

Towards Achieving Net Zero Emissions in India by 2070



Akash Midha and Anuradha Tomar

Abstract Problem regarding climate is one of the biggest problems which we are facing at present. In 2015, 194 parties adopted the Paris Agreement to limit the warming of Earth's surface to not more than 1.5 °C and to achieve the net zero globe by 2050 which means cutting the emissions of greenhouse gases such as carbon dioxide and methane to zero. India has set the target to reduce the emission intensity by 45% by 2030 and to achieve the net zero emission by 2070. India ranks third in carbon emissions in the world. The total carbon dioxide emissions in India in 2021 were around 2.8 billion tonnes. In 2022, these emissions saw an increase by 6%. Net zero would be possible in India by promotion of more and more non-fossil fuel sources instead of burning fossil fuels like coal and oil for the production of electricity and also by increasing deployment and integration of renewable sources in the sector of electricity production and transportation along with increase in production of green hydrogen. 100% renewables pathway can represent the truly decarbonized energy system. Globally, solar PV is needed to provide almost 70% of all primary energy by 2050 which means the solar capacity of 57.6 TW by 2050, and in the case of India, it is estimated that India should have 5630 GW of solar PV to achieve the target of net zero by 2070. To meet the target of net zero, there is requirement of large investments and strong policy framework in the nation.

Keywords Carbon dioxide emissions · Net zero emissions · Climate change · 100% renewable · Green hydrogen

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1 Introduction

Problem regarding climate is one of the biggest problems which we are facing at present. Reduction of emission of greenhouse gases is the most appropriate approach which can limit the global warming [1, 2]. In 2021, the annual global carbon dioxide (CO₂) emissions were 37.12 billion tonnes and the cumulative emissions by the end of 2021 were 1.7 trillion tonnes. Cumulative emissions are the sum total of all emissions since 1750 [3–5]. Over 40% of CO₂ emissions in energy CO sector are from power sector for the purpose of generation of electricity by fossil fuels such as coal, oil and gas which is responsible for CO₂ emissions—the gas primarily responsible for trapping of heat in the Earth’s atmosphere which is known as greenhouse effect and therefore causing global warming [5]. The power sector is followed by the transportation sector, and it is responsible for 20% of CO₂ emissions in the atmosphere [6]. In 2021, India emitted 2.71 billion tonnes of CO₂ in the atmosphere and is the third-largest emitter of CO₂ in the world by volume. However, the per capita emissions of India are 1.93 tonnes which is much less if compared to other countries like USA, China and Australia [3].

Over the past two centuries, CO₂ concentration rose from 280 to more than 380 parts per million (ppm) if we consider the ppm by volume due to which the temperature of Earth’s surface has increased by 0.74 °C over the past century and if CO₂ gets emitted in the atmosphere without any control, then there could be rise of 3.4 °C by the end of the century [7]. In 2015, the Paris Agreement came into force which is a legally binding international treaty in which 194 parties (193 states plus the European Union) had joined it and concluded to limit the warming of Earth’s surface to not more than 1.5 °C and to achieve the net zero emissions of greenhouse gases (and carbon dioxide) by 2050 [8].

If we see in the context of India till September 2022, the share of fossil fuel-based power plants is 236.068 GW (57.9%) while the share of renewables including energy from hydropower is 164.930 GW (40.4%) in the total capacity of India which is around 407 GW [9]. India has set the target to achieve 50% of power from non-fossil fuels and to reduce the emission intensity by 45% before 2030. However, the target has been set by the Government of India to achieve net zero emission by 2070 which is late if compared to other countries of the world which corresponds to global warming of 2.0 °C above pre-industrial levels [10]. At present time, the carbon emissions of India are continuously increasing and it is forecasted that India’s carbon emissions would be at their peak during 2040–2045 before sliding downwards [11].

The contribution of the paper is that it discusses the different studies done by several organizations and authors and on the basis of which comparative analysis of the situation of India has been done with other countries to provide the pathway of net zero emissions in India by 2070.

The paper is organized with Sect. 2 covering summary of India power sector and explaining the installed generation capacity and percentage share of different renewable and non-renewable sources in the Indian power sector. Section 3 discusses the contribution of different power supply technologies in emissions of carbon dioxide.

