, I realised that it is not only the participation of women but also the immense possibilities and potential that Decentralised Renewable Energy (DRE) applications have for women

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to reduce drudgery and improve their livelihood opportunities," said Indu Shekhar Chaturvedi, MNRE Secretary, at the 'Workshop on Policy and Intervention for Women in Renewable Energy' organised by the government in New Delhi in October 2022.

Over the years, this relationship between clean energy and women has only deepened – from Rajasthan to Odisha. We will touch upon the various facets where renewable energy has improved women's lives – socially, economically, and environmentally.

Renewable Energy and Employment

A Council on Energy, Environment and Water (CEEW) analysis estimates that India's targets of 1,00,000 MW of solar and 60,000 MW of wind power capacity will generate about 1.3 million direct jobs. Realising this massive opportunity, the National Institute of Solar Energy (NISE), an autonomous institute of MNRE, has organised the 'Surya Mitra' skill development programme in collaboration with State Nodal Agencies. The programme will prepare candidates to become entrepreneurs in the solar energy sector. Special emphasis is being given to rural women candidates during the selection process. Renewable energy not only opens up new job opportunities for women but also helps the state and market tap into a woman's potential as a skilled and well-trained employee.

For instance, when Smart Power India signed a Memorandum of Understanding (MoU) in 2019 with the Central Electricity Supply Utility (CESU) of Odisha to improve power facilities in the state, it not only set an example by employing skilled rural women but also generated evidence on the business benefit rural women employees bring. They leveraged the presence of Self-Help Groups (SHG) in each village and introduced the concept of 'bijulee didi'. Even civil society has realised the potential of renewable energy to create safe, sustainable, and productive jobs for rural women.

Farmer and rural entrepreneur, Lalita Devi from Uttar Pradesh is the team leader of the Khet Kisan producer company, which produces local pickles, jams and powder made from bananas. Considering the challenge of cooling and storing the products, the group purchased biomass-based cold storage, a technology supported by the CEEW's Powering Livelihoods (PL) programme. It allows farmers to store their produce until market demand and prices increase, enabling them to earn a better price in an environmentally sustainable manner. The company's turnover is Rs. 6.7 crore, of which biomass-based cold storage generating revenue of approximately Rs 1 crore. Powering Livelihoods is an initiative by CEEW-Villgro to support DRE-based enterprises to scale their businesses through an integrated gender lens.

Renewable Energy as a Boon to Rural Enterprises

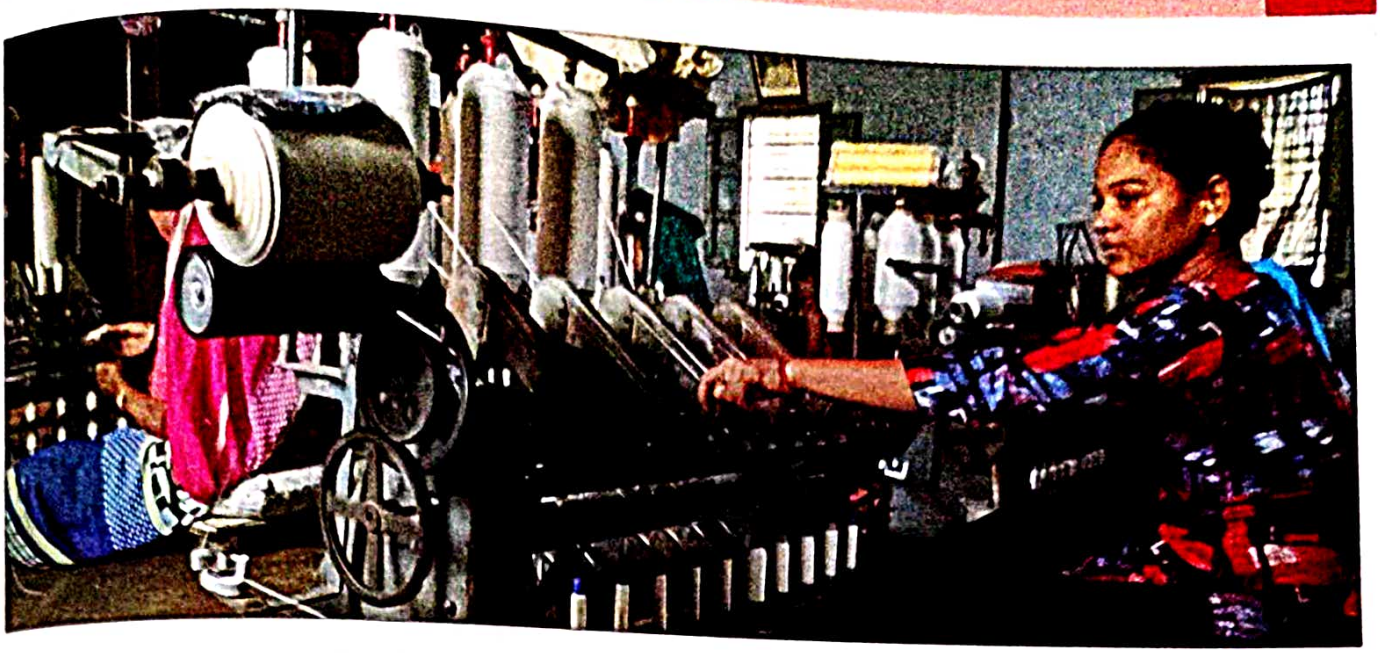
CEEW's analysis of the National Sample Survey Office's (NSSO) 73rd round survey of unincorporated non-farm enterprises indicates that owners of 4.4 million enterprises in rural India complained of erratic power supply as one of the top bottlenecks affecting their business. Workflow interruptions and the damage caused to sensitive electrical equipment by power fluctuations not only limit productivity but also hinder the establishment of new enterprises.

