Recent Initiatives on Fossil Fuel Transition towards Renewable Energy for Combating Climate Change and a Net-Zero Energy Future

Rajeev Gyani and Shyam Singh Chandel*

Solar Photovoltaic Research Group, Centre of Excellence in Energy Science and Technology, Shoolini University, Solan-173212 Himachal Pradesh, India

Abstract: This study presents the recent trends in the transition from fossil fuels towards renewable energy for combating climate change and achieving a net-zero energy target by 2030 as per United Nations Sustainable Development Goal-7 (Energy for All). However, the Net Zero target is difficult to achieve unless effective energy conservation and energy efficiency policies, regulations, and financial investment, are not initiated along with the major energy transition to renewable energy. Therefore, the study's objective is to present the current status of initiatives by different countries including India to address this problem as per the recommendations of various Conference of Parties including COP-29. The case study of India shows that enhanced energy efficiency, energy conservation, effective solar energy policies, and regulations for high energy-consuming sectors like industry, agriculture, buildings, domestic and awareness among society are important for achieving realistic targets. The Chhattisgarh State study identifies the high energy-consuming sectors, leading to a 2.7 million kWh reduction in energy consumption in the past two decades through various initiatives. These measures are leading India towards an efficient Net-Zero energy transition in a realistic way. The study results are of importance for follow-up action in developing and least-developed countries worldwide.

Keywords*:* Carbon emission, Climate change, Cop29, Energy transition, Net zero energy, Sustainable development goals.

1. INTRODUCTION

The development of a society predominantly depends on the development of the energy sector in a country. The power generation from the burning of fossil fuels has brought a situation that is now restricted under the net zero target of UN Sustainable Development Goal (SDG)-7 and climate change mitigation protocols. The ***"Net Zero Energy"*** status is to achieve a stage when the power consumed by the end user is more from renewable energy sources than the energy from fossil-fuel sources and the ***"Energy transition"*** is the process of shifting power generation from fossil fuels to power generation through renewable energy sources to combat carbon emissions. However, to achieve the net zero status, the propagation of renewable energy-based projects needs to be prioritized. But this alone will not be sufficient to achieve net zero by 2030 for which effective energy conservation and energy efficiency initiatives must be parallelly implemented in the major energy-consuming sectors namely industries, buildings, agriculture, and transportation. Unless this transition happens along with energy efficiency measures, the net zero target cannot be achieved by 2030. Therefore, the objective of the study is to address this problem, present the current status of various initiatives taken by different countries to date, and identify limitations and corrective measures required. In this study, the present status of efforts of different countries in the transition from fossil fuels towards renewable energy for combating climate change and toward a net-zero energy future, are presented. An overview of various Conference of Parties (COPs) including COP-29 and follow-up action taken by India effectively to move towards a Net Zero Energy future are elaborated. The depletion of fossil fuels has also become a challenge besides the ever-increasing cost of fossil fuels. This enhanced the process of energy transition from fossil fuel to non-fossil fuels and the utilization of renewable energy sources for power generation. Figure **1** highlights the energy transitions from traditional biomass in 1800 till the 1950s when the focus was on renewable energy which was further elevated in 2020 [1]. The global primary energy consumption using coal and oil followed by renewable energy sources, is shown in Figure **2** [1].

The historical perspective shows that energy transition takes place with time based on technology development, finances, and scaling-up efforts. In 2023, the fossil fuel footprint was about 84 %. However, the world is now committed to opting for power generation through non-fossil sources which can only occur in a

*Address correspondence to this author at the Solar Photovoltaic Research Group, Centre of Excellence in Energy Science and Technology, Shoolini University, Solan-173212 Himachal Pradesh, India;
E-mail: chandel_shyam@yahoo.com; sschandel2013@gmail.com

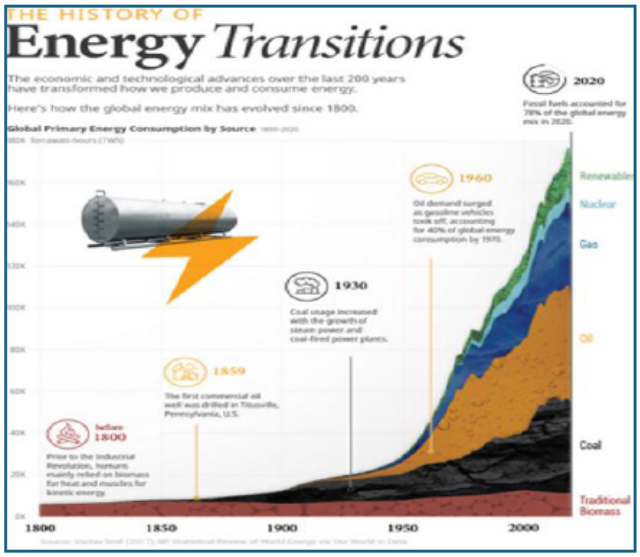

Figure 1: Energy transition-history [1].

