**NAVIGATING NET ZERO: ANALYZING INDIA'S PATH TO SUSTAINABLE DEVELOPMENT AND CARBON NEUTRALITY**

**Keywords**

Carbon neutralization, India, Net Zero, sustainability.

# Abstract

As India continues to experience impressive economic growth, it must also confront the urgent issue of reducing its carbon emissions to combat global warming and promote sustainability. This article explores India's journey toward achieving carbon neutrality and navigating the path to sustainable development. It examines India's current status, policy frameworks, challenges, and regional approaches, with a particular focus on North India, while comparing it with other countries on a global scale. Through a thorough review of the literature, this article sheds light on the evolving landscape of net-zero initiatives worldwide, with a specific emphasis on India's unique position as a developing country with increasing energy demands. It analyses the role of technology, policy coherence, and financial mechanisms in facilitating India's transition to a net-zero economy. Critically, this study compares India's strategies with those of the United Kingdom, Nepal, and Norway, highlighting valuable insights and potential challenges. By examining political viewpoints and regional proposals, including initiatives in Punjab, Haryana, Uttar Pradesh, and Rajasthan, this article emphasizes the importance of inclusive policy formulation and stakeholder engagement. Additionally, the analysis employs a PETSEL framework to identify the barriers hindering India's progress and proposes practical solutions to address these challenges. This finding underscores the significance of robust institutional capacity, heightened awareness, technological advancements, and enhanced financial mechanisms to propel India toward its net-zero aspirations. In conclusion, this paper provides a comprehensive roadmap for India's pursuit of carbon neutrality, advocating for a holistic approach encompassing policy innovation, technological leapfrogging, and international collaboration. By assimilating lessons from global counterparts and harnessing their intrinsic potential, India can emerge as a beacon of sustainable development, contributing substantively to the global fight against climate change.

# Introduction

India has undergone a significant transformation since its independence in 1947. Once an underdeveloped country was established, India has now become a global economic powerhouse. However, this development has come at a cost, as India is now the world's third-largest emitter of carbon dioxide. In 2021, India emitted 2.654 billion tons (1) of carbon dioxide, accounting for 7.3% (2) of global emissions. This was a significant increase from India's emissions in 1990, which were only 0.9 billion tons (3). The increase in India's emissions is due to several factors, including but not limited to population growth, economic advancements, and increasing dependence on fossil fuels.

Carbon neutrality and net zero are terms that are often used interchangeably. However, these two terms have slightly different meanings for in-depth analysis, where the former means reducing emissions to zero and the latter means balancing emissions and removal. To quote the more sophisticated definition, “Carbon neutrality is the balance between the amount of greenhouse gas (GHG) produced and the amount removed from the atmosphere. This can be achieved through a combination of emission reduction and emission removal” (4), whereas “netzero is the state of balancing emissions and removing greenhouse gases. This means that the amount of CO2 and other greenhouse gases emitted into the atmosphere is equal to the amount that is removed from the atmosphere” (5).

Net zero is the need for the hour. The term was first coined in early 2004 in a report by the World Business Council for Sustainable Development. Carbon neutrality became more known when the United Nations

Environment Program (UNEP) announced that it was becoming climate neutral in 2008, followed by the

Paris Agreement in 2015, which focused on limiting GHG emissions to above 1.5° to below the 2° Celsius preindustrial level. However, in 1997, the Kyoto Protocol, the first international agreement, was an agreement much before all of these agreements, where restrictive targets were set for 37 industrialized economies to reduce GHG emissions by setting respective targets. Moreover, since it ended in 2012, many countries have withdrawn their support. The relationship between net zero and sustainability is a budding topic.

Signs of global warming and carbon-related environmental degradation are ubiquitous and more intense and complicated than just rising temperatures (12). The cost of climate change is estimated to reach $20 trillion by 2050. This includes the cost of adapting to the impact of climate change, such as sea level rise

Total Investement forecasted for 2050

Investments (USD billion) East Asia

Investments (USD billion) EU-28

Investments (USD billion) G20

Investments (USD billion) Latin America

Investments (USD billion) Middle East

and North Africa

Investments (USD billion) North

America

data source [-https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020](https://www.irena.org/publications/2020/Apr/Global-Renewables-Outlook-2020)

and extreme weather events, as well as the cost of mitigating greenhouse gas emissions. The IPCC also estimates that climate change has already caused $100 billion in losses in recent years. This includes the cost of damage to infrastructure, agriculture, and human health (13). Well, these unfortunate figures are never-ending. When we think about a solution to it. Therefore, Net-Zero is projected as a solution to the picture. The transition to net-zero greenhouse gas emissions by 2050 would require an additional $3.5 trillion per year in capital spending on physical assets for energy and land-use systems. This is equivalent to half of global corporate profits, one-quarter of total tax revenue, or 7% of household spending in 2020. The total cost of the transition is estimated to be $275 trillion, or an average of $9.2 trillion per year. The spending would be front-loaded, with the largest increase required between 2026 and 2030. The sectors that would receive the most investment include power, transportation, buildings, and industry. The transition would also create new jobs, with an estimated two hundred million jobs being created and 185 million jobs being lost by 2050. The transition to net zero is a significant undertaking, but it is essential to mitigate the risks of climate change. This investment would be a major boost to the global economy and create a more sustainable future for all. This transition would have economic and environmental benefits (14).

It has been estimated that Net-Zero could decrease carbon emissions by up to 21 billion tons of CO2 emissions per year by 2050, which would ultimately play a key role in mitigating climate change and reducing air pollution (15). In this report, we will dwell upon the following:

1. India’s current conditions and approach for determining the scope of net zero.
2. Benefits India can have through it.
3. Policy framework for climate protection.
4. Challenges faced by India.
5. PETSEL analysis for barrier and its solutions.
6. Multivariate Analysis of Factors Impacting Carbon Emissions: A Panel Data Regression Study for India and its Competitors

# Literature Review

Many reports were published on Net-Zero after the 2016 Paris Agreement on national and international levels, and each country is required to submit its INDCs (ended nationally determined contributions) regularly to update their progress to the UNFCCC. Many developed countries, including the USA under the new Biden government and the UK, have committed to reaching a Net-Zero situation by 2050. However, the major contributors of the highest gross carbon emitters, China and Indonesia, are expected to reach this level by 2060.

India is also progressing toward this point. For instance, it has started refraining from its traditional approach to oppose the argument that development and industrialized countries are the major contributors to GHG emissions, so the maximum burden of reducing GHG emissions should also fall upon them claiming that India has contributed very little to GHG emissions. However, as India has now become the fourth largest emitter, the situation has changed (6). Very little research has been conducted on the situation and contribution of NetZero and India. India is a developing country that requires technological advancements to advance its economy, where it requires substitutes for fossil fuels. Biofuels, hydrogen, and renewable electricity are some of the resources that are good substitutes.

The development of (NZEBs) is a great solution for meeting India’s growing need for energy, which produces as much energy as it consumes on an annual basis. They are designed to be highly energy efficient and use renewable energy sources to meet energy needs. There are two types of NZEBs: on-site NZEBs and grid-connected NZEBs. Briefly, the former generates energy on site, and the latter is used on-site as well as a grid to meet their energy needs. NZEBs have immense potential to be catalysts in the Net-Zero race for India to succeed, but they have several challenges. According to a study by the National Institute of Building Sciences, NZEBs can save up to 50% of energy costs compared to conventional buildings (7). Several researchers have attempted to determine the status of NZEBs by using an integrated framework named the sectoral system innovation assessment framework (SSIAf). They also examine the development of net-zero energy buildings (NZEBs) in India from a sectoral niche formation perspective while also identifying several key factors that have contributed to the development of NZEBs in India, including a growing awareness of climate change and the need for sustainable buildings, the increasing availability of renewable energy technologies, the growing demand for green buildings and support from the government. This paper emphasizes the development of NZEBs and outlines the role of the private and public sectors in doing so while discussing its implications. Notably, the government plays a major role in the development of NZEBs (8).

The government of India aims to reach net zero by 2070 (Government of India, 2022a) (9). Nevertheless, reports have also argued that India has enormous potential to achieve net-zero emissions by 2050 given that consistent efforts, significant investment, and policy changes are needed. It also identifies several key areas where India needs to focus its efforts. Moreover, achieving net-zero emissions could create up to ten million new jobs in India and save the country up to $1 trillion in climate damage (10).

India’s intended INCs to the UNFCCC commits to decrease GHG emissions by 33-35% below 2005 levels by 2030. Of course, this study is based on India's national circumstances and development priorities. Four



Source[: https://www.mgsarchitecture.in/architecture-design/projects/737-india-s-first-net-zero-plus-energy-campus.html](https://www.mgsarchitecture.in/architecture-design/projects/737-india-s-first-net-zero-plus-energy-campus.html)

major factors are also involved: improved energy efficiency, the promotion of renewable energy, and the decarbonization of transportation. The report also dwells upon several commitments, for instance, adapting to the impacts of climate change and providing financial assistance to developing countries. It also focuses on key challenges that India faces in implementing INDCs. There has been favorable progress in addressing those issues. The government of India has established the National Clean Energy Fund to raise financial resources for climate change mitigation and adaptation (11).

In this paper, we discuss the importance of net zero, the key challenge that India faces in achieving carbon neutralization and net zero, followed by the opportunities India has among these.