Energy supply to rural households improves the efficiency of businesses and helps increase women's non-farm self-employment. Neetu Tandan is an Agra-based micro-entrepreneur who runs Shri Ambika Naturals using Kissan Dharambir's energy-efficient multi-purpose food processor technology to create fruit squashes, aloe vera drinks, soaps and other nature-based products. She has been running this business for eight months and is able to generate decent revenue from it. She aspires to export her products to international markets one day.

Reliable energy access also affords women extra time that they can utilise in skill training sessions to get a job or start their own business. A women-led initiative, Hariyali Green, was implemented by the Association of Renewable Energy Agencies of States (AREAS) under MNRE (AREAS-MNRE) along with the Natural Resources Defense Council (NRDC) and the Self-Employed Women's Association (SEWA). It aimed to enhance access to clean energy technologies and improve livelihood opportunities at the household level in rural India. Their goal is to create 100 Green Villages by 2025.

Distributed Renewable Energy (DRE) Spurring Rural Women's Micro-Entrepreneurship

DRE is a renewable energy-based system that can generate and distribute energy independent of a centralised electricity grid and provides a wide range of services like lighting, cooking, space heating, and cooling. When we expand the horizon



from RE to DRE, we unlock many more jobs and livelihoods. In India alone, CEEW estimates a market upwards of USD 53 billion for using clean energy for productive enterprises in rural areas such as cold storage, looms, rice mills, and sewing machines. Each solar cold storage could augment the incomes for 50-100 farmers. Each agro-processing unit could help a group of farmers, or as in India, farmer producer organisations (FPOs). Additionally, there is significant potential in textile value chains and small, petty shops, especially for small refrigerators, including in value chains like dairy and fisheries.

In February 2022, MNRE released a draft policy framework for promoting DRE livelihood applications with an explicit gender emphasis. The policy supports the adoption of DRE livelihood technologies among women by providing access to finance for entrepreneurs and end users. This will support the women SHG members in creating new jobs and scaling their existing businesses using DRE technologies.

Established in 2013, Maitree Mahila, a dairy and agriculture producer company, is managed and run by rural women in Rajasthan's Dooni village. They process goat milk and its various products. The group has been using solar-powered DC refrigerators produced by PL-supported DeviDayal Solar enterprise since 2020 to help address the challenge of unreliable electricity. This has helped them increase their processing capacity by three times.

Another initiative by IIT Bombay, with major funding provided by MNRE, was Solar Urja through Localisation for Sustainability (SoULS). It aimed to provide clean, efficient, affordable and reliable electricity even to the last mile households. Under its Solar Urja Lamp (SoUL) project, they have empowered village women from Bihar to assemble and distribute solar study lamps in rural areas without electricity access. In her interview with India Climate Dialogue, Neetu Devi from Gaya district said that being a 'Jeevika Didi' helped her earn a decent income of Rs. 50,000 for assembling 2,900 solar study lamps and distributing more than 200. These female clean energy entrepreneurs or agents curate innovative solutions to cater to women's needs.

Clean Energy Technologies Reduce Women's Drudgery

Access to energy can benefit women both at macro and micro levels. At the macro level, it strengthens livelihoods and boosts local economies, while at the micro level, it is responsible and caters to 'time poverty'.