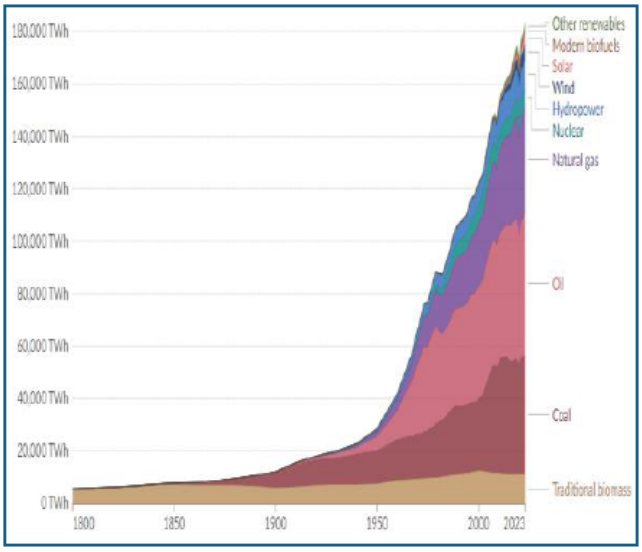

Figure 2: Global primary energy consumption [1].

phased manner. The percentage use of different fuel mixes from traditional biomass to coal, oil, gas, and renewable energy to nuclear power in the overall Energy Mix (EM) during the period 1800 to 2020, are shown in Tables **1**, **2**, and **3** respectively [1].

Table 1: Fuel Percentage Mix during 1800-1948 [1]

Year	Traditional Biomass % of EM	Coal % of EM
1800	98.3%	1.7%
1820	97.6%	2.4%
1840	95.1%	4.9%
1860	86.8%	13.3%
1880	73.0%	26.7%
1900	50.4%	47.2%
1920	38.4%	54.4%
1940	31.6%	50.7%

Table 2: Fuel Percentage Mix during 1950-2000 [1]

Year	Coal % of EM	Oil % of EM	Natural Gas % of EM
1950	44.2%	19.1%	7.3%
1960	37.0%	26.6%	10.7%
1970	25.7%	40.2%	14.5%
1980	23.8%	40.6%	16.3%
1990	24.4%	35.5%	18.4%
2000	22.5%	35.1%	19.7%

Climate change came to focus during COP3 globally after the Kyoto Protocol was adopted in December 1997. However, this energy transition faced numerous technological challenges, and efficiency issues to make it financially viable and efficient. Besides, the use of coal and oil cannot be completely avoided given the various energy needs of a country although the current status of carbon emission prohibits and restricts the combustion of fossil fuels considering

Table 3: Percentage Mix of Fuels during 2000-2020 [1]

Year	Traditional Biomass	Renewables	Fossil Fuel	Nuclear Power
2000	10.2%	6.8%	77.3%	5.9%
2005	8.7%	6.5%	79.4%	5.4%
2010	7.7%	7.7%	79.9%	4.7%
2015	6.9%	9.2%	79.9%	4.0%
2020	6.7%	11.2%	78.0%	4.0%

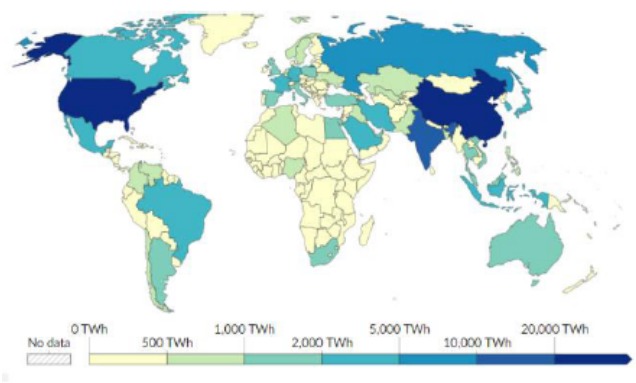

Figure 3: Primary energy consumption, 2023 [2].

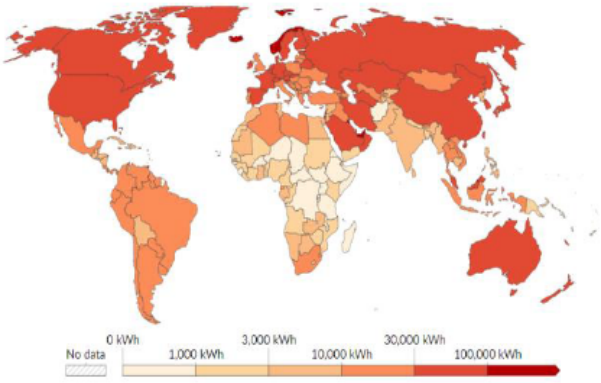

Figure 4: Energy use per person, 2023 [2].

the Paris Agreement of 30th Nov 2015 during COP21. The global primary energy consumption and energy use per person of the world are shown in Figures **3** and **4** [2].