# India’s Position on Net Zero

India is a developing country with great potential to grow. India’s locational and geographical features render it prone to natural calamities and climatic hazards. India accounts for approximately 2.4% of the world’s total surface area but is home to as much as 17.5% of the total world’s population, just recently surpassing China and becoming the world’s most populous country (11). The average energy consumption in India was 0.7 toe in 2021. The electricity consumption per capita reached 920 kWh in 2021, approximately one-third of the Asian average (16). India is a developing country with a per capita GDP (nominal) of approximately 2301 US$ in March 2022 (17).

The point to ask is what is India’s position on Net-zero and if we can control it. The importance of implementing better policies and regulations is also important. We can reduce emissions by implementing a threefold strategy:

1. Increasing energy efficiency is the best way to cope with increasing energy demand. This can be achieved through a variety of means, such as economic pricing of energy fuel, subsidies for best performing industries, strong and strict thresholds for energy appliances across the industry, increasing awareness of energy efficiency through the use of fewer GHG emission appliances, switching to public transport, and using electrical vehicles.
2. All sectors should be expanded as much as possible so that GHG emissions can be minimized. This will need curtail the use of fossil fuels and the transition to green energy.
3. Additionally, afforestation should be promoted to contribute to carbon neutralization. An increasing amount of awareness should be raised from young children to adults.

In addition, the government of India has launched many environmentally conscious action missions. After the Kyoto Agreement, many missions and policies were launched. Beginning in 2008, under the leadership of Prime Minister Singh, the National Action Plan on Climate Change (NAPCC) aimed to address climate change issues and promote sustainable development. Several initiatives were also taken to support businesses in achieving net-zero emissions. The government also mandated Renewable Purchase Obligations (RPOs) for large electricity consumers. They also provided business subsidies to invest in renewable sources of energy and ultimately reduce their carbon footprint. Then, there was also the launch of the JNNSM (Jawaharlal Nehru National Solar Mission), which provided various subsidies, tax incentives, and financial support for solar power projects that helped motivate businesses to adopt solar power. The introduction of programs such as Leadership in Energy and Environmental Design (LEED) certification and Green Rating for Integrated Habitat Assessment (GRIHA) has promoted sustainable construction practices by introducing green building certification. The FAME (Faster Adoption and Manufacturing Electrical Vehicles) scheme was launched to promote electric mobility by providing subsidies across various sectors. One of the other schemes supporting Net Zero is UJALA, which was launched in 2015 to provide energy-efficient LEDs rather than traditional bulbs by selling the former at subsidized rates, resulting in an enormous amount of energy savings. Pradhan Mantri Ujjwala Yojana (PMUY) was launched in 2016 to provide LPG to all households under PM Modi. This list is never-ending. The most recently launched policy was the Green Hydrogen Policy in 2022 to support and promote the use of green hydrogen power in India. Here, this zero-emission fuel, hydrogen, is produced using an environmentally conscious method. They set targets for 2030.

Here, govt. of India has launched a plethora of policies and programs promoting green causes and supporting net zero initiatives. India is committed to acting on climate change, and these policies are just the right step in this direction. India has great potential to be one of the fastest-growing economies in the world. India is already making considerable efforts and making dynamic changes across its economy. Despite these efforts, India’s actions and strategies are based on many factors. Keeping in mind, considerable momentum has been given for development. India’s contribution to global carbon emissions is minimal. This should not be a surprise, but India’s national objective is the rational utilization of resources to the best of their use, including equity and sustainable development, with due consideration to the national interest. Now, we will discuss its approach to low-carbon development:

1. Low contribution to Global warming and GHG emissions- Notably, South Asia consisted of only approximately 4% of the historical cumulative net anthropogenic emissions between 1850 and 2019, whereas industrialized developed countries accounted for more than approximately 10%. Therefore, it is safe to say that India’s argument for developed countries to take more responsibility for net-zero initiatives is completely justified.
2. Crucial time for India for its development—As the 5th largest economy in the country with the highest population, India has escalated its energy demands to fuel its growth. India has high energy needs to meet up with job creation for an increasingly unemployed population, infrastructural development, rural growth, poverty alleviation, increasing startups, environmental protection, etc. While the energy produced from renewable sources is not enough, India’s efforts to cope with energy needs by being environmentally conscious and supporting net zero with a very low threshold of emissions are ironic.
3. India is going for low-carbon policies and strategies for its development—Even after all the given context, India seeks low-carbon development strategies while considering its national interests and situation.

Achieving net zero by 2050 is difficult but not impossible, and a thorough transformation of the global economic system is needed. This is possible but would require intense effort, significant investment funds, innovation, and political support. As this report concerns and emphasizes India (North India), we will discuss it. As India is a developing country with an escalated population, India has several challenges in meeting its net-zero commitment by 2070. We will be briefing about those here:

1. Lack of financial resources: India has a plan to achieve net zero by 2070, but as mentioned in its INDC to UNFCCC, it needs a significant number of financial resources to meet its demand. The government will need to find a reliable solution to this by either increasing the tax regime or international lending (11). We will discuss this more later.
2. Lack of General Awareness: There is a lack of awareness among individuals across the country about how to make environmentally conscious decisions. There should be increasing awareness among the masses because meeting this goal requires collective support and the interest of the public.
3. Low institutional capacity: India also needs to strengthen its institutional capacity for managing its implementation properly. The government will need to create new institutions and organizations for INDC implementation.
4. Lack of technological capacity: Despite very high technological advancements, India does not have enough technological capacity to implement the policy regulations needed for its INDCs. More scholars and developers need to collaborate with good potentially beneficial international partners and institutes overseas to fuel targeted success.

These are several major challenges India is facing in implementing its INDC. However, there are other potential challenges it may face. For instance, there is a lack of data, political disparities, regional disparities, etc. At the firm level, going carbon neutral is somewhat common but involves different challenges.

There are many potential benefits if India can achieve net zero, which will strongly contribute to reducing carbon emissions:

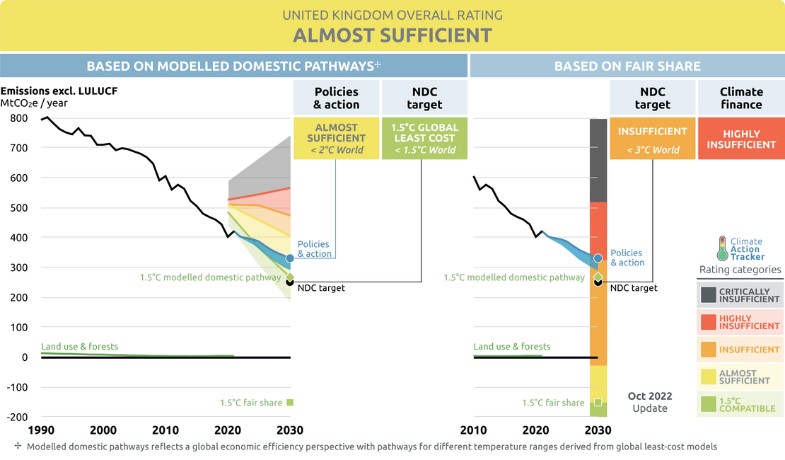
1. Reduced GHG emissions: Achieving net zero ultimately means that there will be neutrality and that India will no longer add to the emissions to the atmosphere. This approach will consequently help to mitigate climatic natural hazards.
2. Improved AQI: India is one of the most polluted countries in the world. Reducing GHG emissions would help improve the AQI considerably. This approach would also help to decrease the increasing number of respiratory and cardiovascular diseases and improve life expectancy.
3. Increase in economic growth:

India is progressing toward net zero, and much more is to be discussed in the coming G-20 meeting for further development.

# A critical comparison with other countries

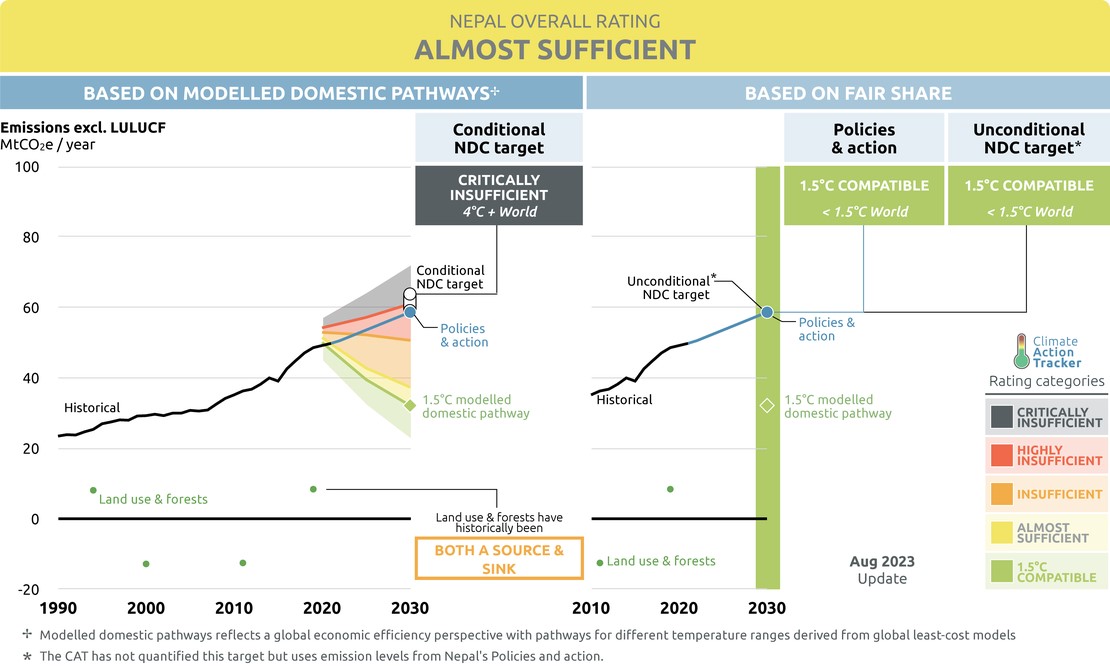
To gain a better understanding of India's path to net-zero emissions, we will now critically compare the policies implemented by India with those of other countries. According to the Climate Action Tracker, only 6 countries have currently made ‘almost sufficient’ efforts to limit warming to 2°C. However, for the sake of easy analysis and more understandable critical analysis, we will focus our efforts on Nepal, the UK, and Nigeria (21).