Section 4 explains about India's share in global CO₂ emissions. Comparative analysis of CO₂ emissions of India has been done in Sect. 5 with other major markets of the world such as USA and China to have a better understanding of the roadmap of India towards net zero emissions. Section 6 explains the pathway to 100% renewables which can represent the truly decarbonized energy system. Section 7 discusses the investment required and cost to achieve the net zero emissions in India, and the last Sect. 8 concludes with various steps required to achieve the target of net zero emissions in India.

2 Indian Power Sector

The development of power sector is the most important factor to develop the Indian economy. There are six regional grids in India which are Northern Region (NR) grid, Southern Region (SR) grid, Eastern Region (ER) grid, Western Region (WR) grid and North-Eastern Region (NER) grid. These grids are synchronized at the same frequency.

Total net generation capacity of the Indian power system by September 2022 is 407.797 GW of which 236.086 GW is from fossil fuels, 164.930 GW is renewable including hydropower and 6.780 GW is obtained from nuclear sources as shown in Table 1 [9].

Table 1 Summary of Indian power system [9]

Category	Installed generation capacity (GW)	% of share in total
<i>Fossil fuels</i>		
Coal	204	50
Lignite	6.6	1.5
Natural gas	24.8	6.2
Diesel	0.5	0.1
Total fossil fuels	236	57.9
Hydropower	46.8	11.5
<i>Renewable</i>		
Solar	60.8	14.9
Wind	41.6	10.2
Cogen	10.2	2.5
Energy from waste	0.495	0.1
Hydropower (small)	4.9	1.2
Total renewable (including hydro)	164.9	40.4
Nuclear	6.8	1.7
Total installed capacity	407.7	100

3 Emissions of Carbon Dioxide from Power Supply Technologies

Electricity production is the main reason for emissions of carbon dioxide which accounts for more than forty per cent worldwide and is followed by the sector of transportation, industrial, residential and commercial. Traditional methods of electricity generation which are based on burning or combustion of fuels like coal, gas and diesel account for most of the CO₂ emissions. Burning or combustion of fuels also releases sulphur and nitrogen oxides which are primarily responsible for many environmental problems such as acid rain and also dangerous for human health causing various respiratory and heart diseases [7].

Nuclear power is a very good source to generate the low carbon electricity. Nuclear power has large density if compared with low carbon sources such as photovoltaics and wind. It has the power density of 4000 W/m³ while photovoltaics and wind have the power density of 4–10 W/m³ and 0.5–1.5 W/m³ [12]. The main problem behind nuclear power is that it is controversial in many countries and is considered dangerous due to its radioactive emissions.

Renewable energy sources are environment-friendly sources but the main problem with them is that they are not available everywhere like photovoltaics are limited to places having good irradiation intensities, wind energy is limited to places having constant unidirectional wind speed and hydropower energy is stuck to dams. Photovoltaic systems release very low direct carbon dioxide emissions. However, if we also consider the indirect emissions still the emissions released by photovoltaics system are only one-fourth of fossil fuel emissions. The emissions released by wind energy are also very low, and emissions released by hydroenergy are six times more than the total emissions by the wind systems. Electricity generation based on biomass is carbon-neutral [7, 12]. Figure 1 shows the CO₂ emissions from various primary energy sources [12].

4 Carbon Dioxide Emissions in India

Considering the total CO₂ emissions, India ranks third and is followed by China and USA, although the per capita emissions of India are much less if compared to global per capita emissions. The total carbon dioxide emissions in India in 2021 were around 2.8 billion tonnes. In 2022, these emissions saw an increase by 6%. Figure 2 shows the CO₂ emissions in India and annual share of India in global emissions from 2000 to 2021. Burning of coal is the major source of release of emissions of CO₂ which released 1.8 billion tonnes of carbon dioxide in the year 2021 accounting for almost 34% of total release followed by oil (622.15 million t), cement (149 million t), natural gas (133.45 million t) and flaring (2.77 million t) as shown in Fig. 3 [3].