It is clear from these figures that primary energy consumption is found to be low in most countries during 2023 whereas the energy use per person is more than 3000kWh in most of the countries and more than 10000kWh in developing and developed countries.

As compared to India the other prominent developing and developed countries' per capita primary energy consumption by sources in 2023 [2] is shown in the Figure **5**.

As of 2023 India's per capita primary energy consumption is much less than other developed and developing countries and also less than the world's average energy consumption. The population of India plays a critical factor in this analysis. Hence, the efforts for energy transition have a wide scope. The electricity generation in India has shown exponential growth from 2000 onwards with steep growth after 2020 (Figure **6**). The per capita electricity rose from about 200kWh to more than 1400kWh with high demand after 2020 (Figure **7**). A reduction is observed during 2019 and 2020 due to COVID-19. The energy use per person was about 1000kWh in 1965, which increased to about 8000kWh in 2023 (Figure **8**).

This indicates to achieve the net zero by 2070; further focus must be on the energy transition and enhancement of energy efficiency measures in the country. The usage of different fuels, power generation capacity, and the pattern of electricity usage are critical factors in defining the protocols for power generation and its utilization.

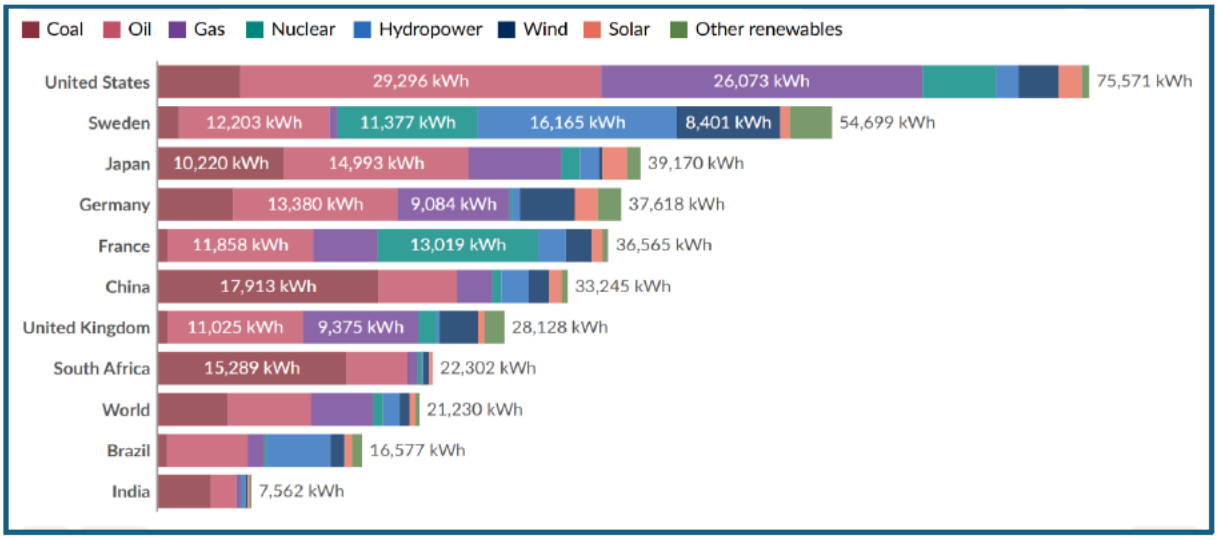

Figure 5: Per Capita primary energy consumption by source by developed and developing countries [2].

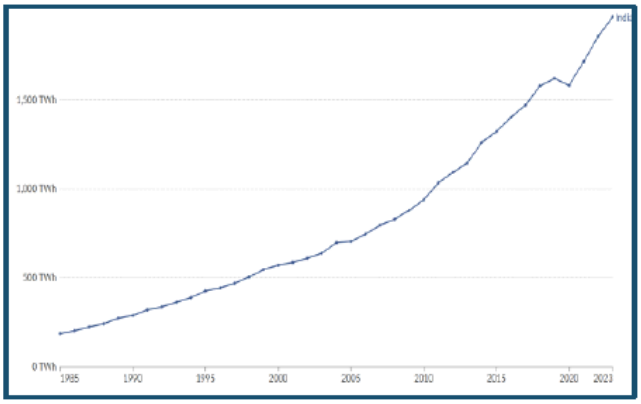

Figure 6: Electricity generation (TW) [2].

