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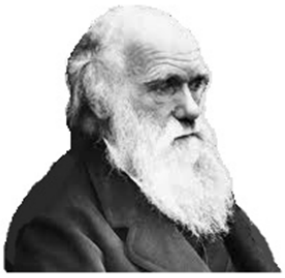

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Framework to Endorse Decarbonization and to Achieve Prospects of Net-Zero Carbon Emission in India

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ABSTRACT

India's pledge to achieve net-zero carbon emissions by 2070 calls for a framework that balances growth with sustainability. In order to reach the prospects of net-zero emissions by our country in the upcoming time period of the century, the article aspects its smoothing on carbon emission outlays in the short to medium term, which is the time frame that matters to policymakers at climate mitigation measures. It examines a comprehensive set of policy frameworks that includes public investment in green projects and subsidies for the development of renewable energy as a first green fiscal stimulus to go along with carbon pricing. Certain model simulations suggest that a comprehensive policy package can enhance the overall output of the low-carbon transition compared to the baseline, largely due to increased green civic investment. Even if carbon emissions continue to rise in the short term, the associated transitional output costs are expected to remain modest. Previous research highlights that upfront green fiscal measures can accelerate the shift toward a low-carbon economy by stimulating innovation, creating jobs, and strengthening resilience. Such fiscal interventions not only help to control carbon emissions but also guide the environment onto a more sustainable and greener trajectory, ensuring that climate action contributes to long-term economic growth and stability. Progress toward partial net-zero requires scaling renewable energy sources such as solar, wind, hydro, and green hydrogen to reduce coal reliance, while advancing energy efficiency across sectors. Introducing carbon pricing mechanisms will internalize environmental costs and incentivize cleaner production, supported by investment in green technologies like carbon capture, advanced storage, and smart grids. Expanding afforestation and carbon sinks alongside sustainable infrastructure development in transport and urban planning will strengthen resilience. Collectively, such measures establish a coherent pathway for India to achieve partial net-zero outcomes and lay the foundation for its long-term climate neutrality target.

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***Keywords*:** Net-Zero, Carbon Emission, decarbonization, carbon calculator, Go-Green

1. INTRODUCTION

India declared its goal to reach net zero by 2070 during the 26th session of the United Nations Framework Convention on Climate Change (COP 26) in November 2021. (FCCC Nov 2021; UNFCCC, 2020). The supervisory concepts of India's long-term low-carbon development policy includes equality and climate justice with differentiated responsibilities as well as deferential dimensions (UN, Paris Agreement; 2015).

The concept of reaching net zero emissions is gaining traction globally. Both wealthy and developing nations are making progress in lowering their emissions. These emissions contribute significantly to both global warming and air pollution. Because of dangerous emissions and global warming, climate change is starting to become a serious apprehension (UNEP 2022). To achieve sustainable future for all nations, real effort must be taken to cut emissions. In order to be a responsible participant in the future of the world. India needs to reduce its carbon emissions contribution to zero with an essential need of restoring atmospheric balance to achieve a biosphere with net-zero emissions.

Significance of Net-Zero Emission

A notable amount of greenhouse gas (GHG) emissions is produced by industrial and other human activities and end up in the atmosphere. Net-zero emissions stabilize the atmosphere and enhance atmospheric conditions to lower global temperatures by eliminating toxic substances from the atmosphere and offsetting greenhouse gas emissions. India may have very significant greenhouse gas emissions due to its size and population. Although it is impossible to totally cease greenhouse gas emissions, efforts can be taken to offset their effects on the atmosphere and make them disappear. Reducing emissions and reaching net-zero emissions is crucial at a time when global temperatures are rising, when net-zero emissions are extended, renewable energy sources give way to non-renewable energy sources. Greenhouse gasses released from many sources can be decreased by using renewable energy sources. Compared to fuels, renewable sources are greener and cleaner. India and other emerging nations must embrace smart devices and carbon capture technologies to lessen the impact of greenhouse gasses.