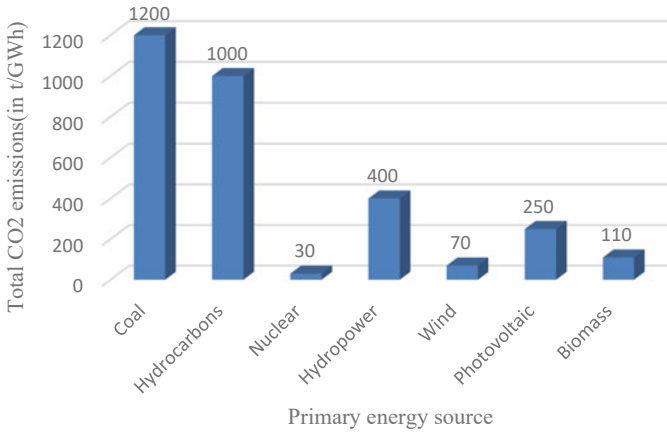


Fig. 1 CO₂ emissions from primary energy sources [12]

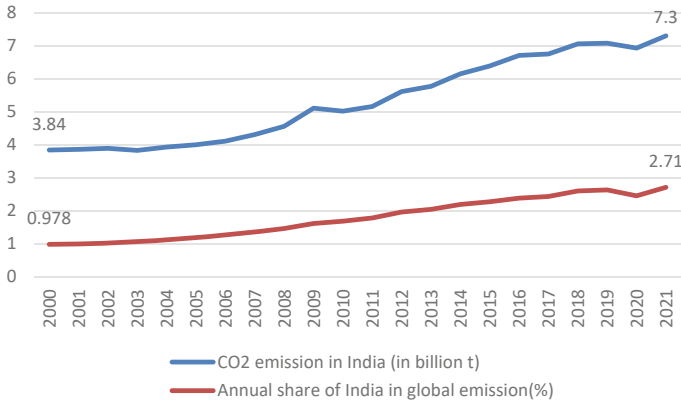


Fig. 2 CO₂ emissions in India (in billion tonnes) and annual share of India in global emissions (in %) [3]

5 Comparative Analysis of CO₂ Emissions of India with Other Major Markets

Considering the total CO₂ emissions, India ranks third and is followed by China and USA. Although the emissions released by India are much less and not comparable to that of the emissions released by China and USA. In 2021, India released 2.79 billion tonnes of carbon dioxide emissions which make the cumulative emissions of 57 billion tonnes while China and USA released 11.80 billion tonnes and 5.12 billion tonnes emissions, respectively. The global emissions in the year 2021 were 41 billion tonnes accounting for the cumulative emissions of 1.74 trillion tonnes by

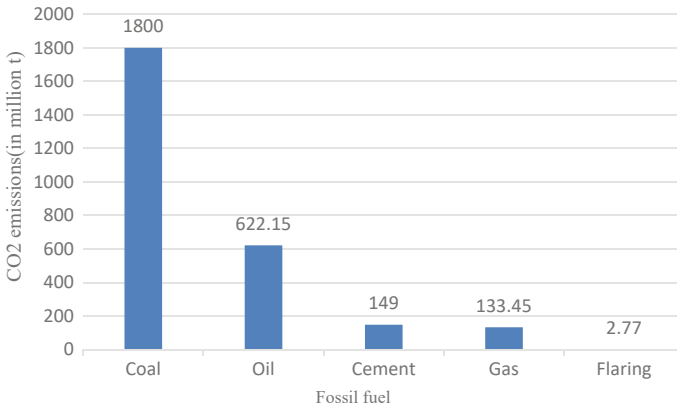


Fig. 3 CO₂ emissions in India from various fossil fuels [3]

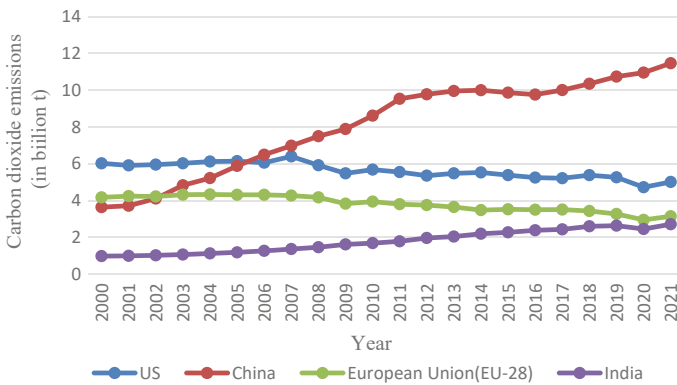


Fig. 4 CO₂ emissions (in bt) of major markets from 2000 to 2020 [3]

2021 [3]. Figure 4 shows the CO₂ emissions released by USA, China, EU and India in billion tonnes.