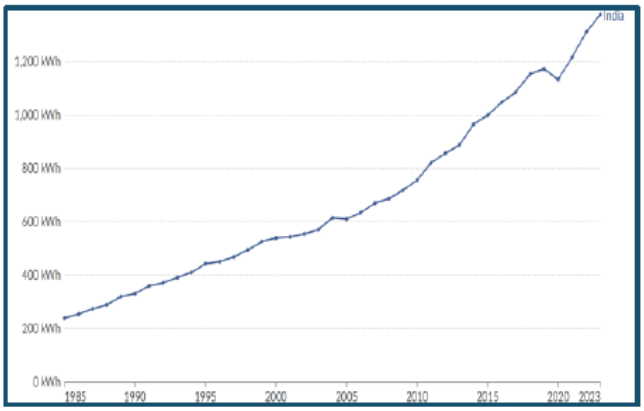

Figure 7: Electricity generation /capita (kWh) [2].

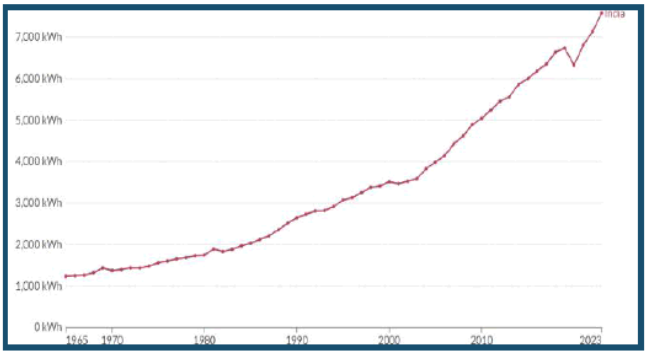

Figure 8: Energy use per kWh in India during 1965-2023 [2].

The paper is organized as follows: In section-2 an overview of the global initiatives on climate action and transition to renewable energy followed by action in India is presented in section-3. A Case Study of the transition to energy in the Chhattisgarh State is presented in section 4. The discussion on achieving a Net-Zero future is presented in section 5 followed by the conclusion in section 6.

2. OVERVIEW OF THE GLOBAL INITIATIVES ON CLIMATE ACTION AND TRANSITION TO RENEWABLE ENERGY THROUGH THE CONFERENCE OF PARTIES (COPS)

The global initiatives on Climate Change are taken through several Conference of the Parties (COP), which is the top decision-making body of the United Nations Framework Convention on Climate Change (UNFCCC). which meets every year in one of its member countries. A key task for the COP is to review the national communications and emission inventories submitted by Parties (Countries). Based on this information, the COP assesses the effects of the measures taken by the Parties and the progress made in achieving the ultimate objective of the Convention. The first COP meeting was held in Berlin, Germany in March 1995. The COP Presidency rotates among five recognized UN regions – Africa, Latin America and the Caribbean, Central and Eastern Europe and Western Europe, and Others – there is a tendency for the venue of the COP to also shift among these groups. In COP 21 which was held in Paris in Nov 2015, the Paris Agreement [3] was signed and is a legally binding international treaty on climate change. It was adopted by 196 Countries at the UN Climate Change Conference (COP21) in Paris, France on 12 December 2015. It entered into force on 4 November 2016. The major goal of this agreement is to hold the increase in the global average temperature to well below 2˚C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5˚C above pre-industrial levels [3]. The UN's Intergovernmental Panel on Climate Change indicates that crossing the 1.5˚C threshold risks unleashing far more severe climate change impacts, including more frequent and severe droughts, heatwaves, and rainfall. The COP3 held in Kyoto, Japan in December 1997, adopted an international treaty known as "Kyoto Protocol" on 11 December 1997 [4]. Under this treaty, the UN Member

countries had to commit to reducing greenhouse gas emissions, based on the scientific consensus that global warming is occurring, and human-made CO_2 emissions are driving it. The effective period of the Kyoto Protocol was till 31st December 2020 (with an amendment in 2012 in Doha, Qatar).

The Outcome of the Recent COP 29

Nearly 200 countries participated in the COP 29 summit held in Baku, Azerbaijan, from November 11 to 22, 2024, and reached a breakthrough agreement on a new financial goal to help countries protect their people and economies against climate disasters and share the benefits of the clean energy boom. The main achievement of COP29 on climate finance, is as follows:

- Triple finance to developing countries, from the previous goal of USD 100 billion annually to US$ 300 billion annually by 2035.
- Secure efforts to scale up finance of US$ 1.3 trillion per year by 2035 to developing countries, from public and private sources.

