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BALANCING CARBON BUDGET IN CITIES IN INDIA

Kiran Choudhary [1], Neha Verma [2], Robin Kumar Saini [3], Poonam Jaiswal [4*]

[1, 2, 3] Research Scholar, Department of Botany, Janki Devi Bajaj Government Girls College, University of Kota, Kota, India
[4*] Professor, Department of Botany, Janki Devi Bajaj Government Girls College, University of Kota, Kota, India

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ABSTRACT

In India, a significant increase in carbon dioxide level particularly in urban areas presents a critical concern, majorly driven by urbanization, industrial activities, and increased vehicle usage ultimately imposing severe health risks for the population. Major cities like Delhi, Mumbai, and Kolkata report CO2 concentrations exceeding safe threshold, emphasizing the need for effective carbon management strategies. Approximately 31% of India's population which resides in urban areas currently consumes around 70% of its total primary energy supply and is projected to expand significantly by 2050, making sustainable energy management a crucial task. Several government initiatives, such as the Atal Mission, Smart Cities Mission, and various national policies, aim to mitigate emissions and promote carbon neutrality by investing in renewable energy and enhancing urban infrastructure. In addition, successful local initiatives highlight the potential for cities to lead in the global effort against climate change. Despite some challenges like funding gaps and community resistance, there are numerous opportunities for implementing carbon reduction strategies through establishing public-private collaborations and building up community engagement, ultimately achieving India's goal of reducing its carbon emissions for a sustainable future.

Keywords: Carbon, Urban, Budget, Energy

1. INTRODUCTION

The alarming rise in carbon dioxide concentration in Indian cities has become a pressing concern. The increasing number of vehicles, industrial activities, and waste burning have led to a significant spike in oxides of carbon levels, posing severe health risks to the urban population. According to recent studies, cities like Delhi, Mumbai, and Kolkata have recorded CO_2 concentrations exceeding the safe limits, contributing to various health issues. In a developing country like India, industrialization, urbanization, and exploitation of natural resources are found to escalate CO_2 levels. Carbon dioxide concentrations in the atmosphere were recorded at 278 ppm in 1750; nearly at the begining of the industrial era which has climbed to 410 ppm Forster et al. (2007), Tans & Keeling, (2012). At the population level, energy consumption and economic development directly drive anthropogenic CO_2 emissions. The magnitude of these drivers on emissions may differ across countries

depending on the population size, the financial structure, and the energy required per economic growth Dietz and Rosa (1997).

1.2. URBANIZATION AND CARBON EMISSIONS

About 2% of the world's land surface is under urban settlements occupied by more than 4.3 billion people, making 54% of the world's population during 2015. This number is expected to rise to nearly 70% by 2050 UN International Resource Panel (2018) significantly expanding existing cities. It is predicted that 95% of urban expansion will occur in the developing world in the next decades. The bulk of urban growth will happen in the cities of the Global South, particularly in China, India, and Nigeria UN International Resource Panel (2018). India is one of the major countries where the bulk of urban growth will occur. Cities consume a large portion of the world's resources such as 60–80% of the world's energy consumption and emit significant amounts of carbon dioxide. The world's cities emit 70% of the world's fossil fuel-related carbon dioxide United Nations Convention to Combat Desertification (2020) and are responsible for 75% of total carbon emissions. According to an estimate in 2019, electricity and heat production account for 34% of global greenhouse gas emissions, industries 24%, agriculture, forestry, and other lands 22%, and transportation 15% of total global greenhouse gas emissions.

2. IMPORTANCE OF CARBON BUDGETING IN INDIAN CITIES

In 2011, cities occupied just 3.0% of the land inhabiting 31% of India's population which is expected to increase to 50% in 2050 NITI Aayog (2021). The second-largest urban population in the world, India's population is thought to have quadrupled from 109 million in 1970 to 460 million in 2018 UN International Resource Panel (2018). Increased energy consumption, transportation emissions, and waste management issues due to the country's rapid urbanization have contributed to significant environmental challenges and climate change Kaushik (2024), Rahiman et al. (2019). Greenhouse gas emissions from transportation, energy consumption, and waste management have resulted in a substantial carbon footprint in Indian cities Ramachandra et al. (2014). These issues have made Carbon budgeting crucial for Indian cities. To mitigate this, the Indian government has launched initiatives like the Atal Mission for Rejuvenation and Urban Transformation and Smart Cities Mission Kaushik (2024).