2. CONTEXTUAL BACKGROUND

India declared its commitment to achieve net-zero carbon emissions by 2070 at the 26th Conference of the Parties (COP26) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Glasgow, United Kingdom, in November 2021. This landmark announcement positioned India as a key player in global climate negotiations, reflecting both the urgency of addressing climate change and the challenges faced by developing nations in balancing economic growth with environmental sustainability. The net-zero pledge underscores India’s long-term vision to transition towards cleaner energy, reduce dependence on fossil fuels, and strengthen its role in international climate action. It contributes a significant step in India’s climate strategy, aligning with global efforts to combat climate change. Knowing the facts helps

to alleviate concern about a subject that is typically portrayed as doom and gloom in the public arena, the environment in which humans currently live has already suffered significantly from the rising global temperature brought on by these greenhouse gases (GHG) emission. Illustrations of these effects include the extinction of certain species, biodiversity loss, droughts, food shortages, forest fires, ocean acidification, melting of poles and glaciers, and rising sea levels (Maximillian et al. 2019; Mora et al. 2018; Yang et al. 2022). The average global atmospheric carbon dioxide (CO_2) concentration grew significantly from 290 ppm to 428 ppm from pre-industrialization, or roughly 1900, and 2024 (Chen 2021).

The rapid pace of global industrialization and the excessive reliance on non-renewable energy sources have led to a substantial increase in greenhouse gas emissions. This escalation has contributed to rising planetary temperatures and triggered multiple forms of environmental degradation, posing serious challenges to ecological stability and sustainability. Moreover, it is anticipated that by 2050, greenhouse gas emissions worldwide will increase by 50%, mostly due to CO_2 emissions from the use of non-renewable energy sources (Rabaey and Ragauskas 2014). Global surface temperature and oceans temperature, together with the average atmospheric CO_2 concentration, will continue to grow in terms of CO_2 emissions in the absence of efficient framework or precautionary measures.

Helmers et al. (2021) conducted a comprehensive study compiling net-zero carbon emission statistics from twenty institutions worldwide. Rather than simply comparing carbon footprints, the researchers examined and partially adjusted the data, supplementing missing contributions to enhance consistency and comparability across institutions. To homogenize results, emissions were measured using two standardized metrics: (i) CO2e emissions per capita and (ii) CO2e emissions per square meter of constructed area. Their findings revealed that eleven institutions reported a per-capita carbon footprint of less than or close to 1.0 metric ton CO2e per person per year, normalized by the number of individuals associated with each institution, regardless of institutional size. Zhu et al. (2021) explored the influence of China's higher education on regional carbon emissions, analyzing data from thirty-one provinces between 2004 and 2015 through panel threshold regression and panel quantile regression models. Their results revealed significant threshold effects of both higher education scale and quality on per-capita carbon emissions. Specifically, expansion in the scale of higher education tends to amplify carbon emissions per capita when technological development surpasses a certain threshold.

Conversely, improvements in higher education quality can mitigate the positive impact on emissions when income levels exceed the threshold. These findings underscore the complex interplay between education, technology, and socio-economic conditions in shaping regional carbon outcomes. Kiehle et. al. (2022), worked on carbon footprint at higher education institute at University of Oulu, which provides a case study for a Northern European institution to extend the pool of available calculation methodologies tested under real-life conditions. The carbon footprint calculation of the University of Oulu utilises a hybrid model, combining approaches of Environmentally Extended Input-Output Analysis and Life-Cycle Assessment. The focus of the work was to consider included scopes and categories of emissions that represent indirect and non-energy-related greenhouse gas emissions, such as commuting or procurement of research and laboratory equipment. Yap et al. and Osman et al. (2022) underscored that accelerating global industrialization and the over-exploitation of fossil fuels have intensified greenhouse gas emissions, driving temperature increases and widespread environmental challenges.

This context highlights the urgent necessity of achieving net-zero carbon emissions. Currently, only 4.5% of countries have reached carbon neutrality, while most aim to do so between 2050 and 2070. The researcher emphasized that life cycle assessments are essential for evaluating all decarbonization measures and for designing effective carbon-neutral systems, their reaearch identification concludes that future research must strengthen life cycle analysis to identify pathways toward system-wide carbon neutrality. Achieving net-zero emissions, their conclusion states that advancing global sustainable development will generate substantial environmental, social, and economic benefits. Aghamolaei and Fallahpour (2023) emphasized that universities and other higher education institutions (HEIs) hold a crucial responsibility in advancing decarbonisation and fostering sustainable development, with the rapid global expansion of university campuses, the adoption of low-carbon and energy-efficient practices has become imperative. Their findings underscore the importance of integrating sustainability measures into campus infrastructure and operations, positioning HEIs as key drivers in the transition toward a greener future.

Lewis-Brown et al. (2023) examined the urgent need to reduce greenhouse gas emissions, remove carbon from the atmosphere, and stabilize natural carbon sinks, which has led to the development of diverse carbon management strategies, including voluntary carbon offsets (VCOs), their study focused on universities and enterprises with both high carbon footprints and significant influence in climate science and policy discussions. The research outcomes raised concerns that reliance on VCOs may create a moral hazard, discouraging institutions and enterprise from pursuing additional emission-reduction measures with the compared the carbon management practices of institutions and enterprise that adopted VCOs with those who did not.