This is expected to keep the clean energy boom growing in all countries. The new finance goal at COP29 builds on global climate action at COP27, which agreed on the historic Loss and Damage Fund, and COP28, which focussed on the agreement to transition from fossil fuels in energy systems and triple renewable energy and boost climate resilience. COP29 [5] also reached an agreement on carbon markets – which several previous COPs could not achieve.

These agreements will help countries deliver their climate plans more quickly and make faster progress in reducing global emissions by half during this decade. The governments of 61 supporting countries, representing,80% of global emissions, have agreed to a series of actions to cut carbon emissions during the coming year. COP29 also agreed to a collective goal of deploying 1500 GW of energy storage globally by 2030. The global community under the Utilities for Net Zero Alliance (UNEZA) established at COP28 under the guidance of the International Renewable Energy Agency (IRENA) and the UN Climate Change High-Level Champions commitment to annual grids and renewables investment of more than 117 billion US$. Around 48% of the planned and committed investment will go into grid infrastructure, underpinning the ambitions outlined by governments to add or refurbish 80 million km of grids by 2040

This Alliance consists of leading global utilities and power companies that commit to the development of grids that are ready for renewable energy, promote clean energy solutions, and advance electrification efforts. UNEZA operates under the guidance of the International Renewable Energy Agency (IRENA) and the UN Climate Change High-Level Champions, ensuring a focused and strategic approach to achieving a sustainable energy future.

The developed nations have agreed to provide a climate-finance goal of $ 300 billion per year to developing countries by 2035 to support their efforts to combat climate change. There was an agreement on the remaining sections of Article 6 on carbon markets. Thus, all elements of the Paris Agreement have been finalized 10 years after it was signed.

3. FOLLOW-UP ON CLIMATE CHANGE AND TRANSITION TOWARDS RENEWABLE ENERGY IN INDIA

India committed to take measures to combat climate change and signed the Kyoto Protocol in August 2002 by committing to reduce CO_2 emissions by 5.2% of the 1990 level during 2008-2012. Later India also ratified the amendment of the Kyoto Protocol on 8th August 2017. After the Kyoto Protocol, the Paris Agreement was drafted and proposed in COP21 which was held in Paris, France in November 2015. India also ratified this agreement on 22nd April 2016. The Paris Agreement was drafted to substantially reduce global greenhouse emissions recognizing that this would significantly reduce the risks and impacts of climate change. India adopted and updated its Nationally Determined Commitments (NDC) which targets to reduce the emissions intensity of its GDP by 33 to 35 % by 2030 from the 2005 level and to achieve about 40% cumulative installed power generation capacity from non-fossil fuel-based energy resources by 2030 [5]. In the COP26, held in Glasglow, the United Kingdom in October-November 2021, India committed to reducing the Emissions Intensity of its GDP by 45% by 2030, from the 2005 level [6]: achieving about 50% cumulative electric power installed capacity from no-fossil fuel-based energy resources by 2030, through transfer of technology and low-cost international finance from Green Climate Fund: and further propagate a healthy and sustainable way of living based on traditions, conservation and through a mass

movement for "LIFE' – 'Lifestyle for Environment' for combating climate change [7].

India's long-term goal is to achieve net zero by 2070, for which a 'Long-term Low Carbon Development Strategy' document [8] has been prepared and submitted to UNFCCC in November 2022 [9]. India plans to achieve the COP commitments through measures on access to energy, energy security, and energy transition. As per the document submitted to UNFCCC [9] following are the strategies committed by India:

- Expansion of renewables and strengthening the grid
- Exploration of low-carbon technologies
- Promoting demand-side management
- Using the fossil fuels resources rationally
- Fuel efficiency encouragement
- Transition to cleaner fuels in a phased manner
- Shifting to public and low-pollution modes of transport
- Promotion of measures of resource efficiency within urban planning guidelines, policies, and bylaws
- Promoting engineering solutions related to Carbon dioxide removal

3.1. Measures for Transition towards Renewable Energy in India

As per the commitment, 50% of cumulative electric power installed capacity must be from no-fossil-based energy resources and to work on demand side management for efficient utilization of power.

Accordingly, carbon emissions: can be effectively reduced by the following measures:

- Shifting power generation from fossil fuels to power generation through renewable energy sources like solar, wind, tidal, biomass, geothermal, hydro, hydrogen, etc.
- Reducing power consumption by using energy-efficient technologies.

The Ministry of New and Renewable Energy (MNRE) government of India. already launched two focused missions in 2010 under the climate change mitigation action plan:

- Jawahar Lal Nehru National Solar Mission (JLNNSM)

  This mission was initiated through the state governments to promote solar power in India. The initial target was 20GW which was enhanced to achieve 500 GW by 2030 out of which 212 GW India has already been achieved by 2024 and is on track to exceed the 2030 target.