Carbon management aims to reduce its environmental impact by measuring, cutting, and compensating carbon emissions. Carbon neutrality or net-zero emission is only achieved when anthropogenic greenhouse gas emissions are balanced with anthropogenic removal or offsetting of the greenhouse gases. This calls for two distinct strategies, one that focuses on cutting emissions by adopting greener, cleaner, and more efficient technology, and the other that removes the released greenhouse gases by constructing carbon sinks.

3. CURRENT CARBON EMISSIONS SCENARIO IN INDIAN CITIES

India has been projected as the fourth largest producer of greenhouse gases however, India ranks 134th when considering per capita greenhouse gas emissions. It is a matter to appreciate that, India having 17% of the world population, emits only 7% of global emissions. In 2019, India's per capita emissions of 2.46 tonnes of CO_2 equivalent were below to the global average of 4.79 tonnes of CO_2 equivalent MoFFCC (2021). In comparison to most of the developed countries, the US (18.4MT),

Russia (17.6MT), and China (8.9MT), India's CO2 emission was 2.5MT per head in 2018, comparatively lower than other major greenhouse gas emitters. In India, electricity generation and transportation are major contributors, making 45% of the total greenhouse gas emissions Ashkanani et al. (2020).

1) **Energy Consumption Patterns:** India is the third-largest energy-consuming nation globally, with Indian cities consuming more than 70% of the country's total primary energy supply, and are responsible for 75% of the total greenhouse gas emissions in urban areas. Traditional sources of electricity production, such as oil, natural gas, and coal, have been the major sources of greenhouse gases Tiseo (2023). With over one-third of India being considered urbanized, urban areas contribute nearly 25% of energy-related CO2 emissions to economic activities. During the financial year 2021, the largest energy consumer in India was the industrial sector. India's energy-related CO2 emissions were nearly 2.4 billion metric tons in 2019. To control urban energy consumption, affect future carbon emissions, and accomplish sustainable development goals, cities must overcome numerous obstacles Rahiman et al. (2019).
2) **Transportation and Emissions:** The transport sector contributes to 12.1% of the Indian energy-related CO2 emissions (MoFFCC 2021). India is a developing country and due to the expansion of economic activities, the transport sector is expected to expand significantly with a 7% growth rate annually from 2012-2030 and likely to be among the countries having the largest transport systems in the world Kamboj et al. (2022). The major concern is the transport sector in India is dependent on fossil fuel and, hence expected to be a major contributor of Carbon emissions by 2050 Paladugula et al. (2018), International Energy Outlook (2020). Studies show that 1% increase in transport sector growth contribute to 0.62% rise in Carbon emission Sims et al. (2014). IEA (2020) reports that transport sector contributes about one-fourth of total energy consumption in India IEA (2020) which raises concern about reducing increasing carbon emissions Varghese and P. N. (2018).
3) **Industrial and Commercial Activities:** Industries are one of the most significant contributors to energy-related CO2 emissions in India. According to International Energy Agency (IEA) estimates, industries contribute 25% of the total Carbon emissions, second only to the power generation sector, which has a 53% share. Residential sources share 4%, while other sectors (agriculture and commercial sources) contribute 4% of carbon emissions Jain (2022). The construction sector accounts for 23% of global CO2 emissions Huang et al. (2017).

4. CARBON BUDGETING FRAMEWORKS AND POLICIES

1) **International Best Practices:** 196 countries adopted the Paris Agreement at the UN Climate Change Conference (COP21) on 12 December 2015 which invited countries to formulate a long-term low greenhouse gas emission development strategy (LT-LEDS) and submit their national climate action plans, i.e. nationally determined contributions (NDCs), since 2020.