6 Towards 100% Renewables

100% renewables pathway can represent the truly decarbonized energy system. 100% renewables would overcome the concerns of global warming and depletion of fossil fuels. The target of 100% renewable energy would be achieved when all energy sources to meet all end-use energy needs in a certain location, region or country would be derived from renewable energy sources only 24 h per day, every day of the year [13]. Emission reduction could be possible if we double renewable energy

deployments by 2030 as per REMAP, 2014 [14]. Several analytical studies have been carried out by various organizations such as by Greenpeace in 2015 [15], by Energy Watch Group (EWG) [16]. The work done by Greenpeace in 2015 was refined and restated by the University of Technology Sydney (UTS) [17] which addresses the three scenarios: 5.0 °C (reference scenario), 2.0 °C, and 1.5 °C. To achieve the 1.5 °C, the net emissions must decline by 45% (relative to 2010 levels) by the end of decade and reach the net zero by 2050. The scenario of 1.5 °C assumes the electrification of transport and heating and cooling sectors at aggressive scale [13]. Solar PV’s share of the final energy supply should reach to 12,684 GW by 2050 [13]. The present global solar installed capacity has crossed 1 TW [18]. The EWG scenario projects that 90% (135,278 TWh) of all primary energy would come from power sector [16] in contrast to the International Renewable Energy Agency (IRENA). Therefore, solar PV is needed to provide 69% of all primary energy (76% of electricity) by 2050 which means the solar capacity of 57.6 TW by 2050 [13, 16] which is much greater than UTS 1.5 °C scenario [17]. In both, the studies achieving 100% renewable energy is technically feasible with the help of stronger policy support [13]. Figure 5 represents the share of primary energy supplies in the world in 1970, 2021 and 2050 [13, 19, 20].

In the case of India, it is estimated that India should have 5630 GW of solar PV in order to achieve its net zero target by 2070. At present, the present installed solar capacity of India is 40 GW only [21].

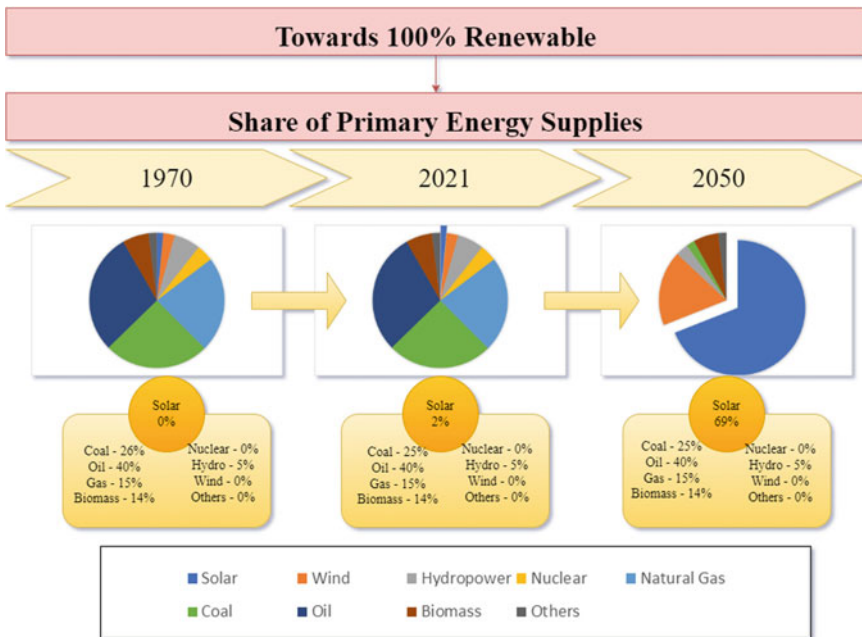


Fig. 5 Share of primary energy supplies in the world in 1970, 2021 and 2050 [13, 19, 20]

7 What's the Cost of Net Zero?

An estimated investment of around 125 trillion \$ is required by 2050 to achieve the target of net zero by 2050 globally. Developing economies make up about 40% of global GDP but account for 50–60% of the investment needs. More than half of the global investments are expected to take place in Asia Pacific with large levels of investment in key countries like China and India [22]. It is estimated that India needs the investment of \$10.1 trillion to achieve its net zero target by 2070 in which \$8.4 trillion is required to scale up power generation, transmission and distribution infrastructure, and \$1.5 trillion is required for green hydrogen power capacity.