1. **UK**- The United Kingdom was the first major economy to pass a net zero emission law in 2019. The target year was set to 2050. Since then, it has been reported that the ambition of the 2030 NDC has increased to align with its long-term target, aiming to reduce emissions to 68% below 1990 levels by 2030. The UK has introduced a range of sectoral and cross-cutting policies to reduce emissions; however, in 2021, the U.S. released its net zero strategy, which led these plans to make additional commitments. Its ambition has been demonstrated by committing to a fully decarbonized power sector by 2035, including a target of 50 GW offshore wind capacity by 2030 and a ban on fossil-fueled car sales supported by a zero-emission vehicle mandate to drive EV sales in the 2020s. Some weaknesses were also seen as more connected to the demand side. Current policies are expected to reduce emissions to 293–331 MtCO2e/yr in 2030 or 58–63% below 1990 levels (excl. LULUCF) (21). It has taken up sectoral decarbonization of transport, buildings, industry, and hydrogen and adopted commitments to tree planting, peatland restoration, and other activities. The UK has been more ambitious in achieving this goal. It has policies including a carbon price floor and a ban on new petrol and diesel cars, whereas India has not yet implemented many policies to reduce emissions. India’s efficiency standards are not as stringent as those of the UK. The UK has released the Jet Zero strategy for reducing aviation emissions, while Govt of India has not implemented any comprehensive plan to decarbonize the transportation sector or industrial sector— the two major sources of emissions. Agriculture is a significant contributor to methane emissions, and there is a lack of strict measures available to reduce methane emissions. Like in the UK, India should prioritize transparency in its policies to ensure accountability and scrutiny, which are crucial for monitoring progress. Additionally, India should learn from the loopholes in the UK's strategies. The UK's Net Zero strategy was criticized for its insufficient energy efficiency measures, so India should focus on improving sectoral energy efficiency.



Source: Climate Action Tracker (21).

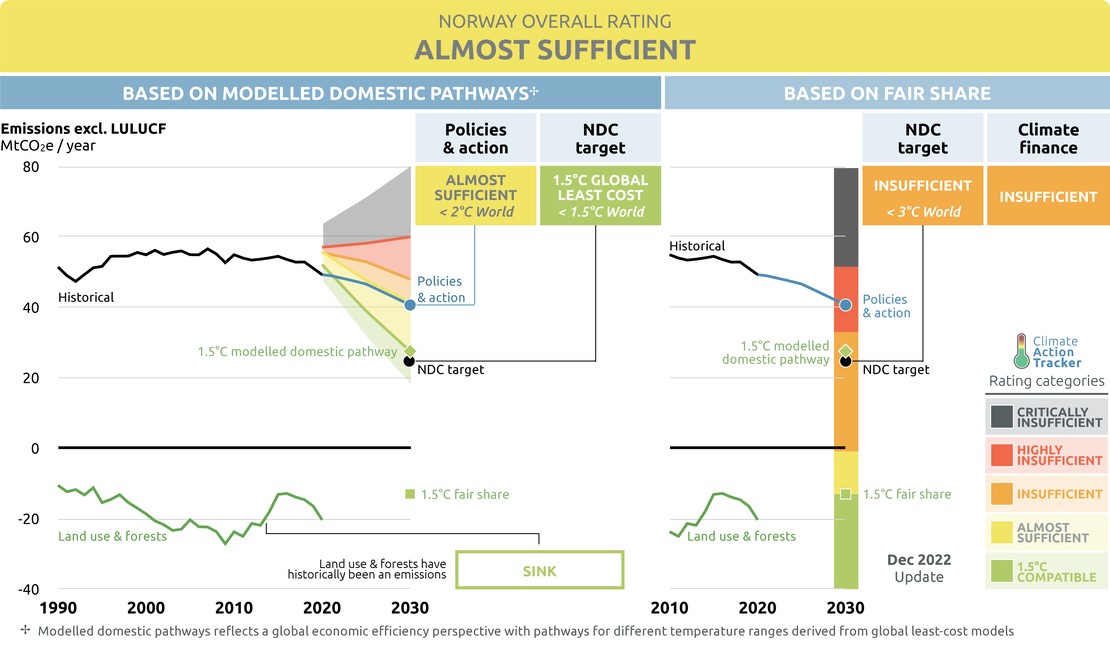
1. **Nepal:** Nepal, India's close neighbor, is a mountainous country with a large rural population. Nepal was recently released in a long-term strategy as a key step in achieving carbon neutrality after releasing its second NDC in 2020, intending to reach carbon neutrality by 2045. The Climate Action Tracker (CAT) has rated its targets and actions as “almost sufficient**”.** The CAT estimates Nepal’s conditional target as 59–64 MtCO2e in 2030, which Nepal will achieve easily with current policies. CAT rates this as “critically insufficient” compared to its modeled domestic pathway. Due to its financial position, China would also require significant international support to succeed. Nepal has also made considerable progress in transitioning to renewable energy sources, with 100% of its electricity generation being from primarily hydroelectricity (99.87%) (21). In contrast, India is far from achieving it soon. To achieve carbon neutrality, India should focus on generating green energy through hydropower and other sustainable sources. Nepal has also implemented policies to promote electric vehicles (EVs), including fiscal incentives and infrastructural development, for charging booths. India has also taken steps to accomplish this goal, but more focused and enhanced plans are needed to match Nepal's goal of phasing out petrol-diesel vehicles with EVs by 2031. We know that both India and Nepal face air quality challenges, but Nepal has published more scrutinized plans and policies for combating these problems where considering India’s geographical size and population size, India’s steps are incompetent at developing more targeted policies and programs. The government of Nepal has also argued that trading its clean energy surplus can offset significant carbon emissions from neighboring countries and play a pivotal role in decarbonizing Nepal’s economy. The potential of solar energy in Nepal is immense. Nepal has almost one million residential solar photovoltaic (PV) systems installed and is growing in large utility-scale solar power. In March 2020, the government published the ‘Kathmandu Valley Air Quality Management Action Plan-2020’ to reduce air pollution levels. The COVID-19 pandemic did not significantly impact Nepal’s emissions; for example, emissions in 2019 and 2020 were 48 and 49 MtCO2e, respectively (21). Nepal has had a focused approach toward achieving net zero with comprehensive plans and policies. The Indian government should also launch a more comprehensive plan for switching to carbon-neutral sources of energy altogether and creating fiscal benefits for EV vehicles.



Source: Climate Action Tracker (21).

1. Norway: Norway, a country in Europe, is on a successful transition to carbon neutrality with its continued strong focus on oil and gas development. It has a NetZero target for 2050**,** with a focus on 90-95% of the populationbelow 1990 levels. A significant financial boost is also needed to achieve the respective targets. Norway’s updated at least 55% of the NDC reduction target aligns with least cost-modeled domestic pathways, which limit warming to 1.5°C. In its latest NDC update, Norway strengthened its 2030 emissions reduction target to at least 55% below the 1990 level. In contrast, India set a target of reducing the carbon intensity of its GDP rather than absolute emissions reduction targets. India could benefit from setting more ambitious and specific emissions reduction targets, as Norway does. Norway leads the world in electric vehicle adoption, with a market share of zero-emission vehicles and plug-in hybrid vehicles combined reaching 86% in February 2022. India has also been promoting EVs, but its adoption rate may not be as high as that of Norway. India could learn from Norway's successful policies and regulations to accelerate the transition to EVs. Norway has made notable progress in several areas related to carbon neutrality, such as setting ambitious emissions reduction targets, leading to electric vehicle adoption, and implementing carbon pricing mechanisms. In addition to making efforts, India may need to set clearer and more ambitious emission reduction targets, accelerate the transition to electric vehicles, reduce its reliance on fossil fuels, and strengthen its climate policies to achieve carbon neutrality. Additionally, both countries could benefit from reevaluating their support for the fossil fuel sector in the context of their climate commitments.

To conclude, India indeed has much to learn from these countries to successfully achieve its targets by 2070. More ambitious and sector-specific emission reduction targets should be set, electrical vehicles should be promoted, renewable energy sources should be transitioned to renewable energy sources, and transparent and highly accountable climate policies and programs should be adopted.



Source: Climate Action Tracker (21).

Additionally, India should reassess its support for the fossil fuel sector to align with its climate commitments. By incorporating these lessons, India can make significant progress toward achieving its carbon neutrality goals and contribute to global efforts to combat climate change.

