Exploring the Critical Role of Circular Economy in Green Energy Transition in India

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ABSTRACT

Abstract- In line with the national commitments of reduction in carbon emissions India is undergoing a radical transition to green energy. The revised targets declared at Glasgow are ambitious and far reaching. But this transition is based on use of many precious elements used in batteries and solar panels as well as many potentially hazardous components. The transition, therefore, needs to be sustainable and should not be the cause of any environmental degradation. The implementation of circular economy with the integrated principles of reuse and recycle is imperative to achieve this objective.

Keywords: Green Energy, Sustainable Development, SDGs, Climate Change, Global Warming

Introduction

Given that India is the most populous developing country, its response to the climate crisis will determine if the mission for sustainable development and climate preservation is successful. India has taken the lead in the effort to protect the environment. The Indian case study on current trends is a story of outstanding achievement in this regard. Even though India has historically only supplied 5% of global emissions. The swift adoption of solar and wind energy sources as well as conservation initiatives have produced excellent results. Particularly in the use of renewable energy, the country has gradually set the bar higher. In addition to the 175 GW by 2022 pledge made in Paris, 450 GW by 2030 pledge made at the UN Climate Summit, and now 500 GW by 2030 pledge made by the CoP-26. By itself, the perform, accomplish, and trade initiative reduced conservation-related CO2 equivalent emissions by almost 92 million tonnes. Through the LED bulb programme, annual CO2 emissions were reduced by almost 39 million tonnes.

These actions led to a 21% decrease in the nation's emission intensity between 2005 and 2014. India is apparently the only G-20 nation to have accomplished its promised goals for lowering emissions in accordance with the Paris Agreement. The National Solar Mission, LiFE project, National Hydrogen Mission, and the Faster Adoption of Manufacturing of Electric Vehicles (FAME) programme are a few examples of the country's cutting-edge strategy for assisting the switch to renewable energy.

Glasgow served as the site of the 26th Conference of Parties (CoP26) to the United Nations Framework Convention on Climate Change. In order to help the world move closer to the goal of limiting global warming to 1.5 degrees Celsius, Indian Prime Minister Shri Narendra Modi submitted a five-point plan for India on November 1, 2021, the first day of the international climate summit.

The prime minister referred to his plan as "Panchamrita," which is Sanskrit for "the five ambrosia." A traditional way of combining five natural foods; milk, ghee, curd, honey, and jaggery.

The five components of the 'Panchamrita' promises are:

1) India will enhance its renewable and green energy capacity to 500 GW by 2030
2) By 2030 India will meet at least half of its energy requirements by green and renewable energy
3) The projected carbon emissions in the country will be reduced by one billion tonnes by 2030
4) The country will achieve a reduction of 45 per cent in the carbon emissions of its economy by 2030 as compared to the 2005 levels
5) India will achieve net zero by 2070

II. Greening of Indian Power Sector

India's climate and geographical diversity present numerous prospects for successfully executing the switch to green energy. India has a solar energy potential of over 750 GW. On the other hand, the potential for small hydropower is 211 GW, and the total potential for wind power is close to 690 GW. India's utilisation of renewable energy sources has increased significantly over the last ten years. These sources made up about 10% of the total grid capacity in 2010. In 2022, this percentage rose to above 28%. In fact, for the first time in 2018, the overall annual addition of RE sources exceeded the total annual addition of coal. In 2015, the Indian government set the target of 175 GW of RE capacity by 2022. As of June 30, 2022, the installed RE capacity on the Indian grid had reached 114 GW. About 161 GW of total capacity is based on non-fossil fuels.

The growth of solar energy in the Indian power sector surged 5700 times between 2010 and 2022, according to an analysis of the data. The total amount of solar capacity built in India increased from 10 MW in 2010 to 57.7 GW in June 2022. Currently, solar accounts for 51% of all RE sources. The majority of this growth occurred in the last seven years. Over the past eight years, solar capacity has expanded from about 2.6 GW to more than 57 GW. One of the key factors influencing the rise of solar energy is the sharp decline in the cost of solar panels. Additionally, the economics of scale and vigorous government promotion have contributed to this enormous rise. In terms of total installed renewable energy capacity, India is now ranked fourth worldwide.