- National Mission for Enhanced Energy Efficiency (NMEEE)

  This mission aims to strengthen the energy efficiency market through the implementation of innovative business models in the energy efficiency sector. It has been envisaged that upon successful execution of the mission, the expected fuel savings will be 23 million tons per year and the greenhouse gas emissions would reduce to the tune of 98.55 million tons per year.

Based on the above two initiatives, the reduction in carbon emissions has been substantial in combating climate change and fulfilling the commitments India made during COP 26. The conservation and efficient measures of electricity consumption are important for the conservation of generated power.

In India, the Energy Conservation Act 2001 [10] initiated various energy conservation and energy efficiency practices in major power-consuming sectors like industries, agriculture, municipalities, and buildings.

For the implementation of the energy efficiency measures, a Bureau of Energy Efficiency (BEE) was established by the government of India on 1st March 2002 under the provisions mentioned in the Energy Conservation Act, 2001.

3.2. Need for Climate Change Education and Awareness

Without regular outreach and awareness about climate change and its mitigation, it is not possible to create a platform where the acceptability of the change is a common consensus. The capacity building and awareness campaign is a regular activity that takes place in most of the States with the assistance of BEE

and the State Government. All the possible stakeholders in the journey of the energy transition with the motive to achieve a net zero state include policymakers, program implementors, consumers, manufacturers, service providers, the public, and government officials. All these stakeholders were connected through seminars, conferences, exhibitions, capacity-building activities, etc. positively changing the mindset and acceptability of change collectively.

3.3. Review of Research Studies on Climate Change

A review of studies on climate change has been conducted by Chandel *et al.* (2016) [11] which is an overview of the initiatives in the renewable energy sector under the national action plan on climate change in India which mentions that India requires serious efforts to utilize renewable energy sources to reduce carbon emissions. Gyani and Chandel (2024) [12] in their study have highlighted a case study of the development of energy efficiency management for decentralized solar mini-grid to conclude that efficiency plays an important role in power generation and consumption. A study by Chandel *et al.* (2023) [13] reviews deep learning techniques for power generation prediction of industrial solar photovoltaic plants. Forecasting solar generation is important for the sustainability of grid power and also for achieving the SDGs by 2030. Thakur and Chandel (2013) [14], Tajjour *et al.* [15], and Garni *et al.* [16] have analyzed maximizing the solar gain and power generation enhancement of grid-connected solar power plant highlighting the need to optimize the designing and operation process.

4. TRANSITION TOWARDS RENEWABLE ENERGY IN THE CHHATTISGARH STATE OF INDIA- A CASE STUDY

Chhattisgarh is a centrally located state of India constituted in November 2000. The state has a large number of coal, iron, and aluminum mines due to which there are many steel industries and power generation projects. The total installed capacity of power utilities in Chhattisgarh State is shown in Table **4** [17] as follows:

As per Table **4**, the total installed capacity of power utilities in Chhattisgarh State is 14101.65MW out of which 12221.85MW (86.67%) is coal-based power generation, 233 MW (1.65%) from hydro and 1555.01MW (11.03%) from renewable energy. This indicates that a huge exercise must be planned to have at least 50% RE mix in the total power generation, which is currently 12.68%. The measures to achieve this target are being taken and under implementation through the installation of megawatt-sized solar power plants and the implementation of energy efficiency measures in the four sectors: industry, building, agriculture, and municipalities. The implementation of programs of the Bureau of Energy Efficiency has been undertaken by the Chhattisgarh State Renewable Energy Development Agency (CREDA), Department of Energy, Government of Chhattisgarh [18]. Under the Perform Achieve and Trade (PAT) program there are 108 designated consumers (industries with power of more than the threshold limit of annual power consumption {measured in million tons of oil equivalent (MTOE) notified by the Government of India. The target is set for every designated consumer (DC) to reduce the specific energy consumption (SEC) of their product, derived through a baseline audit of their industry. Every DC is provided with a three-year duration to perform and make efforts to reduce or at least maintain the

Table 4: Installed Capacity (MW) of Power Utilities in Chhattisgarh State (as of 29.02.24)

State	Ownership / Sector	Mode Wise Breakup								
		Thermal					Renewable			Total
		Coal	Lignite	Gas	Diesel	Total	Hydro	RES*	Total	
Chhattisgarh	State	1840	0	0	0	1840	120	11	131	1971
	Private	7667	0	0	0	7667	0	1544	1544	9211
	Central	2714	0	0	0	2714	113	0	113	2919
	Total	**25404**	**0**	**0**	**0**	**25404**	**233**	**1555**	**1788**	**14101**

SEC. In case they reduce the targeted SEC they are awarded Energy Saving Certificates (ESCerts), if their SEC after the lapse of the third year is more than the targeted SEC then they will be penalized while if they can maintain the targeted SEC as it is, then there is neither penalty nor any incentive. The Sector-wise DCs in PAT Cycle I to VIII is shown in Table **5** [19].