**PETSEL Analysis for Barrier and its Solutions**

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| **Sr. No.** | **Barriers/Challenge**  **s** | **Brief Description** | **Reference** |
| **Political (P)** | Challenges in  Implementing  Various Missions | India's pursuit of sustainable development through national missions, such as the National Mission on Sustainable Habitat and Environment (NMSHE),  National Mission on Strategic Knowledge for Climate Change (NMSKCC), and National Mission on Enhanced Energy Efficiency (NMEEE), is encumbered by multifaceted challenges. These challenges manifest in the form of manpower shortages, financial constraints, and coordination issues, collectively hampering the effective implementation of these critical initiatives. The intricate nature of these impediments underscores the need for a comprehensive and detailed analysis within the Political category of the PETSEL framework. | 22 |

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|  | More interest in large-scale renewable energy | A notable challenge hindering India's transition to sustainable energy sources is the disproportionate emphasis on large-scale renewable energy projects, primarily within the industrial and commercial sectors. This focus sidelines the residential domain, impeding the widespread adoption of renewable energy solutions at the grassroots level. The decelerated progress in renewable energy adoption perpetuates the reliance on nonrenewable sources, slowing the overall pace of  India's shift toward a more sustainable energy landscape. | 22 |
|  | Gaps in National mission for sustainable agriculture | The National Mission for Sustainable Agriculture confronts challenges rooted in deficiencies related to the prioritization of small and marginal farmers. In the context of climate change resilience and adaptation scenarios, the mission exhibits shortcomings, indicating gaps in its inclusive approach. The failure to address the unique needs of these farmers impedes the mission's effectiveness in fostering sustainable agricultural practices, exacerbating challenges in achieving broader environmental and climate-related objectives. | 22 |
|  | Lack of political will and institutional  bottlenecks | A critical hindrance to India's net-zero ambitions lies in the absence of a comprehensive policy framework that establishes clear targets and timelines across different sectors. The lack of a unified net-zero policy framework reflects a deficiency in political will, hindering the formulation of coherent and actionable strategies to address climate change and achieve sustainable development goals. | 23 |
|  | Regulatory  Confusion and  Overlapping  Responsibilities | The intricate web of climate policies in India is further complicated by regulatory confusion and overlapping responsibilities among government ministries and agencies. The lack of clarity regarding which entity is responsible for regulating and implementing climate policies introduces inefficiencies and conflicts. This confusion not only impedes the effective enforcement of policies but also creates barriers to coherent decisionmaking, hindering the overall progress toward net-zero targets. | 22 |
|  | Falling Short of Renewable Energy  Targets | India's pursuit of renewable energy targets, especially in the critical solar sector, faces a significant setback as the nation falls short of its set objectives. This shortfall poses a considerable challenge, as meeting these targets is pivotal for reducing emissions and transitioning toward a cleaner and more sustainable energy landscape. | 22 |
|  | Lack of specific laws and policies | A glaring gap in India's approach to achieving net-zero lies in the absence of specific laws and policies dedicated to promoting low-carbon initiatives. The lack of a regulatory framework tailored to incentivize and guide the development of sustainable practices across | 24 |

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|  |  | various sectors creates a challenging environment for the effective implementation of net-zero projects. |  |
|  | Streamlining  bureaucratic  procedures and  reducing red tape | The bureaucracy surrounding climate initiatives poses a significant challenge to the acceleration of net-zero projects. Streamlining bureaucratic procedures and reducing red tape is imperative for expeditious project implementation. The bureaucratic complexities hinder the efficient deployment of resources, causing delays and inefficiencies in the execution of crucial initiatives aimed at achieving India's net-zero targets. | 25 |
| **Economic**  **(E)** |  |  |  |
|  | Lack of Financial Resources | India's ambitious commitment to achieve Net Zero by 2070, as articulated in its INDC to UNFCCC, faces a substantial hurdle in the form of a lack of financial resources. This highlights the critical need for strategic financial planning and global collaboration. The infusion of substantial financial resources is imperative to support the nation's transition to sustainable practices, requiring meticulous financial management and cooperation on a global scale. | 26 |
|  | Sharp increase in commodity prices | The precipitous rise in commodity prices introduces a pressing economic challenge, making energy less affordable for the populace. Mitigating this challenge demands innovative financial mechanisms to alleviate the impact on energy accessibility. The economic repercussions of heightened commodity prices underscore the necessity for adaptive financial strategies to ensure sustainable energy affordability for the broader population. | 27 |
|  | Tight markets | India, as the world's third-largest energy importer, grapples with the constricting dynamics of tight markets, posing escalating energy security risks. Effectively navigating these risks necessitates a nuanced approach to market dynamics and robust global partnerships. A strategic understanding of market intricacies, coupled with international collaborations, becomes imperative to safeguard India's energy security interests. | 27 |
|  | Heavy realization on coal energy | India's heavy reliance on coal for energy production emerges as a formidable economic obstacle, hindering progress toward cleaner energy sources. To overcome this challenge, diversification strategies and a comprehensive energy transition plan are prerequisites for sustainable economic development. Addressing the dependence on coal requires a strategic shift toward cleaner alternatives, fostering both economic and environmental sustainability. | 22,  31 |
|  | Energy Demand  Growth | The anticipated surge in India's energy demand presents a pressing economic challenge, necessitating a substantial increase in low-carbon energy sources. | 27 |

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|  |  | Meeting this growing demand sustainably requires strategic investments and the formulation of robust policy frameworks. Balancing economic growth with sustainable energy practices is contingent upon visionary policies and targeted investments to ensure a harmonious transition to low-carbon alternatives. |  |
|  | Cost effectiveness and lack of  investment | Economic barriers, including concerns about costeffectiveness and a deficiency in investment, impede the seamless transition to sustainable practices. Overcoming these obstacles requires fostering an environment conducive to investment. Exploring innovative financial models and incentivizing sustainable initiatives becomes pivotal in bridging the economic gaps hindering the widespread adoption of eco-friendly practices.. | 24 |
|  | Low levels of carbon pricing | Carbon pricing in India is still in its nascent stages of development, with current levels too low to have a significant impact on investment decisions. This economic challenge underscores the need for a more robust and mature carbon pricing mechanism. Elevating the levels of carbon pricing is crucial to incentivize sustainable investments and steer economic activities toward environmentally responsible practices. | 25 |
|  | Lack of access to affordable financing | A critical economic challenge lies in the lack of access to affordable financing for businesses and households engaged in energy efficiency and renewable energy projects. This financial barrier impedes the widespread adoption of sustainable practices. Addressing this challenge necessitates concerted efforts to enhance financial inclusivity and create mechanisms that facilitate affordable financing for initiatives contributing to India's sustainable economic development. | 25 |
| **Sociological (S)** | Lack of general  awareness | A sociological challenge hindering India's transition to sustainable practices is the pervasive lack of awareness among individuals across the country. This dearth of awareness impedes the ability of the populace to make environmentally conscious decisions. Addressing this sociological barrier requires comprehensive educational initiatives and public awareness campaigns to foster a sense of environmental responsibility and facilitate informed decision-making among the masses. | 28 |
|  | The need to ensure a just transition | The transition to a net-zero energy system will have a significant impact on India's economy and society. India will need to ensure that this transition is fair and equitable, and that no one is left behind. | 22,  20 |
|  | Balancing Growth  and Sustainability | India confronts a sociological challenge in balancing growth and sustainability. The imperative to achieve sustainable growth without hindering economic development introduces complexities in transitioning to renewables. It is crucial to ensure that this transition is | 31 |

