

Strategy for the Long Term Low Carbon Energy Transition for India in the Context of Sustainable Development

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Abstract

Climate change is a grave systemic risk and one of the most formidable threats to the stability of the global financial system. The transition to a low-carbon economy requires a reallocation of capital and global financial flows. Against this backdrop through this paper we find out the response to the research question of whether there is a need to design and implement a long term clean energy transition strategy for emerging market and developing economies demonstrating India as an example. The developing countries have to ensure affordable and reliable energy to all and reduce its dependence on fossil-based energy taking into account the challenges of lack of availability of adequate financial resources, constrains in the deployment of cost intensive technology at commercial scale and bridging the capacity building gaps. We have conducted systematic literature review on this aspect. Based on the identified research gaps and supplementing the inputs received through interactions and interviews held with the relevant subject experts, academicians and policy makers, we have suggested that detailed sub-national level studies are required to be conducted to estimate the cost of implementing any long-term low carbon energy transition plan for India. Such study should clearly address the challenges of low carbon energy transition from the social, economic and equity perspective of development of the fossil fuel dependent communities. Future studies should underscore the need for grounding of clean technologies at commercial scale for various sectors and estimate the requirement of international climate finance to augment the limited budgetary resources of the national and sub-national governments in India.

Keywords: Greenhouse gas, Low carbon energy transition, Capacity building gaps, Nationally Determined Contributions, Sustainable development Institutional arrangement, Paris Agreement

Disclosure statement

The opinions presented by the authors in this paper are solely their own and do not represent the views of any government or affiliated institutions.

Introduction

The connection between development and climate change has become increasingly evident. Achieving progress in both areas will necessitate substantial investments in low-carbon and climate-resilient infrastructure. A development model that effectively addresses these needs must take into account the political economy of a long-term low-carbon transition while simultaneously fostering communities' resilience to the adverse impacts of climate change. The development pathways chosen by countries significantly influence their greenhouse gas (GHG) emissions, thereby shaping the challenges and opportunities for mitigation. The Intergovernmental Panel on Climate Change (IPCC) has concluded that climate change mitigation efforts designed and implemented within the framework of sustainable development, equity, and poverty eradication, and embedded within the broader development agenda, are likely to be more durable, acceptable, and effective (IPCC, SPM, 2022). The Paris Agreement, a legally binding international treaty, underscores this approach. Article 2.2 of the Agreement mandates that its implementation should reflect equity and the principles of common but differentiated responsibilities and respective capabilities, considering different national circumstances (Paris Agreement, 2015). The Agreement, which came into force on November 4, 2016, also highlights the need for countries to formulate and communicate long-term low GHG development strategies in accordance with Article 4.19. This requires countries to consider policies and action plans that acknowledge their common but differentiated responsibilities and respective capabilities, in light of their unique national circumstances (Rajamani, L. 2016). This paper aims to explore the drivers behind the formulation of long-term low-carbon energy transition plans by countries, examining the potential benefits and associated challenges. It specifically focuses on how developing countries, using India as a case study, can devise effective energy transition plans. According to a discussion paper by the World Wide Fund for Nature (WWF), energy transitions should be planned and executed within the broader context of societal development to achieve a sustainable and climate-neutral future. These transitions should also aim to meet the United

Nations Sustainable Development Goals (SDGs) (Treadwell, K., Cooper, D., 2021).

The European Union has articulated a long-term strategy aimed at achieving carbon neutrality by 2050. Attaining this target will necessitate an additional yearly investment ranging from 175 billion to 290 billion euros over the coming decades. The EU's climate policies emphasize the importance of both private and public investments in transforming the EU economy to meet climate, environmental, and social sustainability goals, including the objectives of the Paris Agreement and the Sustainable Development Goals (SDGs). In the context of India, it is recommended that policymakers prioritize the needs and aspirations of its citizens, especially the vulnerable coal-dependent communities, when designing plans for India's long-term low-carbon energy transition. This approach ensures that no one is left behind and carefully calibrates policies to avoid conflicts between affordability, energy security, and sustainability. This paper further examines the necessary actions to create an enabling policy environment, effectively leveraging various pools of capital at appropriate times for specific purposes. It also underscores the importance of ensuring public participation in the low-carbon transition pathway.