   C40 is a global network of mayors of 96 leading member cities, which make up 22% of the world economy, united to confront the climate crisis with a commitment to using a collaborative, science-based approach to cut their greenhouse gas emissions to 50% by 2030, which will help the world limit

global warming to 1.5°C. Bengaluru, Delhi NCR, Ahmedabad, Mumbai, and Chennai are the member cities in India.

2) **National Policies and Initiatives:** The National Action Plan on Climate Change (NAPCC) was started in India in 2008 and launched various actions and programs to mitigate and neutralize carbon emissions. Promoting alternative energy sources like solar, wind, and green energy, an international solar alliance, a framework for energy-efficient economic development, a national smart grid mission, and a smart cities mission have been initiated. Various standards and codes, like an energy conservation building code, energy efficiency standards for appliances, and fuel consumption standards, are implemented to neutralize carbon emissions. National biofuel policy and fuel efficiency norms are also framed to reduce carbon emissions. Besides these, a national afforestation program, a national clean air program, a climate change action program, a national electric mobility mission plan, faster adoption and manufacturing of hybrid and electric vehicles in India, a steel scrap recycling policy, and the establishment of the National Green Tribunal have been started. The Ministry of Environment, Forest and Climate Change coordinates with different ministries and departments to monitor all these missions, policies, and programs.

5. STRATEGIES FOR REDUCING CARBON EMISSIONS

In India, nationally determined contributions (NDC) goals to achieve by 2030 are: (1) reducing the 2005 GDP's emission intensity by 33-35%; (2) attaining up to 40% cumulative energy capacity from non-fossil fuel-based energy resources; and (3) providing an additional carbon sink equivalent to 2.5 to 3 billion tonnes of CO2 by creating additional vegetation cover. These goals can be achieved by five-fold strategy: (1) non-fossil energy capacity has to increase to 500GW; (2) increasing renewable energy sources to fulfil 50% of the country's energy requirements; (3) reducing projected carbon emission by one billion tonnes; (4) reducing the carbon intensity of the economy by less than 45%. All these have to be achieved by 2030. Besides all these, net-zero carbon emissions by 2070 also have to be achieved.

All these goals and objectives can be fulfilled by focusing energy sector, mainly by integrating renewable Energy (Solar, Wind) as a sustainable measure to reduce carbon emissions. India's power needs are predicted to reach 2,518 billion units by 2030. Hence, needs to increase its capacity to 700GW to meet 50% of energy requirements from renewable sources. Energy Efficiency Measures such as LED Lighting, Green Buildings, etc, will lower the increasing energy demand. India comes third globally Ashkanani et al. (2020). It is expected that 78% of the energy demand will be met by fossil fuels by 2040 Cao et al. (2020). However, given the present pace of CO2 emissions worldwide, anthropogenic activity has contributed to global warming of more than 1°C over pre-industrial levels, with coal burning accounting for more than 0.3 °C of this increase Osman et al. (2020), Wei et al. (2020),.

The transport sector accounts for a 14% share of total Carbon emissions in India, of which road transport alone accounts for 92% of total transportation sector emissions Kamboj et al. (2022). Petroleum-based fuels, largely gasoline and diesel, are the sources of 95% of the world's transportation energy USEIA (2021) Promoting sustainable transportation systems, like increasing the use of electric vehicles and upgrading public transport, may reduce carbon emissions.

Waste-to-Energy (WTE) Technology Initiatives play a significant role in achieving carbon neutrality through energy production integrating with waste management. Three mechanisms reduce greenhouse gas emissions; thermal processing of wastes, generating electrical power or steam, and eliminating methane emissions from landfills. Thermal processing of waste to generate electricity reduces waste volume by 80% Gautam (2023).