Their research findings revealed that adopters tended to measure emissions over longer periods and set net-zero targets earlier than non-adopters, suggesting that while offsets carry risks, they may also encourage more proactive long-term planning. Shakya et al. (2023) highlighted that developing countries face significant obstacles in pursuing net-zero emissions targets, largely due to their shared aspirations for rapid economic growth, improved socio-economic conditions, and enhanced climate resilience. These ambitions often clash with the competitiveness, acceptability, and long-term sustainability of proposed low-carbon initiatives. The researcher stress the importance of understanding both the economic and technical dimensions of net-zero pathways.

They contend that constraints can be more effectively addressed when the co-benefits of such initiatives are transparently identified and integrated into their implementation. This approach not only strengthens feasibility but also builds broader support for sustainable transitions in developing contexts. Suteki et al. (2023) argued that higher education institutions (HEIs) can play a pivotal role in university-based mitigation efforts by reducing local emissions through service-learning approaches that integrate climate change action into academic practice. Their systematic literature review explored how HEIs contribute to climate change mitigation, highlighting the use of e-learning platforms and the creation of climate governance networks as effective strategies. As organizations with substantial influence on local communities,

HEIs can act as catalysts for sustainable development systems. Suteki et al. emphasized the need for institutions to regulate and modernize energy systems, reorganize transportation systems, and actively communicate sustainability messages to their communities. By encouraging climate action at both institutional and personal levels, universities can generate tangible local benefits while advancing broader sustainability goals.

Tang et al. (2023) investigated the relationship between education level, technological development, and their interaction on urban carbon emission efficiency using a generalized method of moments model. Their analysis drew on data from the Yangtze River Delta and the Guangdong–Hong Kong–Macao Greater Bay Area between 2010 and 2021. The study revealed two key findings: 1) Carbon emission efficiency in both urban agglomerations has shown steady growth, though overall levels remain low and regional disparities persist. The main limiting factor is pure technical efficiency, which constrains improvements in comprehensive efficiency. 2) Education and technological development are highly positively correlated with emission efficiency, and their interaction significantly enhances outcomes. Additionally, the research highlighted that economic development, industrial structure upgrading, degree of openness, and Internet penetration act as influential control variables, further strengthening carbon emission efficiency in these regions.

Paredes-Canencio et al. (2024) conducted a comprehensive review of 50 carbon footprint studies published between 2018 and 2022, focusing on how to adopt policies and management systems to curb greenhouse gas emissions for a pivotal role in advancing sustainability by driving innovation, research, and technological solutions. As a result, more establishments are joining the global effort against climate change every day. The study synthesizes methodologies, scopes, outcomes, and emerging trends in carbon footprint assessments, while also proposing a framework for achieving net-zero emissions. Their analysis revealed that the most frequently examined sources of emissions were electrical energy consumption (78%), transportation (74%), and fuel use (64%). These findings highlight the critical areas where must focus their sustainability strategies to make meaningful progress toward carbon neutrality.

3. CONCEPTUAL FRAMEWORK

Net-Zero Practices and Policies needed in India to get its emissions measures down to Net-Zero level to Achieve Partial Net-Zero Carbon Emission

India's transition toward partial net-zero carbon emissions necessitate a carefully balanced mix of policies and practices that reduce greenhouse gas output while sustaining economic growth. Central to this effort is the expansion of renewable energy, with accelerated deployment of solar, wind, and hydro power to gradually replace coal dependence. Complementary measures must include energy efficiency incentives across industries and households to reduce demand-side emissions. Establishing carbon pricing mechanisms through taxes or trading systems will internalize environmental costs and encourage cleaner production pathways. Parallel investment in green technology innovation, such as carbon capture, green hydrogen, and advanced storage solutions, is essential to bridge short-term reductions with long-term sustainability. Expanding afforestation and carbon sink initiatives will offset unavoidable emissions, while sustainable infrastructure development in transport and urban planning will enhance resilience. Embedding a transition framework ensures that vulnerable communities and workers in coal-dependent regions are supported through retraining, financial assistance, and inclusive development programs. These measures altogether establish a pragmatic pathway for India to achieve partial net-zero emissions, laying the groundwork for its long-term 2070 net-zero target.