Research Methodology

This article is based on a comprehensive review of existing literature, aimed at identifying research gaps in the field of low-carbon energy transitions. The methodological approach involved several key steps to ensure a robust understanding of the research question and to address identified gaps effectively.

Literature Review and Identification of Research Gaps:

A thorough review of existing literature was conducted to identify gaps in current research. This step was crucial for framing the research question and understanding the areas that require further investigation.

Collection and Analysis of Secondary Data:

Secondary data were collected from a variety of sources, including the websites of international organizations, ministries, government agencies, and departments. This data provided a broad base of information necessary for a detailed analysis.

Semi-Structured Interviews:

The views of relevant policy experts and academicians working with the national government in various line ministries and institutions, as well as officials from sub-national governments involved in low-carbon energy transitions, were solicited through semi-structured interviews. These interviews were designed to gather in-depth insights and practical perspectives on the topic.

The data collected from these interviews were interpreted and described in the results section, providing a nuanced understanding of the current state of low-carbon energy transition policies and practices. This multi-faceted approach ensures that the research is grounded in both theoretical and practical insights, offering a comprehensive overview of the subject.

Literature review

The term “Just Transition” emerged in the late 1990s, highlighting the intrinsic link between ecosystem conservation and employment (ERM, 2020). The International Labour Organization (ILO) provides a widely accepted definition, focusing on measures to mitigate job losses and industry phase-outs, while promoting new, green, and decent jobs to address environmental, economic, and social issues concurrently (Smith, 2017).

Waisman et al. (2016) emphasize that long-term low emission development strategies (LT-LEDS) should not be merely seen as international reporting requirements. Instead, they should be used to define national long-term strategies that inform and enhance short-term policy decisions. Falduto and Rocha (2020) argue that national LT-LEDS can drive short-term climate action by providing critical information to enhance Nationally Determined Contributions (NDCs). A long-term perspective helps governments consider trends such as the availability and cost of technologies, enabling policymakers to adopt measures that facilitate large-scale deployment.

The experiences of seven countries, including China and Costa Rica, illustrate this approach. China's long-term strategy includes the development and scaling up of technologies like Carbon Capture, Use, and Storage (CCUS), with short- and medium-term actions outlined in

the Chinese Roadmap for CCUS deployment, which may take 10-15 years for commercial scale (Falduto and Rocha, 2020). Costa Rica's strategy identifies risks of long-term carbon lock-in in various sectors and advises policy options to avoid it, such as favoring public transport infrastructure over private vehicles in the transport sector.

For countries without a long-term strategy, it is crucial to consider how to avoid potential carbon lock-in from short- and medium-term actions. Brazil's updated NDC, in the context of the Glasgow Climate Pact, commits to achieving climate neutrality by 2050. This commitment will be translated into policies implemented by the Brazilian Federal Government.

Energy Transition Recommendations by the United Nations

The United Nations report on energy transition recommends that OECD countries phase out coal by 2030 and non-OECD countries by 2040, recognizing the need for support in this transition. Coal phase-out is expected to reduce stranded asset risks, enhance energy self-reliance, and provide co-benefits in health and fiscal sectors. Countries are advised to develop time-bound strategies that address socio-economic aspects of the transition. Sustainable development also calls for medium- and long-term energy planning strategies, decarbonization targets, and policies that promote sustainable energy systems. The report emphasizes the need for increased ambition in NDCs, involving sub-national and city-level decision-makers due to rapid urbanization and the decentralized nature of modern energy systems (United Nations, 2021). However, the study lacks concrete evidence of country-specific institutional arrangements integrating regional or sub-national sustainable development plans with national long-term low-carbon strategies.