The textile sector in India has largely been manual labour intensive. The onset of new RE-powered efficient technologies, such as solar-powered spinning, reeling, and weaving machines, can help ease the lives of an estimated 45 million people directly employed by the Indian textile industry, 60 per cent of whom are women. These machines save time and improve efficiency while abolishing drudgerous practices such as 'thigh reeling' prevalent in the silk value chain. They are especially beneficial in the silk value chain where about 86.5 per cent of workers are women, according to CEEW analysis.

Kuni Dehury, a resident of Kardapal village in Odisha's Keonjhar district, runs a silk spinning centre. The major factor that makes the centre unique is the application of solar power to run it. The centre uses Reshamsutra's solar-powered reeling machines because of which women do not have to bear the burden of electricity bills or the labour-intensive thigh reeling process. Kuni Dehury was also praised by Prime Minister Shri Narendra Modi in his 'Mann Ki Baat' programme for her outstanding efforts. Reshamsutra is a PL-supported enterprise to upscale solar reeling machines and help rural women silk-reelers.

The benefits of these technologies have also been exemplified in several government enterprise development/support programmes and schemes. The Ministry of Micro, Small and Medium Enterprises (MSME), through Mission Solar Charkha, aims to create 50 solar charkha clusters, which employ spinners, weavers, stitchers, and other skilled artisans. One cluster of Solar Charkha would involve a maximum subsidy of Rs 9.59 crore. On International Women's Day in 2021, the Ministry of Textiles announced support for 8000 women thigh reelers from across the country with Buniyaad Reeling Machines so as to eradicate the unhygienic, thigh-reeling practice.

Solar Pumps – Powering Rural Women Farmers

Approximately, 76 per cent of agri-allied activities are dominated by women in India. Climate change is responsible for shifting rainfall patterns in many rural geographies. This makes access to water a primary concern for many rural women, whether for domestic, irrigation, or livestock use. Thus, access to small-scale irrigation systems has become essential for reducing farm production risks and improving the well-being of women farmers. The Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan Yojana (PM-KUSUM) scheme by the MNRE offers subsidies and other incentives like feed-in-tariffs to support the adoption of solar-powered irrigation systems. The scheme aims to add a solar capacity of 30,800 MW by 2022 with a total central financial support of Rs. 34,422 crore, including service charges to the implementing agencies, which has been extended to 2026.

Bahuri Devi is a small-holder tribal farmer from Gumla, Jharkhand and owns 0.63-acre of farmland. She grows vegetables such as potatoes, garlic, brinjal, and cabbage. She received a micro solar pump from 'PRADAN' in June 2020, due to her association with a women's self-help group. After using a solar pump on her farmland, she generates an annual income of about Rs. 120,000, which was Rs. 100,000 earlier. With the use of a Khetworks solar micro water pump, she has been able to farm for two seasons in the last 1.5 years and save about Rs. 12,000 per year due to reduced usage of diesel. With the saved amount, she can now buy raw materials and spend on other household expenditures.

Another project showcasing the impact of community-based solar irrigation is the Jharkhand Opportunities for Harnessing Rural Growth (JOHAR). This project is run by the Jharkhand State Livelihood Promotion Society (JSLPS) in collaboration with the World Bank. The project supports tribal women SHG farmers in cultivating high-value crops by providing a 5-7.5 horse power (HP) solar pump at a subsidised rate. According to JOHAR team members, about 1,000 solar pumps have been installed already, and the project aims to support more than 3,000 pumps by 2023. JOHAR impacted over 2 lakh households by training women farmers representing 19 Farmer Producer Companies (FPCs) and 3800+ producer groups through capacity building and training on finance and allied themes.

Resilient Rural Health Systems for Women

Accessing reliable electricity is a significant constraint in rural health centres in India. According to CEEW's 2017 analysis, 4.6 per cent of functional Primary Health Centres (PHCs) in India are unelectrified. This affects over 38 million rural households. A 2021 study by Shastry and Rai states that lack of reliable electricity in healthcare centres is associated with a decrease of 64 per cent in child deliveries affecting women's access to safe healthcare.

Renewable energy can empower rural hospitals by providing uninterrupted electricity and upgrading basic and critical-care services. In Chhattisgarh, an assessment of 147 PHCs found that solar-powered PHCs showed a 78 per cent increase in deliveries. Nearly, 98 per cent of PHCs said that solar power helped with their daily functioning and improved the status of patients.

Social enterprises have developed portable maternity kits, which comprise portable solar torches

and basic diagnostic kits for testing for anaemia, blood sugar levels, and malaria in Kalahandi, Odisha. With the support of the solar kit, pregnant women were able to access check-ups at home, which has had a positive impact on mortality rates.