6. CARBON OFFSET AND SEQUESTRATION OPPORTUNITIES

1) **Urban Forestry and Green Spaces:** In urban green infrastructure, vegetation can serve as passive carbon sinks globally by storing carbon as biomass and sequestering it through photosynthesis Nowak and Crane (2002), Nowak et al. (2013). There are three ways that urban forests can lower atmospheric CO2 levels; atmospheric CO2 are stored in urban trees as their biomass Nowak and Crane (2002), through evapotranspiration and shading, urban trees lower building cooling demands, which reduces CO2 emissions linked to the use of fossil fuels in energy production McPherson (1998), soil and vegetation also store organic carbon Jo (2002).

   Vegetational approach and science also play an important role in carbon sequestration. The significance of urban vegetation in carbon sequestration is proven by various studies in Indian cities such as Pune Waran and Patwardhan (2001), Varodara Kiran and Kinnary (2011) and Chennai, Pachaiyappan and Ushalaya (2013) and even in smaller cities Dadhich et al. (2023), Many researchers Negi et al. (2003), Ugle et al. (2010), Pandya et al. (2013) showed that indigenous trees such as *Azadirachta indica, Ficus religiosa, Madhuca longifolia*, and *Tamarindus indica* are efficient in carbon sequestration. Studies by Majumdar and Selvan (2018) show that native and evergreen species perform better in biomass accumulation and carbon sequestration over the deciduous and exotic species.

2) **Carbon Capture and Storage Technologies:** The Paris Agreement 2015 aims to limit global warming to 2°C by 2100 and attempt to limit the increase to 1.5°C Fawzy et al. (2020). It is crucial to investigate carbon capture and storage technologies that are thought to be the sole way to reduce CO2 emissions from large-scale power plants. By 2050, these emissions might be cut by 50% Wei et al. (2020), Wienchol et al. (2020), International Energy Agency (2008). Studies indicate that if carbon capture and storage technologies are ignored, the cost of lowering CO2 emissions will skyrocket by 140% GlCCSI (2017), Cuéllar-Franca and Azapagic (2015).

3) **Community-Based Carbon Reduction (CBCR) Projects:** Individualistic approaches to fighting climate change issues usually fail. In such cases, Community-based approaches can potentially address barriers to action Peters et al. (2012). Community-based carbon reduction strategies (CBCRS) are designed to contribute towards addressing climate change and facilitate sustainable low-carbon living Middlemiss (2011), collaborating with citizens on energy, climate, and sustainability solutions Heiskanen et al. (2010). All these efforts, integrating community-led initiatives, can help stabilize the climate Seyfang (2010).

7. SUCCESSFUL CARBON BUDGETING INITIATIVES IN INDIA

In India, in major cities like Mumbai, Bengaluru, and Delhi, carbon budgeting initiatives have been taken, which are yet to give results. In Mumbai, the

Brihanmumbai Municipal Corporation (BMC) became the country's first urban local body to launch its first-ever climate budget for 2024-25. Thus, after Oslo, New York, and London, Mumbai became the fourth city globally to have launched a climate budget. To implement the climate budget, the Environment and Climate Change Department has expanded, and the Government of Maharashtra has revised the State Action Plan for Climate Change (SAPCC) and institutionalized its State Climate Action Cell in 2023. To make the budget highly climate-relevant expenditure and focused on improving climate resilience and mitigation, 9% of the total state budget for the financial year 2023-24 has been dedicated to the Climate budget. The state departments of animal husbandry, fisheries, agriculture, energy, urban development, labour, revenue and forest, rural development, and water supply and sanitation were among the agencies that implemented these high climate-relevant expenditures Agarwal et al. (2024).

Solar power was considered to be the most viable form of green energy in Delhi by the Government of the National Capital Territory of Delhi (GNCTD). Delhi has adopted the Solar Energy Policy 2024 to mitigate carbon emission impacts. The policy reduced 50% tariffs for commercial and industrial consumers, and within the next 3 years, all government buildings having an area of 500 m2 or more must install rooftop solar panels. The total installed solar power capacity is planned to increase three times, up to 4,500 MW by March 2027.