India's Energy Transition and Climate Goals

India's NDC achievements hinge on inclusive growth plans, including energy access, housing, healthcare, education, and poverty eradication (Prasad & Sood, 2019). With its economic growth and potential to become a \$5 trillion economy, India's energy demand is set to increase more than any other country this decade. To achieve its net-

zero emissions target by 2070, most of the decade's energy demand growth must come from decarbonized sources.

The International Energy Agency (IEA) reports that solar power plants in India are now cheaper to build than coal ones due to technological advancements, a conducive policy environment, and proactive private sector involvement. India's renewable electricity capacity is growing faster than any other major economy, with new capacity additions expected to double by 2026. During the 26th Conference of Parties in Glasgow in 2021, Indian Prime Minister Narendra Modi announced ambitious 2030 targets: installing 500 gigawatts of renewable energy capacity, reducing emissions intensity by 45%, and cutting a billion tonnes of CO₂. This announcement has been widely appreciated by global leaders for its potential to attract investment and facilitate new technology deployment, supporting India's transition to a clean, climate-resilient economy.

Ahluwalia et al. (2012) discuss India's energy trajectory from 2012 to 2047, focusing on energy security in terms of import dependence and carbon emissions. Projections, based on version 2 of the India Energy Security Scenario (IESS) calculator by NITI Aayog, show that the low carbon (LC) scenario involves implementing 17 energy-saving options across 8 energy-using sectors. These measures aim to balance energy demand with sustainable development and carbon reduction goals.

Critical Analysis of India's Long-term Low Carbon Energy Transition

Demand Side Actions

The authors utilized the IESS calculator to analyze 17 parameters across eight sectors, aiming to reduce the energy intensity of GDP. This approach offers insights into developing a policy framework for India's long-term low-carbon energy transition, considering sustainable development challenges.

1. Passenger Transport: Potential demand reduction is achievable through better urban planning, smart city development, increasing rail and public transport usage, and promoting electric (EVs) and fuel cell vehicles (FCVs). This multi-faceted approach addresses both

energy efficiency and urban mobility, yet its success heavily relies on substantial infrastructure investments and behavioral changes among the population.

2. Freight Transport: Reducing energy demand involves constructing dedicated freight corridors, integrated logistic planning, and increasing rail freight share. While these measures are promising, they require extensive coordination and investment, potentially facing resistance from established logistics operators.
3. Residential and Commercial Buildings: Energy demand can be curtailed through high-rise construction, energy-efficient insulation, and smart appliances. However, the implementation of these measures could be hindered by existing building codes, high costs, and slow adoption rates in the real estate sector.
4. Industrial Sector: Increased penetration of energy-efficient technologies and a shift to grid-based electricity in industries like cement and steel are crucial. Despite their potential, these changes necessitate significant capital expenditure and technology upgrades, posing financial and operational challenges for industries.
5. Agriculture: Improving tractor and pump efficiency and phasing out diesel pumps can reduce energy use. However, this transition might face resistance due to the upfront costs and the entrenched reliance on diesel-powered equipment.
6. Cooking Sector: Enhancing stove efficiency and switching to electric or induction-based cooking can lower energy demand. This shift requires widespread behavioral change and reliable electricity access, which might be challenging in rural areas.
7. Telecom Sector: Improving base transceiver station efficiency and switching from diesel to solar or electricity is essential. However, the feasibility of such changes depends on the availability of consistent renewable energy sources and technological advancements.

The authors estimate a 36% reduction in total energy demand by 2047 under the low-carbon scenario, driven by the industry, transport, and building sectors. While

promising, achieving these reductions requires overcoming substantial economic, technological, and social barriers.