This cycle of three years carries on repeating with new targets of SEC through set norms. PAT program has enhanced the technical efficiency of the industrial sector thereby reducing the consumption of fossil fuel-based power and also promoting renewable energy usage in industries.

In Chhattisgarh, there were 44 DCs in PAT Cycle I (2012-13 to 2014-15) while the number of DCs in Cycle VIII (2023) increased to 102. Amongst these 102 DCs, 62.75 % are Iron & Steel Industries (64), 23.6% are Thermal Power Plants (24), and 9.8% are Cement Industries (10). This effort has made it possible to save 2.196 MTOE annually in Chhattisgarh. These measures have avoided about 1300MW capacity of power. At the National level, the energy saving is 22.75 MTOE which is about 2.56 % of India's total primary energy supply with an emission reduction of 3.49% of India's emissions, as mentioned in Figure **9**.

Agriculture is an important sector of the Indian economy as it contributes about 17% to the total GDP

Table5: Sector-wise DCs in PAT Cycle I to VIII [19]

Sector/No. of DCs	PAT Cycle I	PAT Cycle II	PAT Cycle III	PAT Cycle IV	PAT Cycle V	PAT Cycle VI	PAT Cycle VII	PAT Cycle VIII	Total Notified DCs
	April'12	April'16	April'17	April'18	April'19	April'20	April'22	April'23	
Aluminum	10	12	1	-	1	-	12	1	**14**
Cement	85	111	14	1	12	37	120	25	**200**
Chlor-Alkali	22	24	-	2	2	-	24	1	**29**
Fertilizer	29	37	-	-	-	-	0	-	**37**
Iron & Steel	67	71	29	35	23	5	134	66	**270**
Paper & Pulp	31	29	1	2	8	2	24	7	**55**
Textile	90	99	34	7	16	7	120	38	**206**
Thermal Power Plant	144	154	37	17	17	-	152	-	**239**
Refinery	-	18	-	-	-	20	0	-	**20**
Railways	-	22	-	-	-	-	26	-	**26**
DISCOMs	-	44	-	-	-	-	95	-	**96**
Petrochemical	-	-	-	8	-	-	0	-	**8**
Buildings	-	-	-	37	31	64	0	-	**133**
Total	**478**	**621**	**116**	**109**	**110**	**135**	**207**	**138**	**1333**

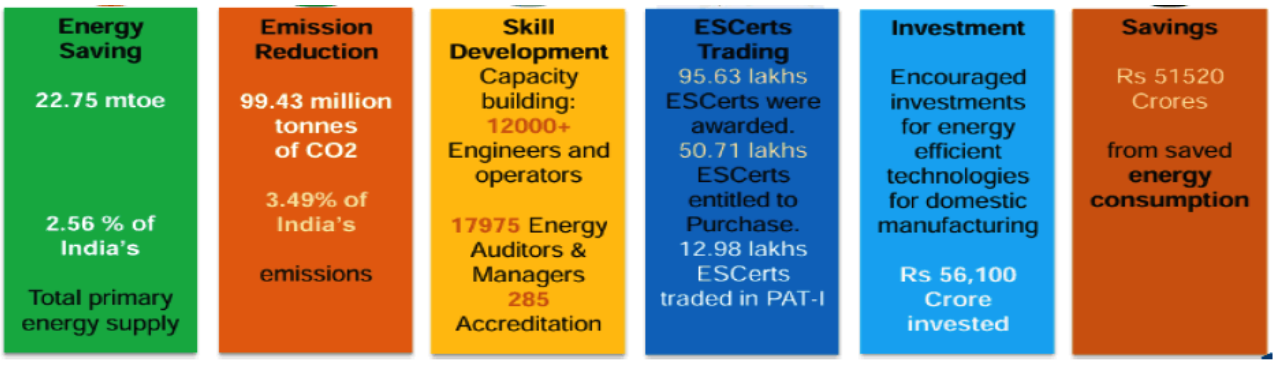

Figure 9: Energy Savings, Emission Reduction, Investment & Financial Savings till PAT II.