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|  |  | equitable and does not disproportionately impact vulnerable communities. Addressing this sociological challenge requires nuanced policies that prioritize inclusivity, recognizing the social dimensions of sustainability in the context of economic development. |  |
| **Technological (T)** | Low technological capacity | India grapples with a technological challenge characterized by low technological capacity, hindering the implementation of policy regulations outlined in its Intended Nationally Determined Contributions (INDC). To overcome this obstacle, India requires a concerted effort to enhance its technological capabilities. This involves fostering collaboration with scholars, facilitating research and development initiatives, and establishing partnerships with potentially beneficial international entities and institutes overseas. Strengthening technological capacity is pivotal for the successful execution of policies aimed at achieving India's INDC targets. | 27 |
|  | Lack of reliable  electricity supply | The lack of a reliable electricity supply poses a significant technological challenge in India. This deficiency forces people to depend on traditional fuels, compromising both the environment and public health. Addressing this challenge demands a technological overhaul of the energy infrastructure, focusing on the development of robust and sustainable electricity supply systems to reduce reliance on traditional, harmful sources. | 27 |
|  | Poor infrastructure for renewable  energy development | India encounters a technological impediment with poor infrastructure for renewable energy development, specifically inadequate transmission lines and grids. The deficiency in infrastructure acts as a bottleneck in the effective integration of renewable energy into the national grid. Resolving this technological challenge necessitates strategic investments in upgrading and expanding the existing infrastructure, ensuring that it can accommodate the evolving landscape of renewable energy technologies. | 25 |
|  | Lack of skilled  workforce | A shortage of skilled workers in the renewable energy sector presents a technological barrier to India's sustainable development goals. Overcoming this challenge requires a comprehensive approach to skill development and education, focusing on building a skilled workforce capable of driving innovation and efficiency in the renewable energy sector. Collaborative efforts between educational institutions, industry stakeholders, and government bodies are essential to bridge the technological skills gap and foster a workforce equipped for the demands of a rapidly evolving technological landscape. | 25 |
| **Legal (L)** | Impeding the urgent transformation | A legal challenge hindering India's urgent transformation lies in financially ailing electricity distribution companies. The precarious financial state of these entities acts as an impediment to the necessary sectoral transformation. Resolving this legal challenge demands a strategic reassessment of financial models for electricity distribution companies, potentially involving policy reforms, financial restructuring, and collaborative efforts to ensure the sector's financial stability. Addressing legal barriers is crucial for expediting the transformative initiatives needed to align with India's broader sustainability goals. | 27 |
| **Environmental (En)** | High level of pollution. | India grapples with a profound environmental challenge characterized by a high level of pollution. The consequences of this challenge manifest in some of the poorest air quality in the world, particularly in Indian cities. Mitigating this environmental challenge necessitates comprehensive regulatory measures, strict enforcement of environmental laws, and the implementation of sustainable practices across industries. The imperative is to curb emissions, promote cleaner technologies, and enhance air quality monitoring systems to safeguard public health and the environment. | 30,  31 |
|  | Inadequate Progress in Green India  Mission: | The Green India Mission, designed to promote afforestation, faces a notable environmental challenge with inadequate progress in several states. This shortcoming underscores the need for a critical evaluation of the mission's implementation strategies, potentially involving policy revisions, community engagement initiatives, and enhanced monitoring mechanisms. Addressing this environmental challenge demands a proactive approach to ensure that afforestation efforts align with the mission's objectives, fostering ecological resilience and biodiversity conservation. | 30 |
|  | Lack of renewable energy options and resources. | A pressing environmental challenge is the urgent lack of renewable energy options and resources. This deficiency hampers India's transition to cleaner energy sources and poses obstacles to achieving sustainable development goals. Addressing this challenge requires a comprehensive strategy encompassing policy reforms, technological innovations, and investments in renewable energy infrastructure. The focus should be on diversifying the energy mix, promoting research and development, and fostering a conducive legal framework to incentivize the rapid adoption of renewable energy technologies. | 24 |

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| --- | --- | --- | --- |
| **Sr.**  **No.** | **Barriers/ Challenges** | **Solutions** | **Refer ences** |
| **Political (P)** | Allocation of resources and streamline coordination | To address challenges in implementing various missions, India must allocate more resources, streamline coordination, and enhance the institutional capacity of entities responsible for these missions. This involves a strategic deployment of financial and human resources, fostering collaboration between energy suppliers and consumers, and fortifying the capabilities of institutions to ensure the effective execution of critical national missions. Strengthening coordination mechanisms facilitates knowledge exchange, promoting a more integrated and synergistic approach to sustainable development. | 22, 30 |
|  | Streamline priorities | Effective coordination between government ministries and departments, along with streamlined approval processes, is imperative. This solution entails a systematic approach to aligning priorities and optimizing decision-making processes. By enhancing coordination, the government can ensure that policies and initiatives align with broader sustainable development goals, contributing to a more efficient and coherent approach to addressing challenges. | 32 |
|  | Develop and  implement adaptation measures | To tackle climate change impacts, the government needs to develop and implement adaptation measures. These measures should be comprehensive, addressing vulnerabilities and enhancing resilience across various sectors. By integrating climate adaptation strategies into policy frameworks, India can proactively protect itself from the diverse challenges posed by changing environmental conditions, fostering long-term sustainability. | 32 |
|  | Comprehensive net-zero policy framework | India's journey toward net-zero emissions requires the development and implementation of a comprehensive policy framework aligned with national development goals. This solution involves crafting a roadmap with sector-specific goals and short-term milestones. A clear and robust policy framework provides direction for industries and policymakers, guiding the nation's transition to a low-carbon economy with a well-defined strategy and set objectives. | 23 |
|  | Clear definition with dedicated  authorities | To enhance clarity and direction in India's transition to a low-carbon economy, a detailed roadmap with sectorspecific goals and short-term milestones is essential. This solution ensures that various industries and policymakers have a clear understanding of their roles and responsibilities. Establishing dedicated authorities for each sector further reinforces accountability and | 31 |

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| --- | --- | --- | --- |
|  |  | facilitates more effective implementation of sustainable practices. |  |
|  | Improve policy consistency and provide incentives | To accelerate progress, improving policy consistency is crucial. Addressing issues related to distribution companies and incentivizing residential solar installations encourages a more consistent and supportive policy environment. Furthermore, providing incentives for compliance with environmental regulations and encouraging investments in alternative renewable energy sources, such as offshore wind projects, fosters a more conducive landscape for sustainable development. | 32 |
|  | Develop and  implement specific laws and regulations that encourage lowcarbon operations | In the automobile industry, India needs to develop and implement specific laws and regulations that encourage low-carbon operations. This involves creating a legal framework that incentivizes environmentally friendly practices and compliance with stringent emission standards. By providing clear guidelines and legal incentives, the government can steer the automobile industry toward sustainable operations, contributing significantly to India's net-zero targets. | 24 |
|  | Addressing Complex  bureaucratic procedures | The complexity and sluggishness of bureaucratic procedures pose a challenge to net-zero initiatives. Streamlining these procedures, simplifying approval processes, and enhancing administrative efficiency are imperative solutions. By improving the bureaucratic framework, India can expedite the implementation of net-zero projects, ensuring a more agile and responsive governance structure to meet sustainability objectives. | 25 |
| **Economic (E)** |  |  |  |
|  | Develop sectoral investment and private sector engagement plans | India's economic strategy for achieving net-zero targets involves developing sectoral investment and private sector engagement plans. Strengthening national sector capacities and involving industry and financial decisionmakers in the Nationally Determined Contributions (NDC) process are critical. Attracting international investments and support from the global community for clean energy projects is essential. Creating a conducive environment for low-cost, long-term capital ensures sustained financial backing for transformative initiatives, fostering economic resilience and aligning with sustainable development goals. | 22 |
|  | Regulation and  improve distribution system | Regulating and gradually phasing out coal while promoting cleaner energy alternatives is a pivotal economic solution. Improving electricity distribution systems to minimize energy wastage enhances efficiency. This economic strategy not only supports the transition to sustainable energy sources but also addresses environmental concerns associated with coalbased power generation. | 22 |

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| --- | --- | --- | --- |
|  | Favorable Policy environment creation | Creating a favorable policy environment for investment in renewable energy and clean technologies is crucial for India's economic trajectory toward net-zero emissions. This involves formulating policies that incentivize and support businesses in the renewable energy sector, fostering a conducive landscape for economic growth and sustainability. | 32 |
|  | Fast Transition to better energy  sources | India must expedite the transition to renewable energy sources like solar, wind, and hydropower for economic sustainability. Investing in clean energy infrastructure and gradually phasing out coal-based power generation is essential for reducing emissions. This economic approach not only aligns with environmental goals but also positions India at the forefront of the global clean energy revolution, attracting investments and enhancing economic competitiveness. | 31, 32 |
|  | Installation for more renewable energy | Setting ambitious targets for renewable energy capacity expansion is an economic imperative. India's goal of installing 500 gigawatts of renewable energy capacity by 2030 demonstrates a commitment to clean energy adoption. This economic strategy encourages innovation, job creation, and technological advancements, positioning India as a leader in the global clean energy landscape. | 27, 33 |
|  | Offer financial incentives such as tax rebates and subsidies to encourage investment | The Indian government should provide financial incentives, such as tax rebates and subsidies, to encourage investment in low-carbon technologies. This economic solution aims to attract private funding and venture capital, fostering a robust ecosystem for lowcarbon initiatives. By leveraging financial incentives, India can stimulate economic growth while advancing its net-zero agenda. | 24 |
|  | Increment in level of carbon pricing | Raising the level of carbon pricing serves as an economic lever to send a strong market signal and encourage investment in clean energy technologies. This approach aligns economic incentives with environmental responsibility, driving innovation and sustainable practices in industries. Incremental carbon pricing provides a market-driven mechanism to internalize the externalities associated with carbon emissions, fostering a more sustainable economic model. | 25, 32 |
|  | Innovative financing mechanisms | India can further its economic agenda by developing and implementing innovative financing mechanisms, such as green bonds and carbon markets. These mechanisms attract investments for sustainable projects, diversifying funding sources and promoting economic resilience. This economic strategy not only facilitates the financing of clean energy initiatives but also positions India as a | 25 |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | leader in adopting innovative financial instruments to drive sustainable development |  |
| **Sociological (S)** | Revision of NVM | To address sociological challenges, India should revise the National Water Mission (NWM) to prioritize equitable access to water resources, especially for marginalized communities. Implementation of watersaving technologies and policies is crucial to ensure fair and sustainable water distribution. This sociological solution aims to rectify disparities in water access, fostering social equity and resilience among marginalized communities. | 22 |
|  | Prioritize inclusive growth and social equity | Implementing policies and programs that prioritize inclusive growth and social equity is essential. This involves ensuring that clean energy projects create job opportunities and benefits for marginalized communities. By incorporating social considerations into policy frameworks, India can foster a more inclusive and equitable transition to a low-carbon economy, addressing sociological challenges and promoting sustainable development. | 30, 32 |
|  | A change in  lifestyles | India's citizens will need to make changes to their lifestyles in order to reduce their greenhouse gas emissions. This could include measures such as driving less, eating less meat, and consuming less energy at home. | 31 |
| **Technological (T)** |  |  |  |
|  | Upgrade  infrastructure | India's technological solution involves upgrading infrastructure for renewable energy development. This includes enhancing transmission lines and grids to facilitate the integration of renewable energy into the national grid. Upgrading infrastructure ensures the reliability and efficiency of renewable energy systems, contributing to technological advancements in the clean energy sector. | 25, 32 |
|  | Support the skill development | Supporting the development of a skilled workforce in the renewable energy sector is crucial. Investing in education and training programs ensures the availability of a skilled workforce capable of driving innovation and efficiency in the clean energy industry. This technological solution not only addresses the shortage of skilled workers but also promotes human capital development in alignment with India's sustainable technological aspirations. | 23 |
| **Legal (L)** | Update  regulatory  framework for  urgency | To tackle legal challenges, India should review and update its regulatory framework to support the urgent transition to a net-zero economy. This legal solution involves revising laws and regulations to align with the evolving environmental landscape. Updating the regulatory framework ensures that legal structures | 23 |
|  |  | facilitate rather than impede the transition to sustainable practices, fostering legal environments conducive to netzero goals. |  |
| **Environmental (En)** | Shift to cleaner and more efficient technologies. | India's environmental strategy involves shifting to cleaner and more efficient technologies. Leveraging existing policy measures and fully implementing them accelerates the adoption of sustainable technologies. This environmental solution aims to reduce pollution, enhance energy efficiency, and align industrial practices with global environmental standards, contributing to India's commitment to a greener future. | 27,  30, 32 |
|  | Enhance efforts and provide necessary resources | To address environmental challenges, India should enhance efforts to involve states like West Bengal, Jammu & Kashmir, and Himachal Pradesh in the Green India Mission. Providing necessary resources and support for successful afforestation initiatives is crucial.  This environmental solution ensures a more comprehensive and inclusive approach to environmental conservation, promoting biodiversity and ecological resilience. | 22, 30 |
|  | Development of Renewable  energy sources and energy transition from fossil fuels. | A critical environmental solution is to promote the development of renewable energy sources and the transition from fossil fuels. Ensuring that organizations have access to clean and renewable energy options fosters a more sustainable energy landscape. This environmental strategy aligns with global efforts to mitigate climate change, reducing reliance on fossil fuels and encouraging the widespread adoption of renewable energy technologies. | 24 |