Supply Side Actions

The authors discuss sustainable energy supply actions to reduce emission intensity by switching to cleaner fuels beyond BAU levels. They highlight several potential interventions:

1. **Electricity Generation:** Super-thermal technology and reduced transmission losses are crucial. The deployment of bio-energy, solar PV, and wind (both onshore and offshore) is emphasized. Although these measures promise cleaner energy, they involve significant technical and financial challenges, particularly in scaling up renewable capacity.
2. **Energy Demand and Generation:** The low-carbon scenario envisions higher electricity generating capacity compared to BAU, with a significant increase in the share of wind and solar. However, integrating such a large share of renewables presents technical challenges in ensuring grid stability and reliability.
3. **Coal-Based Generation:** Under the BAU, coal generation capacity increases to 515 GW by 2047, whereas in the low-carbon scenario, it peaks at 292 GW in 2032 and declines to 261 GW by 2047. This decline in coal dependency has implications for domestic production of thermal generation equipment, which the study does not fully explore.

The shift from coal to renewable energy sources aligns with global climate goals but presents several policy and practical challenges. These include the need for robust grid infrastructure, substantial investments in renewable technologies, and addressing the economic implications for the coal industry and associated workers.

The study offers a comprehensive roadmap for India's low-carbon energy transition, it underscores the complexity and multi-dimensional nature of this undertaking. The proposed strategies require not only technological advancements and financial investments but also significant policy support, institutional coordination, and societal acceptance to be effective.

The article provides an in-depth analysis of the steps necessary for a transition to a low-carbon energy system, with a focus on the integration of renewable energy (RE) and grid modernization. It covers demand-side actions, supply-side interventions, policy perspectives, and international comparisons, primarily using examples from South Africa and India. The article emphasizes the importance of comprehensive planning, technological innovation, and international cooperation to achieve these goals.

Grid-scale Storage and Smart Grids

The variability of electricity generated from renewable sources like solar and wind is a well-known challenge. The article correctly highlights the importance of building grid-scale storage capacity to address this variability. The Lawrence Berkeley National Laboratory study's estimation of 140 GW of balancing capacity by 2047 underscores the scale of the challenge.

Grid Modernization: Upgrading existing grids to smart grids and professional management is crucial. Smart grids can optimize electricity distribution, reduce losses, and enhance reliability. This transition requires significant investments and the training of highly skilled personnel.

State and Sub-national Levels: Effective management at these levels is essential for the successful implementation of these measures, ensuring that local conditions and needs are met.

Supply-side Interventions

The article discusses various supply-side interventions, including reducing transmission and distribution losses, deploying smart grid measures, and adopting new transmission technologies. These interventions are critical to improving the efficiency and reliability of the electricity grid.

Electric Vehicles (EVs): The role of EVs in reducing emissions is mentioned, with optimism about future technological developments. While EVs have the potential to significantly reduce emissions, their widespread adoption depends on infrastructure development, consumer acceptance, and technological advancements.

Policy Perspectives

The authors highlight several policy measures necessary to support the transition to a low-carbon path. These include energy pricing and taxes, regulation, public investment, and cooperation across different government levels.

Energy Pricing and Taxes: Proper pricing can incentivize energy efficiency and the adoption of renewable energy sources. However, the article notes that exploring these issues in depth is beyond its scope, leaving a gap in understanding how these measures can be effectively implemented.

Urbanization: Policies focused on urbanization are crucial as cities are major energy consumers and sources of emissions. Clear and consistent policies are needed to guide urban development in a sustainable direction.

International Comparisons: South Africa

The article draws comparisons with South Africa's Integrated Resource Plan 2019 (IRP 2019), which aims to decommission 11,000 MW of coal-fired generation capacity and add 22,500 MW of renewable capacity by 2030.

Just Energy Transition: The studies on South Africa's just energy transition strategy emphasize the need for a comprehensive approach that includes addressing job losses, planning for coal mine closures, and funding needs. The feasibility of workforce transfer from coal regions to renewable sectors is promising but requires careful planning and support.