Through various initiatives and policies of the federal government, many states in the nation have adopted solar energy. Table 1 lists the top five states in the nation for renewable energy as of May 2022. Important state-level measures to increase the RE capacity further are also addressed.

Table 1: The top 5 states in terms of Renewable Tenergy as on May 2022

State Rank	State	Renewable Capacity	Remarks
1	Rajasthan	18707 MW	In just about 6 months moved from 4th to 1st rank. The concerns related to transmission infrastructure and distribution companies financial needs to be addressed.
2	Gujrat	17330 MW	State is doing well on solar but also planning to expand wind power capacity. A 30 GW renewable energy park is to be established.
3	Tamil Nadu	16604 MW	The state has been leading in terms of wind power capacity. An important development is the renewable power capacity of 20 GW with battery storage
4	Karnataka	15952 MW	Recently approved Renewable Energy policy for next 5 years. 10 GW capacity of Renewable Energy is to be added in next 5 years
5	Maharashtra	10695 MW	6.5 GW of Renewable Energy projects to be added in northern and western regions of the state

Pradhan Mantri Kisan Urja Suraksha evam Utthan Mahabhiyaan (PM KUSUM)

A significant portion of the Indian electricity load comes from agriculture. Therefore, if agriculture is not considered, the goal of decarbonizing the national electricity system cannot be achieved. Keeping this in mind the PM KUSUM scheme has been launched. By 2022, 25,750 MW of installed capacity will have been completed under this plan. The PM KUSUM system consists of three parts:

1. Ground Mounted Grid Connected Renewable Power Plants

Component A of the scheme is the installation of distributed ground-based, grid-connected renewable power plants. This program's goal is to encourage the building of renewable energy facilities with capacities ranging from 500 kW to 2 MW on underproductive agricultural land. The overall installed target capacity is 10 GW. The distribution

companies will purchase the electricity generated by the power plant developer.

The power regulatory body of the state where the project is installed will decide on the Feed in Tariff. A single farmer or a group of farmers can install the plant. The project may potentially be developed by larger panchayats or cooperative groupings.

2. Installation of 17.50 lakh standalone Solar Powered Agriculture Pumps

Installation of 17.50 lakh independent Solar Powered Agriculture Pumps is part of the PM KUSUM scheme's component B. A pump can have a maximum horsepower rating of 7.5 HP. In the 30-30-40 programme, the farmer will receive financial assistance for the pump installation. 30 percent of the benchmark cost or tender cost of the pump will be supported by the central government. The state government will contribute 30% toward the cost as a subsidy, leaving the farmer responsible for the remaining 40%. Only in the North Eastern States, Sikkim, Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Lakshadweep, and the Andaman & Nicobar Islands would the farmer be responsible for paying 20% of the total. The central support will rise to 50% for these states.

3. Solarisation of 10 Lakh Grid-connected Agriculture Pumps

The goal of the scheme's C component is to solarize 10 lakh grid-connected agricultural pumps. The maximum pump power in this component is similarly 7.5 HP. The pump will be powered by the electricity produced by the solar PV panels. However, the farmer will also have the advantage of sending the extra production to the grid.

This scheme's financial support follows the same 30-30-40 paradigm as it does for component B. The financial support model for the states in the special category, as indicated in component B, shall be 50-30-20.

Residential Rooftop Solar PV

More than 20% of India's total electricity demand, according to estimates, comes from the residential sector. The market for residential rooftop solar PV has lagged behind large ground-mounted solar farms while having tremendous potential. This is also supported by the data. As of February 2022, just about 6 GW of the nation's approximately 50 GW of solar PV installations were placed on residential rooftops. Despite this, the residential sector has a significant amount of untapped energy and might use more than the 1.3 PWh of electricity it currently consumes annually.

To further promote the adoption of residential rooftop solar PV, the government has started phase II of its Grid Connected Solar Rooftop Program. As part of this scheme, rooftop solar arrays with a 40 GW capacity are to be erected by 2022. In accordance with this programme, central financial assistance is also provided, but only if the project makes use of domestically produced solar modules and cells. For the initial 4 GW capacity, residential users are also given some financial assistance.