Solar Street Lights Boost Rural Women's Safety and Mobility

A major factor blocking women's economic integration is concern about public safety. In 2012, safety audits conducted by UN Women's partner Jagori in five municipal areas of Delhi identified that enabling street lights provides more safety as darker areas face the majority of crimes. Women restrict their activities and movements when they don't feel safe going outside, reducing personal empowerment and participation in the workforce.

In a 2020 study by Pal and Banerjee, the installation of 366 solar-powered street lights in four villages of the Golaghat district of Assam by Numaligarh Refinery Limited (NRL) helped women feel safe walking in the evening and at night. Solar street lights have also helped young girls who can now go for their tuition classes in the evening without fear.

Access to Clean Energy Equals Access to Better Education and Health

Women, because of gender-based division in household work, are involved in collecting fuel for cooking and transporting them over long distances. Rural Indian women, on average, spend five to eight hours every day on cooking, and 20 per cent of this time is used in securing fuel wood alone. This has, in turn, reduces their time for study, schooling, or paid employment. Further, biomass fuel causes severe and long-term health problems such as respiratory diseases.

The World Health Organisation (WHO) reports that 500,000 deaths occur yearly due to unclean cooking fuels in India. The International Energy Agency (IEA) estimated that the average firewood load carried by women for several miles daily varies from 25-50 kg. This labour work along with creating time poverty for women also impacts their postures and lead to back pain. Providing clean energy access can reduce the drudgery among rural women, giving them time for education or skill upgradation and improving their health.

How Renewable Energy can help Rural Women

The renewable energy sector has vast opportunities in its value chain and can promote gender equality if accessible to all. Access to energy has historically been crucial for women's economic development. Today, access to modern forms of energy is considered indispensable for alleviating poverty, accessing jobs, assuring independence, and providing social services. Because of its importance in furthering human development, access to energy was included among the United Nations' 17 Sustainable Development Goals (SDGs) in 2015. Significant intra-household dynamics link Affordable and Clean Energy (SDG 7) with gender equality (SDG 5).

In its study, the International Renewable Energy Agency (IRENA) stated that DRE solutions could generate a resilient energy system and support vital adaptation measures for women's communities. Also, long-term access to a reliable energy supply through DRE solutions builds services, self-resilience and adaptive capacity among women. It decreases their vulnerability to climate change risks without requiring huge upfront infrastructure investment.

While the past decade has seen significant advancement in interlinking RE and women's empowerment, a lot more can still be done. Empirical evidence shows that despite the renewable energy sector having immense possibilities for the involvement of women, they are still under-represented. A CEEW study reveals that in India, women account for only an average of 11 per cent of the total employees in the rooftop solar business of surveyed companies as compared to the global average of women in the renewables sector at 32 per cent.

Areas of action that all stakeholders should focus upon are:

- Need to educate and empower rural women on the benefits of RE and clean energy in improving their quality of life. For example, empowered women will demand more sustainable cooking energy, which frees up their time to engage in paid work and reduces their health burdens.
- Empowering women as energy entrepreneurs with the support of the country's Entrepreneurship Development Programmes (EDPs). EDPs can assist and facilitate access to

several government schemes and policies for women entrepreneurs in the energy space by supporting business registration and accessing government support.

- Going beyond energy provision and focusing on the productive use of DRE to improve women's socio-economic participation: their skilling, equipment financing, and market linkages for the products being produced by end-users.
- "Engendering" energy programmes and policies by conducting gender sensitisation and capacity-building sessions with policymakers. Identifying and responding to women's needs should be included within ministry mandates.
- Targeted gender budgeting to be prepared alongside the department budget for each ministry. This will assist and create a roadmap for each ministry and identify schemes and, therefore, implementation process gaps.
- A mechanism to collect sex-disaggregated data on policies/scheme end users across ministries needs to be developed. This will assist in better understanding the existing policy's impact on rural women and girls.

For renewable energy to truly transform the lives of rural women, all stakeholders – government, private industries, philanthropies, community-level organisations and technology enterprises – will have to join hands. Only when women are at the centre of renewable energy expansion, will India be able to achieve both inclusive and sustainable growth.