India's long-term low-carbon development strategy rests on certain key transitions (Figure 1) based on the contextual background to attain the net-zero pathways viz.

1) How to get to a future with Net-Zero emissions,
2) How to establish Nations Net-Zero Goals,
3) Most effective strategy for nations to synchronize their short-term emissions minimization targets with their long-term carbon footprint reduction aims,
4) Establishing long-term programmatic approach to Net-Zero projects,
5) India's long-term plans for low-carbon development,
6) Green energy infrastructure to unlock Net-Zero,
7) Supporting businesses to "Go Green" by 2030,
8) India's Requirements to Reach Net Zero Carbon Emissions.

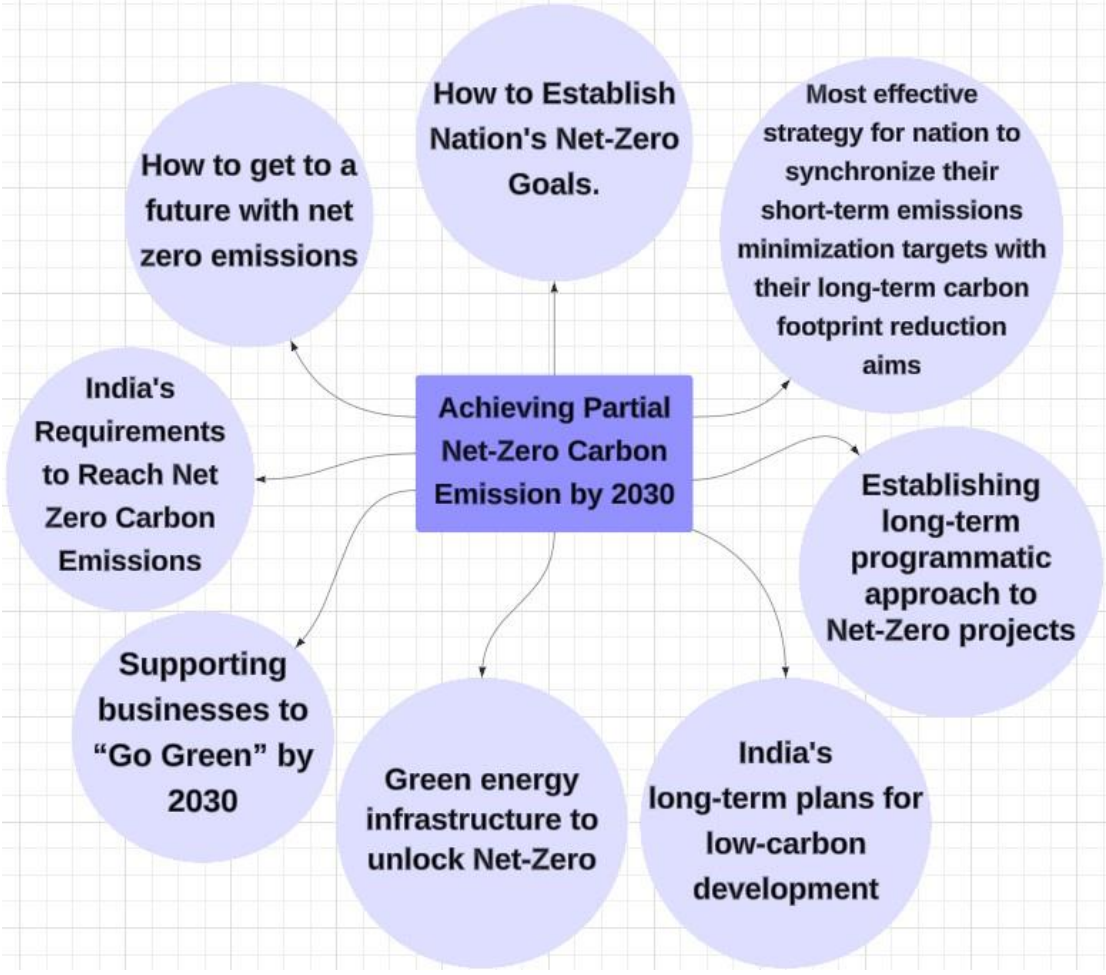

Figure 1. Parameters to Achieve Net-Zero Carbon Emission.