Battery Storage

Major green energy sources such as solar and wind are erratic in nature because the sun doesn't always shine and the wind doesn't constantly blow. There are worries due to this changeable nature as the installation of these plants integrated with the grid is rising dramatically. For instance, there will be a dramatic load ramp in the evening when the grid is feeding a lot of load during the day. Additionally, there is a significant fluctuation in temperature across the majority of a country like India. The load exhibits significant seasonal change as a result. The variability with these variable sources affects both the source and the load. Bulk storage is going to be quite significant in this situation. Bulk storage at the grid level allows for the storage of extra electricity for usage during periods of low generation.

The grid operators face a significant task when it comes to reducing renewable energy. The electricity generated from these sustainable sources should be the network's first priority supply due to its lower cost. The operators are frequently compelled to reduce the output of these renewable energy facilities due to the limited flexibility of traditional generation systems. Battery storage systems at the grid level can solve this issue. The surplus energy could be kept in the batteries as opposed to being reduced from low cost and green electricity.

The type of storage that the future grid will need can only be provided by battery-based systems. The greatest alternative for this has come to be Lithium-Ion. In actuality, lithium-ion batteries account for more than 90% of all installed big storage. Over the past ten years, the cost of these batteries has decreased by more than 80%. This is anticipated to be the new

power grid's next major development. The installed capacity of bulk storage batteries has significantly increased as a result. The total installed capacity of these batteries was 10 GWh as of the end of 2017.

By 2030, India will have 27GW/108 GWh (four-hour storage of grid level BESS) installed capacity. In this direction, the first pilot project for the installation of 1000 MWh of battery storage has already been put out to bid.

Small scale batteries put at the customer premises are as as significant as grid-level storage. As was already indicated, these batteries allow for the efficient exploitation of tiny rooftop solar plants and provide consumer independence. These batteries are crucial for the utility as well because they help with demand response programmes and tend to lower peak demand. In Germany, batteries are fitted with new rooftop systems in more than 60% of cases.

Battery Swapping Policy for Electric Vehicle

Electric car adoption is crucial to achieving the nation's aim of a green energy transition. However, there are significant obstacles in this sector, such as a lack of infrastructure for charging, expensive expenses, and lengthy refilling times. The battery switching system may be one answer to several of these problems. The administration stated its intentions to implement such a programme in the nation in the budget for 2022–2023 Based on this, the NITI Ayog published a draught battery switching policy. The fundamental goal of the proposed policy is to reduce EV idle time caused by low battery charge while using the least amount of money and space possible. With this new system, EV owners will be able to swap out their drained battery with a charged one at approved stations rather than having to wait for the vehicle to be charged at a charging station. In the initial phase, the policy must be put into effect in all major cities with a population of more than 4 million. The second phase of the programme is expected to reach all major cities with a population of more than 0.5 million.

Circular Economy for Green Energy Transition

The basic idea behind implementing a circular economy is to reduce waste by making the most of resources, making goods durable, and effective implementation of their recycling. The transition to green energy in India depends on utilization of solar panels and batteries which are mafde of precious as well as potentially harmful elements for the environment. The implementation of circular economy, therefore, is the need of hour. The basic elements of circular economy and how the same can be implemented in green energy transition are discussed in the following sections.

Recycling

The fundamental concept for effective transition to green energy with circular economy is recycling and reusing. Recycling helps in eliminating waste and ensures continual use of resources. India at present don't have a policy on management of PV waste and recycling at the end of life. However, the successful experience of Europe with Extended Producer Responsibility (EPR) framework can serve as an effective guideline. Extended Producer Responsibility (EPR) pushes the manufacturers to factor in environmental costs as part of their project planning – both technical and financial.