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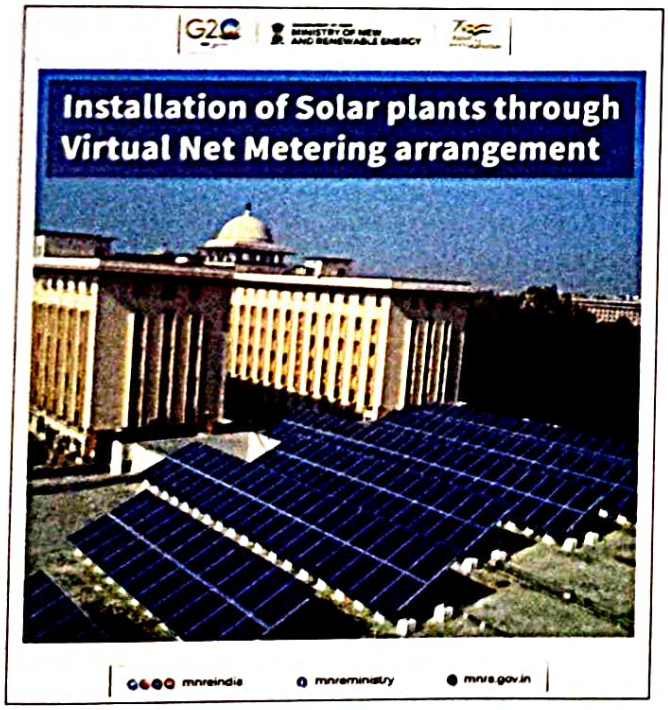

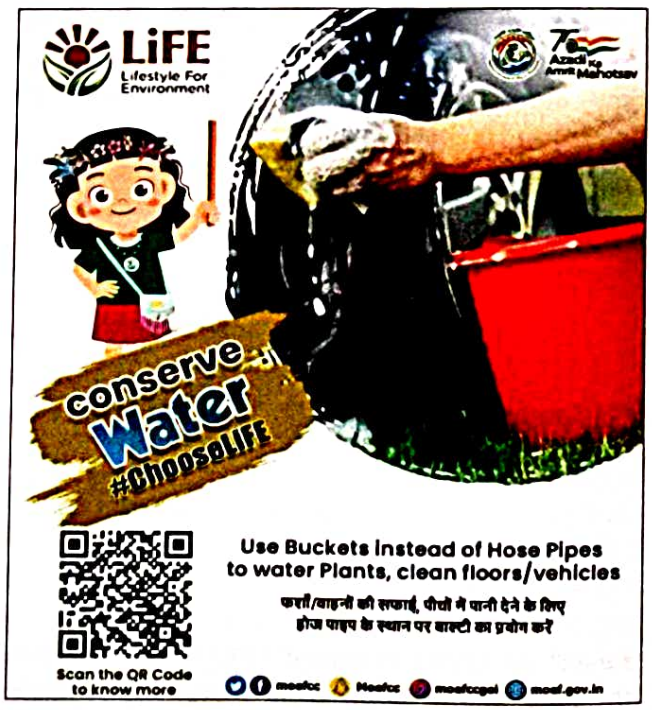

India: A Green Hydrogen Global Hub

Rajiv Theodore

Increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition.

The new year began with one of the most significant announcement in clean energy--National Green Hydrogen Mission, a stellar initiative that is expected to translate into a cumulative reduction in fossil fuel imports of over Rs. 1 lakh crore and a cutback of nearly 50 MMT of annual greenhouse gas emissions by 2030.

The Union Cabinet chaired by Prime Minister Shri Narendra Modi approved the Mission with an initial outlay of Rs. 19,744 crore to make India a global hub for manufacturing of this clean energy source. The mission seeks to promote development of green hydrogen production capacity of at least 5 MMT (Million Metric Tonnes) per annum with an associated renewable energy capacity addition of about 125 GW in the country by 2030. On the long run, it envisages an investment of over Rs. 8 lakh crore and creation of over 6 lakh jobs by 2030.

The Ministry of New and Renewable Energy (MNRE) will formulate the scheme guidelines for implementation. The Mission will also help India export high-value green products making it one of the first major economies to industrialise without the need to 'carbonise'. India's distinct advantage in terms of low-cost renewable electricity, complemented by rapidly falling electrolyser prices, can enable green hydrogen to be not just economical compared to fossil-fuel based hydrogen but also compared to the green hydrogen being produced around the globe.

Some Salient Features of the Mission

- Creation of export opportunities for green hydrogen and its derivatives; decarbonisation of industrial, mobility and energy sectors; reduction in dependence on imported fossil fuels and feedstock; development of indigenous manufacturing capabilities; creation of employment opportunities; and development of cutting-edge technologies.
- Facilitate demand creation, production, utilisation and export of green hydrogen. Under the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT), two distinct financial incentive mechanisms -- targeting domestic manufacturing of electrolysers and production of green hydrogen -- will be provided under the Mission.
- Support pilot projects in emerging end-use sectors and production pathways. Regions capable of supporting large scale production and/or utilisation of hydrogen will be identified and developed as Green Hydrogen Hubs.
- Public-private partnership framework for R&D

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(Strategic Hydrogen Innovation Partnership - SHIP) will be facilitated under the Mission. R&D projects will be goal-oriented, time bound, and suitably scaled up to develop globally competitive technologies. A coordinated skill development programme will also be undertaken.