# Multivariate Analysis of Factors Impacting Carbon Emissions: A Panel Data Regression Study for India and its Competitors

Efforts to mitigate climate change and transition towards a sustainable future have become imperative in the face of escalating environmental challenges. Central to this endeavor is understanding the complex interplay of factors influencing carbon emissions, particularly in rapidly developing nations like India and other competitors (United Kingdom, Nepal and Norway) who are very far in race for achieving net zero position. Note that the reason why we are including these specific countries in our analysis is mentioned previously so we will not be discussing that here. In this study, we conduct a multivariate analysis to investigate the various determinants of carbon emissions in India. Utilizing panel data regression techniques, we delve into the intricate relationships between economic indicators, energy consumption patterns, demographic dynamics, and environmental policies to unravel the driving forces behind carbon emissions in these countries’ contexts. By examining these factors comprehensively, our study aims to contribute valuable insights into their path towards sustainable development and carbon neutrality, offering implications for policy interventions, strategic planning, and global climate action initiatives. 1 For dependent variable here we have Carbon emissions (kt) and for independent variables we have these variables:

1. GDP (constant 2015 US$)
2. GDP per capita (constant 2015 US$)
3. Energy use (kg of oil equivalent per capita)
4. Fossil fuel energy consumption (% of total)
5. Combustible renewables and waste (% of total energy)
6. Renewable energy consumption (% of total final energy consumption)
7. Population density (people per sq. km of land area)
8. Population growth (annual %)
9. Urban population (% of total population)
10. Urban population growth (annual %)
11. Foreign direct investment, net inflows (% of GDP)

# 1. INDIA

The table presents descriptive statistics for key variables related to carbon emissions, economic indicators, energy consumption, and demographic factors in India. Descriptive statistics offer a snapshot of the central tendency, variability, and range of these variables, providing essential insights into their distribution and characteristics over the study period. By examining mean values, standard deviations, and minimum and maximum values, we gain a deeper understanding of the magnitude and variability of factors influencing carbon emissions in the Indian context.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | Mean | Std. Dev. | Min | Max |
| CO2emissio~t | 25 | 1132032 | 467519.8 | 563575.4 | 2147107 |
| CO2emissio~c | 25 | 1.00152 | .2926317 | .6474513 | 1.642465 |
| GDPconstan~S | 25 | 1.01e+12 | 4.56e+11 | 4.65e+11 | 1.95e+12 |
| GDPpercapi~S | 25 | 888.5031 | 297.3732 | 528.8982 | 1490.029 |
| Energyusek~t | 25 | 451.8596 | 85.13909 | 351.2121 | 630.9009 |
| Fossilfuel~n | 25 | 64.46899 | 5.812327 | 53.76396 | 73.57698 |
| Combustibl~e | 25 | 31.62069 | 6.371151 | 21.37392 | 42.6258 |
| Renewablee~n | 25 | 44.4232 | 6.128519 | 33.85 | 52.95 |
| Population~s | 25 | 368.0786 | 45.54311 | 292.7671 | 439.6781 |
| Population~l | 25 | 1.712308 | .2885548 | 1.240362 | 2.141141 |
| Urbanpopul~p | 25 | 28.56472 | 2.106403 | 25.547 | 32.384 |
| Urbanpopul~l | 25 | 2.698957 | .1811489 | 2.423845 | 3.09293 |
|  |  |  |  |  | 3.620523 |
| Foreigndir~i | 25 | 1.103614 | .8851037 | .0272255 |  |

1Note that we have used data from the World Development Indicators Data Bank for the time period between 1990 and 2014 to avoid any bias due to insufficient data.

We used Stata to run linear regression and analyze our dependent variable - carbon emissions (kt) - as well as our independent variables. We have included the results below and will be providing an explanation of our findings.

Results

The findings emanating from the linear regression analysis conducted on CO2 emissions (kt) in India spanning the period 1990 to 2014 yield several discernible implications, thereby contributing substantively to the understanding of the economic determinants of carbon emissions within the Indian context.

Significant Determinants:

* *Gross Domestic Product (GDP), measured in constant 2015 US dollars*, exhibits a noteworthy positive impact on CO2 emissions (kt), underscored by a coefficient of 3.19e06 and a p-value below the conventional significance threshold of 0.05. This implies that an augmentation in GDP is associated with a corresponding escalation in CO2 emissions.

* Conversely, *GDP per capita (constant 2015 US$)* manifests a statistically significant negative association with CO2 emissions (kt), characterized by a coefficient of -3323.566 and a p-value below 0.05. This indicates an inverse relationship wherein an increase in GDP per capita is accompanied by a decline in CO2 emissions per capita.

While variables such as fossil fuel energy consumption and foreign direct investment (% of GDP) exhibit potential impacts, their statistical significance remains elusive at the customary 0.05 level.

* *GDP and CO2 Emissions Dynamics:* The positive coefficient attributed to GDP accentuates the propensity for CO2 emissions to escalate concomitantly with an expansion in the overall GDP of India. This observation aligns with established patterns observed in burgeoning economies, wherein industrialization and economic progress correlate with heightened energy consumption, predominantly derived from fossil fuels.

* *GDP per Capita and CO2 Emissions Nexus:* The negative coefficient ascribed to GDP per capita signifies a discernible decline in CO2 emissions per capita amidst an elevation in GDP per capita. Plausible explanations for this phenomenon encompass heightened operational efficiency, technological advancements, and a transition towards cleaner energy sources concomitant with rising incomes.

* *Energy Utilization and CO2 Emissions:* While energy use (kg of oil equivalent per capita) exhibits a positive coefficient indicative of a positive association with CO2 emissions, this relationship lacks statistical significance at the conventional significance level (p > 0.05).

* *Renewable Energy Dynamics*: Notably, the proportion of renewable energy consumption (% of total final energy consumption) fails to demonstrate a statistically significant relationship with CO2 emissions in this analytical framework. This suggests that the current magnitude of renewable energy consumption in India may not wield substantial influence in curbing CO2 emissions.

* *Population Dynamics*: Population density and growth rates exhibit no discernible impact on CO2 emissions in this analytical framework, intimating that factors beyond demographic considerations assume a more prominent role in shaping emission patterns.

* *Urbanization Effects:* Urban population (% of total population) and urban population growth rates similarly do not evidence statistically significant effects on CO2 emissions in this analytical model.

* *Foreign Direct Investment Implications*: Foreign direct investment (% of GDP) reveals a positive coefficient, indicative of a conceivable yet statistically insignificant influence on CO2 emissions.

In summation, the salient outcomes of this analysis underscore the pivotal roles played by both GDP and GDP per capita in shaping CO2 emissions in India. While heightened GDP correlates with increased emissions, an elevated GDP per capita tends to coincide with diminished emissions per capita. These findings advocate for policy paradigms that concurrently foster economic growth and prioritize efficiency and cleaner technologies, thereby offering a strategic avenue for mitigating CO2 emissions in the Indian context.