Financing Climate Action

Bolton et al. (2024) discuss the financial challenges developing countries face in phasing out coal. They argue for conditioning renewable finance on coal phase-out and scaling up just energy transition partnerships between developed and developing countries.

Financial Support: Developing countries often lack the financial resources needed for a rapid transition. Adequate and predictable financial support is essential for these countries to meet their climate goals while ensuring inclusive growth.

India's Low-carbon Transition

India's climate mitigation measures and policies for emerging technologies like green hydrogen, battery storage, and low-carbon manufacturing are commendable. However, the article highlights several near-term challenges:

Economic Challenges: Rising commodity prices, energy affordability, and energy security risks are significant barriers. Additionally, financially struggling electricity distribution companies impede the sector's transformation.

Health and Pollution: Continued reliance on traditional cooking fuels and poor urban air quality pose health risks. Addressing these issues requires a multi-faceted approach that includes providing access to cleaner fuels and improving urban infrastructure.

International Cooperation: The Indo-German Partnership for Green and Sustainable Development is a positive step, with Germany committing significant financial and technical support. Such partnerships are crucial for mobilizing the necessary resources for India's decarbonization efforts.

Gap Identification

The article identifies several critical gaps and challenges that hinder the transition to a long-term low-carbon energy system:

Financial Constraints: The IPCC (2018) underscores the enormous financing needs for infrastructure investments in mitigation and adaptation strategies. Developing countries, in particular, face challenges in mobilizing sufficient funds from private and public sources due to high risks associated with low-emission investments.

Capacity Building Deficits: Waisman et al. (2016) emphasize the necessity of robust capacity building for national and sub-national authorities to effectively implement climate actions. This includes enhancing technological capabilities and fostering innovation to meet the demands of a low-carbon economy.

Technological and Innovation Gaps: Despite declining costs and increased deployment of renewable energy technologies like solar and wind, many developing

countries lack the infrastructure and technological capacity to adopt these technologies at scale. The absence of enabling conditions, limited finance, and inadequate technology transfer further exacerbate this gap.

Just Transition Challenges: The transition away from fossil fuels, as outlined by the IPCC (WG III SPM, 2022) and initiatives like the EU's Just Transition Mechanism, poses significant socio-economic challenges. Regions highly dependent on fossil fuels for revenue and employment require policies that promote economic diversification and support affected communities through re-skilling and job creation in green sectors.

Policy and Regulatory Frameworks: Effective policy frameworks are crucial for incentivizing low-emission investments and managing climate risks. However, there is a need for clearer and more supportive policies that de-risk investments and attract private capital into climate-resilient infrastructure projects.

Analysis

Financial Mobilization: The transition to a low-carbon economy necessitates substantial investments in infrastructure. However, the current financial mechanisms often fail to attract adequate private sector investment due to high perceived risks. Policies that de-risk investments and create a favorable investment climate are essential to mobilize private capital.

Capacity Building: Strengthening the capacity of national and sub-national authorities is crucial for effective climate action implementation. This includes developing technical expertise, enhancing innovation capabilities, and integrating climate considerations into broader development agendas like urbanization and health.

Technological and Innovation Advancement: Bridging the technological gap requires targeted investments in research and development, technology transfer, and fostering innovation ecosystems. Developing countries need support in scaling up renewable energy technologies and adapting them to local conditions.

Just Transition: Transitioning away from fossil fuels must be managed equitably to avoid socio-economic disruptions.

Policies should focus on creating alternative employment opportunities, particularly in regions heavily reliant on fossil fuels, and ensuring inclusive growth through targeted investments in affected communities.

Policy and Regulatory Support: Clear and supportive policy frameworks are essential for guiding investments and reducing uncertainties for investors. This includes robust climate risk disclosures, regulatory frameworks that incentivize green investments, and international cooperation to align financial flows with climate goals.