- All concerned ministries, departments, agencies and institutions of the central and state governments will undertake focussed and coordinated steps to ensure successful achievement of the Mission objectives.
- Rs. 19,744 crore outlay include Rs. 17,490 crore for the Strategic Interventions for Green Hydrogen Transition Programme (SIGHT), Rs. 1,466 crore for pilot projects, Rs. 400 crore for Research and Development, and Rs. 388 crore towards other mission components.
- The manufacturers of Green Hydrogen / Ammonia and the renewable energy plant shall be given connectivity to the grid on priority basis to avoid any procedural delays.
- To ensure ease of doing business a single portal for carrying out all the activities including statutory clearances in a time bound manner will be set up by MNRE.
- Manufacturers of Green Hydrogen / Green Ammonia shall be allowed to set up bunkers near Ports for storage of Green Ammonia for export / use by shipping. The land for the storage for this purpose shall be provided by the respective Port Authorities at applicable charges.

The Story So far

Prime Minister Shri Narendra Modi aims to transform India into an energy independent nation by 2047 where green hydrogen will play an active role as an alternate fuel to petroleum/ fossil-based products. In 2020, India's hydrogen demand stood at 6 million tonnes (MT) per year and is estimated that by 2030, the hydrogen costs will be down by 50 per cent. The demand for hydrogen is expected to see a five-fold jump to 28 MT by 2050 where 80 per cent of the demand is expected to be green in nature. Top industry leaders such as Reliance Industries Limited (RIL), Gas Authority of India Limited (GAIL), National Thermal Power Corporation (NTPC), Indian Oil Corporation (IOC) and Larsen and Toubro (L&T) plan to foray into the green hydrogen space.

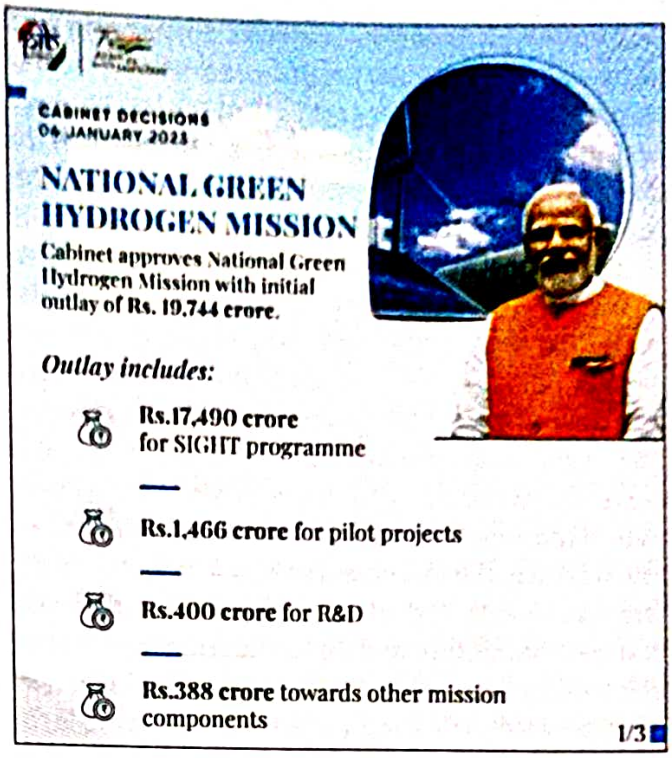
- RIL plans to become a net-carbon zero firm by 2035 and invest nearly INR 750 billion over the next three years in RE.
- Indian Oil is at the forefront of the green hydrogen revolution. It is planning to setup India's first green hydrogen unit for the Mathura refinery, which will be used to process crude oil.
- NTPC has recently set up a tender to establish a first-of-its-kind hydrogen refuelling station to be powered entirely by renewables in Leh through a stand-alone 1.25 MW solar system.
- Two hydrogen refuelling stations have been established (one each at Indian Oil R&D Centre, Faridabad and National Institute of Solar Energy, Gurugram).
- India has declared its ambition to become an exporter of hydrogen to Japan, South Korea, and Europe.
- Various hydrogen powered vehicles have been developed and demonstrated under projects supported by Government of India. These include 6 Cell buses by Tata Motors Ltd., 50 hydrogen enriched CNG (H-CNG) buses in Delhi by Indian Oil Corporation Ltd. in collaboration with Govt. of NCT of Delhi, 2 hydrogen fueled Internal Combustion Engine buses (by IIT Delhi in collaboration with Mahindra & Mahindra).