The Indian government has introduced the production-linked incentives (PLI) scheme, and there is requirement of thousands of crore to promote the production of efficient solar modules. Various cement industries have committed Rs. 1400–1700 crore for waste heat recovery systems (WHRS) in FY 2022. Various investments are also being done in the domain of recycled steel. The government of India is also on its way to promote perform, achieve and trade (PAT) scheme to increase the efficiency in energy-intensive industries [23].

8 Conclusion

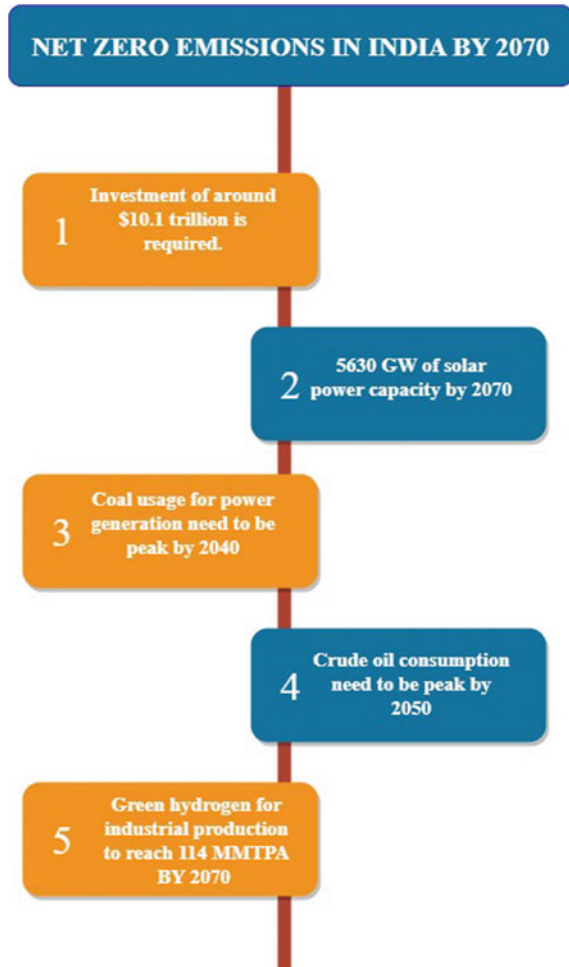
The Government of India has set the target to achieve the net zero emissions by 2070 which is very late as per the Paris Agreement according to which the target of net zero emissions is needed to be achieved by 2050. Net zero emissions by 2070 means the global warming of 2.0 °C by the end of century. Electricity production is the main reason for emissions of carbon dioxide which accounts for more than forty per cent worldwide and is followed by the sector of transportation, industrial, residential and commercial. Traditional methods of electricity production are responsible for a lot of CO₂ emissions while the emissions released by nuclear and renewable energy for the generation of the same amount of electricity which arise the need to promote renewable energy. Considering the total CO₂ emissions, India ranks third. In 2021, India released around 2.8 billion tonnes of CO₂ emissions.

To attain net zero emissions in India by 2070, the following are required:

- An estimated investment of around 10 trillion dollars.
- India should have the installed solar capacity greater than 5600 GW by 2070.
- Coal usage and crude oil consumption need to be peak by 2040 and 2050, respectively.
- Production of green hydrogen should be more than 100 MMTPA by 2070.

Net zero would be possible in India by promotion of more and more non-fossil fuel sources instead of burning fossil fuels like coal and oil for the production of electricity and also by increasing deployment of renewable energy sources in the sector of electricity production and transportation along with increase in the production of

Fig. 6 India towards net zero emissions [22–24]



green hydrogen. In the studies done by UTS and EWG, 100% renewable globally is technically feasible with the help of strong policy framework (Fig. 6).

The economic aspects and investment required to achieve net zero emissions in India could be explored and studies could be done to achieve it early so to align the target of India with the global target as set up in the Paris Agreement. The policy framework is needed to be revised.