In conclusion, addressing these gaps requires coordinated efforts at local, national, and international levels. Enhanced financial mobilization, capacity building, technological innovation, and supportive policies are crucial to achieving a sustainable and equitable transition to a low-carbon energy future.

Discussion

The literature review conducted through a web-based search using keywords such as 'long term low carbon development', 'low carbon transition', and 'just energy transition' highlights the necessity for countries to formulate comprehensive long-term strategies that integrate low carbon energy transitions. These strategies are crucial for guiding the implementation of nationally determined contributions (NDCs) across successive climate action cycles. However, a significant knowledge gap exists regarding the effective implementation of such transitions in developing countries, particularly in overcoming challenges related to accessing clean energy technologies and securing low-cost, long-term finance while promoting sustainable development.

Based on insights gathered from interactions with experts and academicians at national, sub-national, and local levels in India, it is evident that there is a critical need to design and implement long-term energy transition plans at the sub-national scale. These plans must align closely with India's NDC goals and Sustainable Development Goals (SDGs). For instance, upgrading existing grids to smart grids with grid-scale storage capacity can enhance energy management capabilities, contribute to achieving ambitious NDC targets, and alleviate challenges associated with energy poverty.

Feedback from interviews with policy experts underscores the importance of fostering collaboration and partnerships between India, developed countries, and multilateral development banks. Such collaborations are essential to mobilize investments in crucial areas like energy efficiency improvements, renewable energy systems—including the production of green hydrogen and green ammonia—and Integrated Renewable Energy and Storage Projects (IRESPs). These initiatives are pivotal in accelerating India's transition towards a low-carbon economy while ensuring energy security and advancing sustainable development objectives.

Addressing these challenges and seizing opportunities through robust sub-national energy transition strategies, international partnerships, and targeted investments will be instrumental in achieving India's climate and development ambitions in the coming decades.

Conclusion

It is recommended to undertake detailed sub-national level studies to comprehensively understand the implications of planning and implementing a national-level long-term low carbon energy transition pathway, particularly focusing on vulnerable communities. Such studies should evaluate the economic, social, and environmental dimensions of sustainable development to ensure inclusive and equitable outcomes.

Furthermore, there is a pressing need to commission studies that assess the costs associated with scaling up the deployment of clean energy niche technologies that are not yet commercially viable. These studies should also evaluate the feasibility of mobilizing investments from the private sector and explore the creation of long-term financing facilities. Leveraging bilateral partnerships with developed countries could play a crucial role in attracting the necessary investments.

In the context of India's commitment to achieve net-zero emissions by 2070, it is essential to conduct sub-national energy transition studies. These studies should prioritize assessing the co-benefits of adaptation planning alongside mitigation efforts. Additionally, they should evaluate the scale of additional and long-term climate finance required

at the sub-national level. The insights gained from such studies can provide valuable inputs to national policymakers for mobilizing climate finance and private capital from multilateral development banks and international financial institutions.

Recommendations

- **Conduct Sub-national Studies:** Initiate detailed studies at the sub-national level to analyze the socio-economic impacts of national-level low carbon energy transition plans, ensuring inclusivity and sustainability.
- **Assess Clean Energy Technologies:** Evaluate the feasibility and costs of scaling up deployment of emerging clean energy technologies. Focus on technologies that are not yet commercially viable but hold promise for achieving long-term climate goals.
- **Mobilize Private Sector Investment:** Explore mechanisms to attract private sector investments into clean energy sectors through innovative financing models and bilateral partnerships with developed countries.
- **Integrate Adaptation and Mitigation:** Integrate adaptation planning with mitigation strategies in sub-national energy transition plans to maximize co-benefits and resilience against climate impacts.
- **Inform National Policy:** Use findings from sub-national studies to inform national-level policies on climate finance mobilization, ensuring alignment with India's net-zero emission targets and sustainable development objectives.
- **By prioritizing these recommendations,** India can strengthen its path towards achieving ambitious climate goals while fostering sustainable and inclusive development across all regions.

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