Increasing renewable energy use across all economic spheres is central to India's Energy Transition. Green Hydrogen is considered a promising alternative for enabling this transition. Hydrogen is utilised for long-duration storage of renewable energy, replacement of fossil fuels in industry, clean transportation, and potentially also for decentralised power generation, aviation, and marine transport. In terms of integrating renewable energy, Hydrogen provides a means for storage of variable renewable energy for stabilising its output. It plays a unique role in long duration energy storages, converting excess available energy into

hydrogen and utilisation in grid support.

It may be noted that several countries which would eventually adopt green hydrogen technologies are not ideally situated to satisfy their projected hydrogen demand by producing it locally and they will eventually become dependent on imported green hydrogen. This potential opportunity in hydrogen trade for India which currently relies heavily on importing fuel to meet its demand. India has vast potential to divert its renewable power capacities to produce green hydrogen for the export market, making India a global green hydrogen hub. Pursuing Green Hydrogen aggressively, India has a distinct advantage in low-cost renewable-energy generation and world-class clean-power execution capabilities makes green hydrogen the most competitive form of hydrogen in the medium run. This enables India to be potentially one of the most competitive producers of green hydrogen in the world. Since 75 per cent of the cost of green hydrogen is dependent on renewable energy, India should target to further bring down the cost of solar power to Rs. 1 per Kw/h through lower cost of financing. Energy security is another reason to pursue green hydrogen as it will enable the emergence of a domestically produced energy carrier that can reduce the dependence on fossil fuel imports of $ 160 bn per year. In addition, with 500 GW renewables expected to come on line by 2030, green hydrogen could act as a solution to extract value out of excess renewable power with a conducive policy measures is expected to create a green hydrogen ecosystem. India should tap the export markets since there is a huge potential in the markets of EU, Japan and South Korea. India should also encourage industrial Research and Development in electrolysers and other green hydrogen components as Indian companies cannot be dependent on foreign technology suppliers.

Industrial applications such as refining and non-urea fertilisers have to be mandated to go 100 percent green hydrogen by 2030 to ensure economies of scale for this nascent industry to flourish. With these measures, the price of green hydrogen should fall from $ 4 per kg to $ 1 per kg by 2030. With proper policy support, industry



action, market generation and increased investor interest, India can position itself as a low-cost, zero-carbon green hydrogen manufacturing hub of the world. Hydrogen, as an energy carrier, is crucial for achieving decarbonisation of hard-to-abate sectors. Many sectors such as iron ore and steel, fertilisers, refining, methanol and maritime shipping emit major amounts of CO_2, and carbon free hydrogen will play a critical role in enabling deep decarbonisation.

The government is expected to allocate around Rs. 60 billion each for its production-linked incentive schemes for electrolysers and green hydrogen from the Rs. 200 billion green hydrogen mission. "We will have a PLI for electrolysers, and a PLI for manufacturing green hydrogen," New and Renewable Energy minister R.K. Singh had said in October. "But the PLI for manufacturing green hydrogen will only be required for the initial capacities, maybe four to five million tonnes. After that, green hydrogen will stand on its own feet." The Ministry of New and Renewable Energy is said to have moved a cabinet note detailing green hydrogen consumption obligations, subsidies, and standards. These would be major enabling provisions to develop the domestic green hydrogen industry and its adoption in India by bringing down market prices.

Although green hydrogen is now considered as a viable way to cut carbon emissions, major challenges remain in scaling up the technology and making it cost-effective. It is also not certain the demand will grow proportionately, and the fuel may not become the first choice in transport and industry. Changes do not happen overnight. Hydrogen cannot simply replace existing fuels, a gradual shift is the only way forward that will require changes in not only the infrastructure but also in terms of safety, consumer behavior, and skill development of millions of people currently working with fossil fuels. Electrolyser manufacturing is emerging in India, although at an initial phase, the ingredients to be a manufacturing champion with its access to skilled and cost-competitive labour, and deep experience in power electronics is evident. India needs to invest in R&D, and material supply chain, and increase local demand for green hydrogen. The use of hydrogen requires a major shift in the existing energy landscape and replacing existing infrastructure which has an available period of use, will not only become unfeasible financially, but also involve massive wastage of resources.