The exponential rise of solar PV plants as a green source of electricity is a major boost to the decarbonisation of the electric energy system. But one important concern, particularly from the point of view of climate, is the imminent challenge of disposal of solar PV panels once they complete their life. Although the installation of the solar PV plants on a large scale is a recent development and the useful life of these panels is high, this problem will come up in a big way only after 15-20 years. But still considering the level of challenge, it needs to be planned and implemented at the earliest. According to the International Renewable Energy Agency, India alone is expected to generate about 0.5 million metric tonnes (mmt) of solar PV waste by 2030. Considering the revised ambitious new target of 500GW by 2030, the amount of solar waste generated can be 4.5 to 7.5 million tonnes by 2050.

The solar panel is an essential source for, in the spirit of sustainable development, reuse and recycle of the material involved. The bulk of solar PV modules used are of crystalline silicon type. These modules are made of glass and aluminium. Silicon metal solar cells, copper connectors, silver and other metals like tin and lead are also part of the module.

From 1 MWp of solar plant we can recover approximately 70 tonnes of glass, 56 tonnes of steel, 47 tonnes of concrete, 19 tonnes of aluminium, 7 tonnes of silicon and copper, and 6 tonnes of plastic. A sustainable approach is when about 50-70% of the recycled material is reused.

In India also, in view of the exponential growth of solar PV installations, handling of PV waste is an important concern. Solar Waste Action Plan (SWAP), in this regard, is an important initiative in the country. A pilot project, under SWAP initiative has already been completed.

Under this project a capacity of processing 2.5 tonnes of solar PV waste per day was started at Gummudipoondi, Tamil Nadu in September 2020. The plant uses the mechanical crushing method for disposal. It is planned to increase the capacity to over 200 tonnes of waste per day. The total recovery is also planned to be increased from the present 60-80 percent to 95%.

Based on the experience of this project, one of the major challenges identified is bringing the panel to the waste disposal site. This responsibility may be fixed on the developer. But considering the long life of the panel, its implementation will be a challenge. The developer, moreover, can include the cost in the price of the panel itself which will discourage the consumers. In view of these challenges the use of mobile processors of PV waste is also being discussed and explored.

The transition to green energy is leading to exponential demand for vital minerals like lithium, cobalt, and rare earths. Some critical metals, like lithium, might have growth rates of over 40 times, and nickel and cobalt demand could increase by more than 20 times. If implemented successfully the circular economy can reduce reliance on mining and secure longer-term usage of these material.

Utilising circular, low-carbon materials

An important aspect of decarbonisation is the technology/material used should not only be carbon emission free but the emissions involved in its manufacturing should also be minimum. Accordingto a World Economic Forum report, the materials needed to make automobiles might account for 60% of all lifetime emissions by 2040, compared to 18% in 2020, when most cars are expected to be electric.

The emissions produced by the global production of all materials have been on a rapidly rising trend. According to a recent UNEP analysis, the emissions involved have increased from 5 billion tonnes of carbon dioxide equivalent in 1995 to over 11 billion tonnes in 2015, or about a fifth of all emissions of greenhouse gases. Circular economy shall be helpful in reducing these emissions also. For example, the emissions generated when producing aluminium using recycle is about 95 % less than the emissions produced when getting it from original sources.

Integrating Circularity in the System

The implementation of circular economy should be an integral part of the system and it must be taken into account during the planning phase of an energy transition to be truly sustainable. It is important to consider how the solar PV panels and batteries being installed on a huge scale can be made to last longer, disassemble easily, and be recycled. If the panels which shall be removed after 25 years of service can be deployed again with some refurbishments, it'll be a great boost to the sustainability efforts. Life extension is a crucial aspect of circular design. We ought to create enduring goods that can be utilised for different purposes. Utilized automobile batteries still have between 60 and 80 percent of their original capacity, which means they can be used successfully in other applications that call for less performance, including stationary energy storage to support the grid.

II. Conclusion

The transition to green energy in India is a massive development. The target declared at CO-26 of installation of 500GW renewable energy plants by 2030 combined with large scale implementation of electric mobility means exponential increase in the use of precious elements and material potentially harmful for the environment. The implementation of circular economy in this scenario is a primary requirement for making this transition green as well as sustainable. This paper examined these aspects and presented that the three-pronged approach of recycle, reuse and integration of aspects of circular economy in the design phase has to be pursued to achieve this sustainable transition.

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