and provides employment to over 60% of the population. Agriculture demand-side management savings have been achieved by saving electricity in pumping units by replacing non-efficient pumps with energy-efficient pumps. As per the National AgDSM Dashboard of Energy Efficiency Services Limited (EESL) [20], 210.23 million units per year of savings have been achieved (http://agdsm.in/). Municipal demand-side management has reduced the consumption of electricity in community streetlights and community water supply systems by replacing energy-efficient electrical gadgets. The streetlight national programme of EESL indicates on their SLNP dashboard [21] that 8979.54 million units of energy is saved per year just by the installation of 13,369,541 Energy Efficient Streetlights in State and Gram Panchayat Projects, Individual Urban Local Bodies (ULB) Institutional projects and State Level projects. Out of these 381199 Streetlights are installed in Chhattisgarh State. The National Ujala Dashboard of EESL [22] mentions that through the installation of 36,86,98,663 LED Lamps, there have been energy savings of 47882 million units of energy per year. BEE also implements AgDSM and MuDSM through SDA [23] supporting farmers and municipalities to reduce electricity by applying energy-efficient measures in pumping systems and Streetlights. The commercial buildings sector is the most electricity-consuming in the building sector as they operate day and night. The commercial building sector in India is expanding rapidly at over 9% per year. It has been estimated that more than 50% of the building stock that will exist in the year 2030 is yet to come up in the country. To reduce energy consumption in buildings the government of India through BEE has launched Energy Conservation Building Code (ECBC) [24, 25]. ECBC provides guidelines to design and construct buildings in such a manner that their consumption is reduced by 25% for their lifetime. There are three levels of energy performance standards in the ECBC, *i.e*. ECBC, ECBC Plus and Super ECBC. The ECBC-compliant building has achieved about 25% savings, ECBC plus building 35% savings and compliance with super ECBC buildings are expected to show 50% or more energy savings as compared to conventional buildings. Recently shunya labelling [26] has also been initiated for Net Zero and Net Positive buildings.

BEE has also launched the Energy Conservation & Sustainable Building Code (ECSBC) which covers commercial as well as Office buildings [26]. Apart from ECBC, BEE has also initiated Eco Niwas Samhita (ENS) and has prepared to set minimum energy-efficient residential building norms. Out of the total electricity consumed in the building sector, about 75% is used in residential buildings. Thus, the energy efficiency measures in the building sector directly impact the reduction of carbon emissions. The reduction in power consumption and utilization of renewable energy in the building sector is an important energy transition towards a net zero future.

5. DISCUSSION ON THE CONVERGENCE OF DIFFERENT SECTORS FOR ACHIEVING A NET-ZERO FUTURE

The activities performed under energy efficiency and energy conservation are the effective measures for achieving the Net-Zero future. Enhancing the footprints of renewable energy in the overall power generation sector. Targeting renewable energy mix up to 50% of cumulative electric power installed capacity by 2030 is achievable by keeping solar energy-based power generation on a fast track in a phased manner. Developing manufacturing infrastructure for equipment required for installation of solar power projects, supporting policies and regulations, capacity building for availability to train manpower, and affordable financing and incentives are key factors that need to be in place to achieve the desired goal. The government of India through the Ministry of Power (MoP) and Ministry of New and Renewable Energy (MNRE) has amended the Energy Conservation Act 2001 and has also issued guidelines for the state governments to issue state-specific renewable energy and solar policies that attract investments in RE power generation sector with minimum capital available from the central and state governments. 28 States and Union Territories have announced RE/solar policies due to which RE-based power generation has exponentially increased in the last ten years. At the central government level, Solar Energy Corporation of India (SECI), Bureau of Energy Efficiency (BEE), and Energy Efficiency Services Limited (EESL) are three organizations that are focusing on supporting the State/UT governments to increase RE-based power generation capacity and apply energy efficiency measures through demand side management of existing and upcoming projects. Apart from Energy Conservation and efficiency activities, solarization

Remote un-electrification which avoids the laying of transmission lines for very smaller load is not viable as well as clean energy utilization. Out of 20126 census villages in Chhattisgarh State, 467 census remote

villages are electrified through solar mini-grids. Energy access to un-electrified habitations without using fossil fuel has additional assistance to carbon mitigation efforts.

6. CONCLUSION

The study presents an analysis of recent trends in the transition from fossil fuels towards renewable energy worldwide including India as per United Nations Sustainable Development Goal-7. for combating climate change and achieving a net-zero energy future. Based on the study results the following conclusions can be drawn:

1. The initiatives recommended for Net Zero transition by various UN COPs are being followed by a number of countries but much more needs to be done at the policy, regulation, and field implementation level to achieve the targets.

2. India has followed a systematic strategy as is evident from various measures taken in a sustainable manner which can be followed by other less developed countries.

3. India has been following measures and targets as recommended by different COPs to date through central and state governments as is evident from the case study of the Indian state of Chhattisgarh on energy transition from fossil fuels to renewable energy.

4. Further follow-up research, and effective monitoring of energy transition programs along with proposed financial aid to developing countries as per COP 29, are required for the enhanced energy transition to renewable energy and energy efficiency to achieve the Net-Zero goal.

DECLARATION OF CONFLICT OF INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

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