There is a need to consider developing new infrastructure rather than dismantling existing framework. Producing hydrogen requires diversion of excess renewable capacity since most of the energy produced is used up in meeting the constant energy demands. Hence, there is a need to produce more surplus energy. There is a possibility that India could face geo-political resistance presented by the oil producing nations. The thought of a commodity replacing oil will not be readily accepted even as disruptions in the oil and gas supply chains will be catastrophic to India's economy.

Private Sector and Green Hydrogen Initiatives

The future of hydrogen in India can also be seen from the interest in hydrogen by companies like Reliance Industries, Tata Group, Adani Group, Jindal, and more importantly, Indian Oil and NTPC. Pilot projects in hydrogen production, distribution, storage, and application have been already announced by these companies, and they are making massive investments in this sector to ensure they continue to have an edge in the energy business. Government policy in India is also extremely supportive of new investments in the hydrogen ecosystem and recently Indian enterprise can satisfy their renewable purchase obligations (RPOs) by purchasing green hydrogen. In India, the production cost of green hydrogen is around Rs. 500 per kg. The government expects to reduce the cost of manufacturing green hydrogen by 40-50 per cent through its policy initiatives.

The recent developments could see India emerging as a key base for hydrogen electrolyser production with 8GW capacity by 2025. The investor interest is so high that western companies are also entering into India's green hydrogen market through joint ventures. India's Greenko is building a 2GW factory in partnership with Belgium's John Cockerill and Nevada-based Ohmium. Reliance is building electrolyser factories in partnership with Denmark's Stiesdal, and L&T with Norway's Hydrogen Pro. Gautam Adani, has committed financing to a one GW factory as the first step in its recently announced plan to produce three million tonnes of hydrogen by 2030, which would require 16GW of electrolyser capacity. There is little doubt that Indian companies are pushing hard to develop a local industry by tapping into the financial heft of local conglomerates and technical know-how from the Western world.

Marquee names in India Inc as well as renewable energy companies have already bet big bucks in green hydrogen manufacturing and most major industrial houses are doing so as part of their decarbonisation drive. Reliance Industries Limited (RIL), whichplans to utilise the green hydrogen it produces for inhouse consumption initially, not retail sales. The company is looking to utilise global technology to reduce manufacturing costs. In October 2021, RIL joined hands with Danish company Stiesdal A/S to develop and manufacture hydrogen electrolysers. On almost similar lines, state-owned oil marketing company Indian Oil Corporation aims to replace at least a tenth of its current fossil-fuel-based hydrogen at its refineries with carbon-free green hydrogen. In fact, most companies plan to consider captive use first.

The Hinduja group, which launched its renewable energy business in 2016, is looking to

expand in green hydrogen manufacturing for this purpose. The group wants to leverage its presence in the supply chain across sectors. Transport would be one major sector. Commercial vehicle maker Ashok Leyland, part of the Hinduja group, plans to include multiple fuels in its portfolio. Adani Enterprises Limited, which has launched a separate petrochemical company and a new energy company with the core focus on green fuels. Adani Petrochemicals plans to offer a variety of green fuels and utilise its supply chains and RE units for production and transport. The company has a four-pronged plan to manufacture Green Hydrogen, Green Methanol, Green Ammonia and Green Fertiliser.

Gurugram-based ACME Group has said it is planning to invest about Rs 1.5 trillion in green hydrogen and ammonia for its upcoming units in Tamil Nadu, Karnataka and Oman. The RE company is also looking for foreign equity partners and off-take tie-ups for these projects. Another renewable energy major ReNew Power has recently signed a preliminary agreement with the Egyptian government to invest $ 8 billion to produce green hydrogen in the country. Despite this bullishness prices will be competitive only with an assured market. The global green hydrogen market was valued at $ 1.83 billion in 2021 is expected to hit over $ 89.18 billion by 2030, expanding at a compound annual growth rate of 54 per cent from 2021 to 2030.

The Asia-Pacific region is the fastest growing area in the green hydrogen market. India has set a target of an annual production capacity of 25 million tonnes by 2047. The number could well be revised upwards as the technology evolves and the demand outlook improves. India's current output of green hydrogen is low and comes from a just handful of pilot projects. By the end of this decade, the country wants to produce 5 million tonnes of green hydrogen. By 2030, India also plans to add 175 GW capacity of green-hydrogen-based energy. India today is in the process of finalising a roadmap for becoming green hydrogen economy which would require Rs. 15 trillion and another Rs. 15 trillion to meet middle-term goal by 2030. So, in all, these initiatives would require an investment of Rs. 30 trillion by 2030.