4. DISCUSSION

4. 1. How to get to a future with Net-Zero Emissions

The nation intends to take a number of actions toward achieving net-zero emissions in the future. Numerous proactive measures have been taken to minimize emissions and get them down to zero. India has recently announced several significant future initiatives in Glasgow

Climate Pact (2021); United Nations Climate Change Conference; COP26 (UNFCCC, 2020). It is projected that by 2030, when many of India's sustainable development objectives will have been accomplished, the nation will have reached its target of 500 GW Green energy. In order to reduce its reliance on fossil fuels and expand its use of renewable energy, India is also aggressively seeking to fully use its non-fossil fuel resources. As reliance on fossil fuels declines, so does the impact of greenhouse gases. In the next five years, India will install 50% renewable fuel sources for electricity generation, as per the its pledge in UNFCCC. In order to reduce carbon emissions, India is also utilizing cutting-edge energy sources like green hydrogen energy. The Perform, Achieve and Trade strategy, (PAT, NACPP) which India also embraced, helped to avoid 92 million tonnes of CO_2 emissions in the first and second cycles. These actions, both now and in the future, could bring the nation's emissions down to Net-Zero.

4. 2. How to Establish Nation's Net-Zero Goals

The net-zero emission targets are crucial, globally, almost all nations have established Net-Zero goals for their emissions of greenhouse gases and carbon. Earth is a globe that can support life, and nations all around the world are aiming toward net-zero emissions in order to protect this fact. The average global temperatures have risen by 1.5 °C compared to the optimum temperature, (NASA, 2022). Citizens from units of government, corporations, and private sectors are promising to cut back on their carbon emissions (Florence et. al. 2021). In addition to India, China, the United States, and European Union have declared goals to attain net zero emissions. Remarkably, over 9,000 businesses and one thousand towns globally have embraced the United Nations' Race to Zero program, which aims to eliminate greenhouse gas emissions globally by 2050, whereas India has declared to be a partial achievement of Net-Zero by the end of 2030 and can sustain the same by following the acknowledged key practices adopted by other developed nations.

4. 3. Most effective strategy for Nation to synchronize their short-term emissions minimization targets with their long-term carbon footprint reduction aims

Nation wants to reduce their greenhouse gas emissions to almost partial by 2030. The long-term objectives for reducing carbon footprints are slated for 2070 (PIB Delhi, 2023). The long-term objectives for reducing carbon footprint should be in line with the short-term objectives. The short-term objectives ought to be both challenging and doable. The formulation and execution of policy decisions ought to be the main objectives of the near term. In order to bring about a long-term shift in the previous carbon footprints, long-term objectives of carbon footprint reduction should be concentrated on verifying the short-term outcomes. Policy Recommendations for Synchronizing Short-Term Emissions Targets with Long-Term Carbon Reduction Goals viz. (Govt. of India, 2022)

a) **Science-Based Pathways:** Establish clear interim milestones aligned with the overarching net-zero objective. Ensure short-term actions, such as renewable energy expansion and efficiency improvements, are consistent with long-term decarbonization trajectories. Adopt internationally recognized frameworks such as IPCC pathways to benchmark progress.
b) **Integrated Policy Design:** Harmonize climate policies with national economic and social development plans. Avoid lock-in of high-carbon infrastructure by mandating

transition strategies for energy, transport, and industry sectors. Embed climate considerations into fiscal policies, trade agreements, and industrial strategies.

c) **Robust Monitoring and Accountability:** Develop transparent reporting mechanisms with annual progress reviews. Establish independent oversight bodies to evaluate compliance with emission targets. Use digital tools and satellite monitoring to track emissions in real time.
d) **Technology and Innovation Investment:** Prioritize funding for emerging technologies such as carbon capture, green hydrogen, and advanced energy storage. Create innovation hubs and public-private partnerships to accelerate deployment. Provide incentives for research and development that bridges short-term reductions with long-term transformation.
e) **International Cooperation:** Engage in global climate agreements and regional partnerships to share best practices. Coordinate carbon pricing mechanisms and trade policies to prevent competitive disadvantages. Support developing nations with finance and technology transfer to achieve synchronized progress.

Implanting such recommendations within national climate strategies, governments can transform short-term emission reduction measures into foundational steps toward long-term carbon neutrality. This alignment ensures that immediate actions are not isolated efforts but part of a coherent trajectory, fostering resilience, equity, and sustainability while advancing the broader objective of a net-zero future.