References

1. United Nations Framework for Climate Change (2017, June 10) [Online]. Available: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveg.pdf
2. Chouhan BS, Rao KVS, Kumar Saxena B (2017) Reduction in carbon dioxide emissions due to wind power generation in India. In: 2017 international conference on smart technologies for smart nation (SmartTechCon), pp 257–264. <https://doi.org/10.1109/SmartTechCon.2017.8358379>
3. Ritchie H, Roser M, Rosado P (2020) CO² and greenhouse gas emissions. Published online at OurWorldInData.org. Retrieved from: <https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions> [Online Resource]
4. International Energy Agency (IEA). Global energy review: CO₂ emissions in 2021 [Online]. Available: <https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf>
5. <https://www.world-nuclear.org/information-library/energy-and-the-environment/carbon-dioxide-emissions-from-electricity.aspx>
6. <https://www.statista.com/topics/7476/transportation-emissions-worldwide/>
7. Abdallah L, El-Shennawy T (2013) Reducing carbon dioxide emissions from electricity sector using smart electric grid applications. *J Eng* 2013(Article ID 845051):8 p. <https://doi.org/10.1155/2013/845051>
8. United Nations Paris Agreement (2016) [Online]. Available: <https://www.un.org/en/climatechange/paris-agreement>
9. Ministry of Power (GOI) (2022, October) [Online]. Available: <https://powermin.gov.in/en/content/power-sector-glance-all-india>
10. Vaughan A (2021) India's pledge on net zero. *New Scientist* 252(3359):10. [https://doi.org/10.1016/S0262-4079\(21\)01952-7](https://doi.org/10.1016/S0262-4079(21)01952-7)
11. <https://www.livemint.com/news/india/india-sees-carbon-emissions-peaking-in-204045-11635947031283.html>
12. Ciupăgeanu DA, Lăzăroiu G, Tîrșu M (2017) Carbon dioxide emissions reduction by renewable energy employment in Romania. In: 2017 international conference on electromechanical and power systems (SIEMEN), pp 281–285. <https://doi.org/10.1109/SIEMEN.2017.8123333>
13. Renné DS (2022) Progress, opportunities and challenges of achieving net-zero emissions and 100% renewables. *Solar Compass* 1:100007. <https://doi.org/10.1016/j.solcom.2022.100007>
14. IRENA (2014) Remap 2030: a renewable energy roadmap. International Renewable Energy Agency, Abu Dhabi, UAE. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2014/IRENA_REmap_Report_June_2014.pdf
15. Teske S (Project Manager and Lead Author) (2015) Energy [r]evolution—a sustainable world energy outlook 2015. 100% renewable energy for all. Greenpeace International, Global Wind Energy Council, and Solar Power Europe. https://www.researchgate.net/publication/310018861_Energy_Revolution_A_sustainable_world_energy_outlook_2015/link/582c1cea08aef19cb806d65d/download
16. Ram M, Bogdanov D, Aghahosseini A, Gulagi A, Oyewo AS, Child M, Caldera U, Sadovskaia K, Farfan J, Barbosa L, Fasihi M, Khalili S, Dalheimer B, Gruber G, Traber T, De Caluwe F, Fell H-J, Breyer C (2019) Global energy system based on 100% renewable energy—power, heat, transport and desalination sectors study by Lappeenranta University of Technology and Energy Watch Group, Lappeenranta, Berlin
17. Teske S (2019) Achieving the Paris climate agreement goals. Springer-Open. <https://doi.org/10.1007/978-3-030-05843-2>
18. <https://www.pv-magazine.com/2022/03/15/humans-have-installed-1-terawatt-of-solar-capacity/>
19. Singer S, Denruyter J-P, Yener D (2017) The energy report: 100% renewable energy by 2050. In: *Towards 100% renewable energy: techniques, costs and regional case-studies*. Springer International Publishing

20. Renné DS (2022) The opportunities and challenges for 100% renewable energy. Sustainable energy development and innovation: selected papers from the World Renewable Energy Congress (WREC) 2020. Springer International Publishing, Cham
21. <https://economictimes.indiatimes.com/industry/renewables/india-needs-5630-gw-installed-solar-capacity-to-become-net-zero-nation-by-2070-report/articleshow/86984707.cms>
22. <https://climatechampions.unfccc.int/whats-the-cost-of-net-zero-2/>
23. <https://www.businesstoday.in/magazine/corporate/story/how-much-india-needs-to-spend-to-get-to-net-zero-340538-2022-07-06>
24. Tomar A et al (eds) (2022) Proceedings of 3rd international conference on machine learning, advances in computing, renewable energy and communication: MARC 2021, vol 915, p XV, 781. ISBN: 978-981-19-2830-7. Springer Nature. <https://doi.org/10.1007/978-981-19-2828-4>