## 2. United Kingdom

The table displays descriptive statistics for key variables related to carbon emissions, economic parameters, energy utilization, and demographic features in the United Kingdom. Descriptive statistics enable us to grasp the distribution and characteristics of these variables, elucidating their central tendency, variability, and range throughout the study period. By examining mean values, standard deviations, and minimum and maximum values, we gain valuable insights into the factors shaping carbon emissions in the UK.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | Mean | Std. Dev. | Min | Max |
| CO2emissio~t | 25 | 518640.1 | 39754.67 | 415609 | 570681.6 |
| CO2emissio~c | 25 | 8.667307 | .9375927 | 6.433347 | 9.937878 |
| GDPconstan~S | 25 | 2.33e+12 | 3.78e+11 | 1.75e+12 | 2.86e+12 |
| GDPpercapi~S | 25 | 38639.43 | 5018.425 | 30439.65 | 44508.61 |
| Energyusek~t | 25 | 3532.151 | 317.1852 | 2777.311 | 3879.823 |
| Fossilfuel~n | 25 | 87.71785 | 1.903212 | 82.71658 | 90.65259 |
| Combustibl~e | 25 | .6616297 | .6667498 | .1422979 | 2.474805 |
| Renewablee~n | 25 | 1.87 | 1.573489 | .61 | 6.53 |
| Population~s | 25 | 248.2764 | 9.532279 | 236.6287 | 267.0289 |
| Population~l | 25 | .4954153 | .2185775 | .2397454 | .7870326 |
| Urbanpopul~p | 25 | 79.61136 | 1.423856 | 78.112 | 82.365 |
| Urbanpopul~l | 25 | .7034906 | .3561407 | .2349647 | 1.131869 |
| Foreigndir~i | 25 | 3.993291 | 2.88024 | .602904 | 9.934546 |

We used Stata to run linear regression and analyze our dependent variable - carbon emissions (kt) - as well as our independent variables. We have included the results below and will be providing an explanation of our findings.

Results:

The present linear regression model endeavors to elucidate the intricate interplay between CO2 emissions per capita and various independent variables within the United Kingdom, spanning the temporal expanse from 1990 to 2014. A meticulous examination of the findings reveals the following insights:

* *Gross Domestic Product (GDP) (constant 2015 US$):*

Coefficient: Positive (1.48e-06)

Statistical Significance: p < 0.05

Interpretation: The positive coefficient signifies a statistically significant association between GDP and CO2 emissions per capita, suggesting that as GDP increases, so does the propensity for heightened CO2 emissions per capita. This implies a positive correlation between economic expansion and carbon emissions within the UK.

* *GDP per capita (constant 2015 US$):*

Coefficient: Negative (-88.3609)

Statistical Significance: p < 0.05

Interpretation: The negative coefficient, coupled with statistical significance, implies an inverse relationship between GDP per capita and CO2 emissions per capita. This suggests that as affluence increases, there is a tendency for reduced CO2 emissions per capita, potentially indicative of a proclivity towards cleaner technologies and renewable energy sources.

* *Energy Use (kg of oil equivalent per capita):*

Coefficient: Positive (131.2561)

Statistical Significance: p < 0.05

Interpretation: The positive coefficient, accompanied by statistical significance, underscores a positive association between energy consumption per capita and CO2 emissions per capita. This aligns with expectations, given the prevalent reliance on fossil fuels for energy production and the resultant carbon emissions.

* *Fossil Fuel Energy Consumption (% of Total):*

Coefficient: Positive (9164.648)

Statistical Significance: p < 0.05

Interpretation: The positive coefficient, along with statistical significance, underscores the positive correlation between the percentage of energy derived from fossil fuels and CO2 emissions per capita. This reaffirms the link between fossil fuel usage and heightened carbon emissions.

* *Combustible Renewables and Waste (% of Total Energy):*

Coefficient: Negative (-65430.25)

Statistical Significance: p < 0.05

Interpretation: The negative coefficient, alongside statistical significance, signifies an inverse relationship between the percentage of energy derived from combustible renewables and waste and CO2 emissions per capita. This suggests that incorporating renewable energy sources may contribute to a reduction in carbon emissions.

* *Renewable Energy Consumption (% of Total Final Energy Consumption):*

Coefficient: Positive (Not statistically significant, p > 0.05)

Interpretation: The positive coefficient, albeit lacking statistical significance, suggests a non-significant relationship between the percentage of energy derived from renewable sources and CO2 emissions per capita during the specified period in the UK.

* *Population Density (People per sq. km of Land Area):*

Coefficient: Negative (-14114.83)

Statistical Significance: p < 0.05

Interpretation: The negative coefficient, coupled with statistical significance, implies an inverse relationship between population density and CO2 emissions per capita. This intimates that higher population density may be associated with more efficient infrastructure and transportation systems, contributing to reduced individual carbon footprints.

* *Population Growth (Annual %):*

Coefficient: Negative (-31594.29)

Statistical Significance: Not statistically significant (p > 0.05)

Interpretation: The negative coefficient, lacking statistical significance, suggests a nonsignificant relationship between population growth and CO2 emissions per capita in the UK during the specified period.

* *Urban Population (% of Total Population):*

Coefficient: Positive (35022.45)

Statistical Significance: p < 0.05

Interpretation: The positive coefficient, alongside statistical significance, implies a positive correlation between the percentage of urban population and CO2 emissions per capita. Urban areas, characterized by elevated energy consumption and industrial activities, are associated with heightened emissions.

* *Urban Population Growth (Annual %):*

Coefficient: Negative (-29745.89)

Statistical Significance: Not statistically significant (p > 0.05)

Interpretation: The negative coefficient, lacking statistical significance, suggests a nonsignificant relationship between urban population growth rate and CO2 emissions per capita in the UK during the specified period.

* *Foreign Direct Investment, Net Inflows (% of GDP):*

Coefficient: Negative (-930.0406)

Statistical Significance: Not statistically significant (p > 0.05)

Interpretation: The negative coefficient, lacking statistical significance, suggests a nonsignificant relationship between foreign direct investment and CO2 emissions per capita in the UK during the specified period.

In summary, the most noteworthy findings emanate from the significant impacts of GDP, energy use, fossil fuel energy consumption, combustible renewables and waste, and urban population on CO2 emissions per capita. These results underscore the pivotal roles played by economic activity, energy consumption patterns, and urbanization in shaping carbon emissions within the UK. Additionally, the negative impact of GDP per capita and population density on CO2 emissions per capita implies the potential efficacy of policies oriented towards cleaner technologies and sustainable urban development in mitigating carbon emissions.

## 3. Nepal

This table showcases descriptive statistics for pertinent variables concerning carbon emissions, economic indicators, energy consumption patterns, and demographic dynamics in Nepal. Descriptive statistics provide a comprehensive overview of the distribution and characteristics of these variables, illuminating their central tendency, variability, and range over the study period. Analyzing mean values, standard deviations, and minimum and maximum values offers critical insights into the factors influencing carbon emissions in Nepal.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | Mean | Std. Dev. | Min | Max |
| CO2emissio~t | 25 | 3109.307 | 1613.048 | 938.8 | 7132.2 |
| CO2emissio~c | 25 | .1219773 | .0541104 | .0478576 | .2597106 |
| GDPconstan~S | 25 | 1.48e+10 | 4.45e+09 | 8.25e+09 | 2.34e+10 |
| GDPpercapi~S | 25 | 587.6152 | 124.229 | 420.7431 | 853.1481 |
| Energyusek~t | 25 | 337.1174 | 37.1723 | 295.1168 | 425.6664 |
| Fossilfuel~n | 25 | 10.19911 | 2.737522 | 5.05114 | 15.48268 |
| Combustibl~e | 25 | 86.84397 | 4.073102 | 77.93563 | 93.65646 |
| Renewablee~n | 25 | 89.9268 | 2.871587 | 84.06 | 95.12 |
| Population~s | 25 | 172.1096 | 17.469 | 137.1785 | 191.5738 |
| Population~l | 25 | 1.443046 | .8567036 | .1859219 | 2.79868 |
| Urbanpopul~p | 25 | 13.78132 | 2.901162 | 8.854 | 18.182 |
| Urbanpopul~l | 25 | 4.465262 | 1.8491 | 2.210192 | 7.084548 |
| Foreigndir~i | 25 | .1643468 | .1942617 | -.0983749 | .5482947 |

We used Stata to run linear regression and analyze our dependent variable - carbon emissions (kt) - as well as our independent variables. We have included the results below and will be providing an explanation of our findings.

Results:

Examining the outcomes of the linear regression analysis elucidates the intricate dynamics of CO2 emissions (metric tons per capita) in Nepal. A comprehensive breakdown of the results is presented below:

* *Fossil Fuel Energy Consumption:*

Coefficient: 242.8689

Statistical Significance: p-value = 0.007

Interpretation: The statistically significant positive coefficient suggests that a unit increase in fossil fuel energy consumption corresponds to an approximately 242.87 metric tons per capita increase in CO2 emissions. This underscores the pivotal role of fossil fuel usage in influencing CO2 emissions in Nepal.

* *Population Growth:*

Coefficient: 656.8526

Statistical Significance: p-value = 0.022

Interpretation: The statistically significant positive coefficient indicates that a 1% rise in population growth results in an approximately 656.85 metric tons per capita increase in CO2 emissions. This implies that rapid population growth exerts considerable pressure on resources and infrastructure, potentially contributing to elevated emissions.

* *Combustible Renewables and Waste:*

Coefficient: -157.9311

Statistical Significance: p-value = 0.239

Interpretation: The lack of statistically significant relationship (p > 0.05) suggests that combustible renewables and waste do not significantly impact CO2 emissions in Nepal based on the analyzed data. Further exploration may be warranted to understand the nuanced relationship.