4. 4. Establishing long-term programmatic approach to Net-Zero projects:

Creating a government finance strategy to provide investors and businesses with long-term clarity on the duration of funding commitments; and creating sustainable governance structures for net-zero. Establishing "Key plans for Net-Zero Delivery" to oversee the implementation of best practices for important projects, put net-zero delivery" at the heart of government thinking and take charge of net-zero priorities when they involve several departments. (Ziyu and Seiyong; 2023)

4. 5. India's long-term plans for low-carbon development

India is taking important and significant steps to safeguard the environment and advance the Race to net-zero Emissions. (PIB Delhi. 2023), (MoEFCC 2023).

a) By constructing equipment to harness 50% of its renewable sources by 2030 to raise its renewable energy quotient. A significant portion of greenhouse gas emissions will be decreased by increasing the usage of renewable energy.
b) India is also looking forward to improve energy efficiency across a number of industries, including industrial manufacturing, power and electricity, and transportation. The energy efficiency measures will assist in lowering the excessive consumption and fuel and power waste in many industries.
c) India is significantly working towards both imported and native EV plants for the transition to electric vehicles in an effort to achieve net-zero emissions and pollution from moving automobiles.
d) In order to enhance natural forest cover and reduce the consequences of climate change, India seeks to protect and grow its biodiversity and forest cover. Afforestation and forest

conservation contribute to the achievement of net zero emissions and other developmental objectives.

e) India is currently attempting to lessen the consequences of climate change by strengthening its natural resource management capabilities. This aids in disaster management and emergency situations in addition to improving resource allocation in a population that is expanding.

4. 6. Green energy infrastructure to unlock Net-Zero:

a) Developing a cross-sectoral infrastructure strategy to support the development of infrastructure for electricity, hydrogen, other liquid and gaseous fuels, and CO_2 networks that support the Indian green economy is one way to use infrastructure to unlock net-zero.

b) Another is to reform the government's approach to planning by streamlining procedures so that locally supported solar and onshore wind generation systems could be developed in communities more easily. These are some of the ways that Green energy infrastructure can help to achieve net-zero emission.

4. 7. Supporting businesses to "Go Green" by 2030

a) Examining the ways which uses the capital allowances and tax system to encourage investment in decarbonization to achieve net zero influx by the end of 2030. (PIB Delhi. 2023)

b) Implementing the suggestions made by Ministries from the Department of Business, Department of Energy and Department of Industrial development and Department of Education to further work with Go-Green implementation.

c) Releasing recommendations on the skills required in the Indian labour market to transition to net-zero as well as the commitments from the net-zero strategy, and reporting on progress on a regular basis.

d) Starting a campaign "Grow Green" that provided vouchers and informational resources to small and medium-sized businesses to assist them in planning and funding the energy transition.

4. 8. India's Requirements to Reach Net-Zero Carbon Emissions

India has actively taken and implemented the decision to take the lead in the fight against global warming and climate change. People from across the nations globally are impacted by the phenomena of global warming and climate change. Immediate actions are required to achieve net-zero emissions for a better environment in order to safeguard both the present and future generations (PIB Delhi. 2023).

India's commitment to achieve net-zero carbon emissions by 2070 demands a comprehensive strategy that balances climate action with economic growth and social equity. A rapid energy transition is essential, with renewables projected to supply the majority of power, and coal dependence reduced to minimal levels. Sectoral reforms must prioritize electrification of transport, decarbonization of industry, and sustainable agriculture, supported by carbon capture technologies and afforestation to enhance carbon sinks. Strong governance frameworks including transparent monitoring, robust policy instruments, and alignment with self-determined net-zero contributions are critical to ensure accountability, along with a

necessary transition approach to safeguard vulnerable communities, and integrate climate action. By embedding innovation, equity, and resilience into its climate strategy, Nation can synchronize short-term emission reductions with its long-term net-zero vision.

5. CONCLUSION AND RECOMMENDATION

Policies that promote economic growth while advancing net-zero carbon objectives establish a coherent pathway to sustainability. By aligning climate action with innovation, resilience, and social equity, such measures ensure that decarbonization strengthens long-term development rather than constraining progress, thereby embedding environmental responsibility within the broader framework of national advancement. Collaborative working with industry leaders to further improve technology roadmaps in research and development that identifies critical decision points to assure that priority technologies meet the Indian growth and position for success in net-zero goals by 2030 and beyond. Increasing accessibility and involving the people by developing a "carbon calculator" to give consumers information on carbon costs; working with industries to introduce a standardized approach to ecolabelling.

Providing support to a number of innovator locations that aim to advance net-zero and its associated economic opportunities; streamlining the local net-zero funding landscape to make it more effective and efficient for both central and state government; and reforming the planning system at both the state and national levels. Expanding the government's public reporting on net-zero to increase the amount of information available to the public.

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