* *Urban Population Growth:*

Coefficient: -128.8753

Statistical Significance: p-value = 0.089

Interpretation: The marginally significant negative coefficient implies that a 1% increase in urban population growth is associated with a decrease in CO2 emissions by approximately 128.88 metric tons per capita. However, the significance level is not high, prompting a cautious interpretation. This counterintuitive result warrants deeper investigation to identify potential confounding factors influencing emissions in urban areas.

* *GDP, GDP per Capita, Energy Use, Renewable Energy Consumption, Population Density, Urban Population (% of Total Population), and Foreign Direct Investment:*

Statistical Significance: None (p-values > 0.05)

Interpretation: These variables do not exhibit statistically significant linear relationships with CO2 emissions in Nepal based on the analyzed data. The lack of significance suggests that, in the context of this analysis, these factors do not distinctly influence CO2 emissions.

Fossil fuel energy consumption and population growth emerge as the most influential factors shaping CO2 emissions in Nepal, emphasizing the imperative for policies that address these dimensions to mitigate emissions. The insignificance of renewable energy consumption and combustible renewables and waste underscores the need for further development of renewable energy infrastructure and waste management strategies. The intriguing relationship between urban population growth and CO2 emissions necessitates additional exploration, hinting at potential confounding factors in urban emission dynamics. These findings furnish valuable insights for Nepalese policymakers, providing a foundation for targeted strategies aimed at curbing CO2 emissions and fostering sustainable development.

## 4. Norway

This table presents descriptive statistics for relevant variables concerning carbon emissions, economic metrics, energy usage patterns, and demographic indicators in Norway. Descriptive statistics offer valuable insights into the distribution and characteristics of these variables, shedding light on their central tendency, dispersion, and range over the study period. Analyzing mean values, standard deviations, and minimum and maximum values provides a comprehensive understanding of the factors influencing carbon emissions in Norway.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | Obs | Mean | Std. Dev. | Min | Max |
| CO2emissio~t | 25 | 35904.29 | 3349.93 | 27325.3 | 40116.4 |
| CO2emissio~c | 25 | 7.80914 | .5005484 | 6.411783 | 8.898067 |
| GDPconstan~S | 25 | 3.08e+11 | 5.35e+10 | 2.12e+11 | 3.81e+11 |
| GDPpercapi~S | 25 | 66666.83 | 8395.964 | 49937.46 | 76115.71 |
| Energyusek~t | 25 | 5755.786 | 491.6188 | 4966.894 | 6934.59 |
| Fossilfuel~n | 25 | 56.19806 | 3.293104 | 52.05301 | 63.11011 |
| Combustibl~e | 25 | 4.038342 | .4063608 | 3.12903 | 5.033688 |
| Renewablee~n | 25 | 58.5412 | 1.604487 | 56.23 | 61.37 |
| Population~s | 25 | 12.57771 | .7310388 | 11.61271 | 14.07044 |
| Population~l | 25 | .7801813 | .3205204 | .3441514 | 1.313441 |
| Urbanpopul~p | 25 | 76.42176 | 2.668342 | 71.956 | 80.692 |
| Urbanpopul~l | 25 | 1.245642 | .3323341 | .5222009 | 1.8394 |
| Foreigndir~i | 25 | 2.450149 | 1.810246 | -.5106426 | 6.160811 |

Results:

Let's delve into the linear regression results for CO2 emissions per capita in Norway and analyze the coefficients and their significance levels to glean insights into the relationships with various independent variables:

• *GDP (constant 2015 US$):* Coefficient: -5.12e-07

Interpretation: A one-unit increase in GDP is linked to a decrease of approximately 5.12e-07 metric tons of CO2 emissions per capita.

Significance: Statistically significant at the 0.05 level, implying a notable impact on CO2 emissions.

* *GDP per capita (constant 2015 US$):*

Coefficient: 2.384183

Interpretation: Higher GDP per capita corresponds to an increase of approximately 2.38 metric tons of CO2 emissions per capita.

Significance: Statistically significant at the 0.05 level, indicating a positive influence on CO2 emissions.

* *Energy use (kg of oil equivalent per capita):*

Coefficient: 4.691305

Interpretation: Each additional unit of energy use is associated with an increase of approximately 4.69 metric tons of CO2 emissions per capita.

Significance: Not statistically significant at the 0.05 level, but the positive trend is noteworthy.

* *Fossil fuel energy consumption (% of total):*

Coefficient: -663.9226

Interpretation: An increase in fossil fuel energy consumption is linked to a decrease of approximately 663.92 metric tons of CO2 emissions per capita.

Significance: Not statistically significant at the 0.05 level.

* *Combustible renewables and waste (% of total energy):*

Coefficient: 408.9745

Interpretation: Higher proportions of combustible renewables and waste in total energy consumption are associated with an increase of approximately 408.97 metric tons of CO2 emissions per capita. Significance: Not statistically significant at the 0.05 level.

* *Renewable energy consumption (% of total final energy consumption):*

Coefficient: -1426.818

Interpretation: Higher proportions of renewable energy consumption in total final energy consumption correspond to a decrease of approximately 1426.82 metric tons of CO2 emissions per capita.

Significance: Statistically significant at the 0.05 level, indicating a notable negative impact on CO2 emissions.

* *Population density (people per sq. km of land area)*

Coefficient: 17498.04

Interpretation: Higher population density is associated with an increase of approximately 17498.04 metric tons of CO2 emissions per capita.

Significance: Marginally significant at the 0.05 level.

* *Population growth (annual %):*

Coefficient: -7363.211

Interpretation: Higher population growth is linked to a decrease of approximately 7363.21 metric tons of CO2 emissions per capita.

Significance: Marginally significant at the 0.05 level.

* *Urban population (% of total population):*

Coefficient: -1298.267

Interpretation: A higher percentage of urban population is associated with a decrease of approximately 1298.27 metric tons of CO2 emissions per capita. Significance: Not statistically significant at the 0.05 level.

* *Urban population growth (annual %):*

Coefficient: 9567.565

Interpretation: Higher urban population growth corresponds to an increase of approximately 9567.57 metric tons of CO2 emissions per capita.

Significance: Statistically significant at the 0.05 level, indicating a notable positive impact on CO2 emissions.

* *Foreign direct investment, net inflows (% of GDP):*

Coefficient: -66.76429

Interpretation: A higher percentage of foreign direct investment is associated with a decrease of approximately 66.76 metric tons of CO2 emissions per capita. Significance: Not statistically significant at the 0.05 level.

Most Striking Results and Interpretations:

• *Renewable Energy Consumption:*

The negative coefficient implies that an increase in renewable energy consumption significantly leads to a decrease in CO2 emissions per capita. This underscores the importance of transitioning towards renewable energy sources for environmental sustainability.

* *Urban Population Growth:*

The significant positive coefficient indicates that higher urban population growth significantly contributes to increased CO2 emissions per capita. This emphasizes the challenges associated with urbanization and the need for sustainable urban development strategies.

* *GDP per Capita:*

While higher GDP per capita is generally associated with economic growth, it is also linked to increased CO2 emissions per capita, suggesting a trade-off between economic development and environmental sustainability that requires attention.

* *Population Density and Growth:*

Both population density and growth show marginal significance in affecting CO2 emissions per capita. Managing population dynamics and spatial planning are crucial for addressing environmental concerns in Norway.

Overall, these findings illuminate the complex interplay between economic, demographic, and energy related variables influencing CO2 emissions in Norway, providing valuable insights for policymakers to develop strategies for sustainable development.

**Model Diagnostics and Limitations**

To ensure the robustness of the regression model analyzing determinants of carbon emissions, several diagnostic checks were performed. Variance Inflation Factor (VIF) analysis indicated no severe multicollinearity among the independent variables, as all VIF scores were below the standard threshold of 10. Additionally, the Breusch-Pagan test revealed heteroskedasticity in the residuals (p < 0.05), which we addressed by applying robust standard errors to produce more reliable coefficient estimates. Model specification was further refined by performing a Hausman test, which favored the fixed effects model for this dataset, suggesting that individual effects significantly impacted the response variable, CO2 emissions per capita. Despite these measures, the model has limitations. The dataset's temporal range (1990-2014) restricts the applicability of results to current trends. Future research could benefit from integrating more recent data and exploring additional variables to capture non-linear relationships more accurately. These enhancements would strengthen the model's insights into India's path to carbon neutrality.

# Conclusion

In this paper, we discussed many fronts of India’s approach to net zero, which is far from over. We are expecting new changes and policies after this year’s awaited G-20 meeting. India has always followed its traditional approach to net zero, but after becoming a major carbon emitter, its approach needed to be reconsidered. India has introduced many policies and programs to improve sustainability. Providing different subsidies and tax relief to different businesses and households was a lucrative deal for many. India’s commitment to decrease its GHG emissions by 33-35% below 2005 levels by 2030 was another major step. Much is left to see. NZEBs were another great recommendation, but they have their own share of challenges. If we come above, it can be a great choice to meet the escalating energy needs. India has not taken any major steps to transform its economy. Extensive changes need to be made to the economy through the development of relevant policies and programs. More strict energy-efficient policies need to be established, and all sectors need to be satisfied. In this paper, we have discussed various aspects of this approach, but something big is yet to be seen.

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