The Green Initiative taken by the Bruhat Bengaluru Mahanagara Palike (BBMP) has started preparing a Climate Action and Resilience Plan (BCAP) to build resilience against climate-related hazards. The plan aims to find measures to reduce GHG emissions. Key areas like energy, transportation, waste management, urban planning, and environmental conservation were discussed with experts from academia, NGOs, and practitioners Shah (2024).

8. CHALLENGES AND OPPORTUNITIES

A study by the Shakti Sustainable Energy Foundation states that Indian cities can reduce 53% of their urban carbon emissions by 2030 and 89% by 2050 using low-carbon measures Shakti Sustainable Energy Foundation (2024). There are many challenges to achieving the target regarding finance, community participation, etc.

1) **Financial investment in Carbon Reduction Projects** is one of the primary challenges in implementing low-carbon urban planning. The high costs of sustainable infrastructure, energy-efficient buildings, zero-emission fuel, and transport often demand substantial upfront costs. The lack of political will to allocate climate budgets toward sustainability initiatives is also the major reason for the lack of financing of sustainability projects. Various countries around the world have started implementing Carbon budgets or climate-mainstreaming of municipal budgets, as a way to show their commitment to drive their cities' transition.
2) **Public-private partnerships** for technical development may play an important role in achieving environmental sustainability goals Kirikkaleli et al. (2022). The Indian government has raised $2.2 billion to build 125 GW of renewable energy and 5 million metric tons of green hydrogen capacity. The private sector has committed more than $200 billion to help India's energy plan (Bhattacharya et al., 2022).
3) **Community Engagement and Behavioural Change** incorporating participation and successful implementation of carbon reduction initiatives

within a community can be hampered by several factors, including a lack of knowledge and comprehension about climate change, resistance to lifestyle changes, socioeconomic disparities, limited access to information, insufficient community leadership, worries about the economic impact, challenges reaching diverse populations, and navigating complex policy landscapes. Awareness programs and, community sensitization will help to achieve the target.

4) **Integrating Carbon Budgeting into Urban Planning** results in designs for low-carbon urban architecture that would emphasize walkability, proximity, and sustainability Moreno et al. (2021). Complex data collection and analysis, a lack of standardized methodologies, financial limitations, political will, stakeholder engagement, and the need to strike a balance between environmental concerns and economic development—especially when taking into account the upfront costs of sustainable infrastructure—are just a few of the difficulties that come with incorporating carbon budgeting into urban planning. These challenges must be navigated while navigating the complexities of land use, transportation, and building design decisions that affect a city's carbon footprint. Planning urban green spaces such as rooftop gardens, and green canopies on streets helps in balancing carbon emissions through carbon sequestration Parker and Simpson (2020).

5) **Future Directions for Carbon Budgeting in India:** Enhancing data transparency and monitoring (Implement robust monitoring, reporting, and verification (MRV) systems to ensure accurate emission data collection and prevent manipulation, Increase capacity building for carbon auditors to improve data quality, Publicly share emission data to promote accountability), expanding the carbon market to include more sectors, giving priority to the integration of renewable energy sources like solar and wind power, and actively engaging the private sector by incentivizing private companies to invest in low-carbon technologies are the main goals of future directions for carbon budgeting and carbon pricing mechanism in India.

   Creating strong legislative frameworks to better control carbon emissions, creating sector-specific carbon budget plans for major polluting businesses to help them reach the goal of 50% non-fossil energy by 2030, and shifting to net-zero emissions by 2070.

   Policy Makers, Urban Planners, and Citizens should Join hands to create a sustainable future and work together to design and implement eco-friendly solutions, promote green infrastructure, and foster resilient communities.

9. POLICY RECOMMENDATIONS FOR CARBON BUDGETING

To enhance urban sustainability, green urban development initiatives like efficient transportation systems, waste management, and building energy efficiency should be the focus. Collaboration with other countries to share best practices and access climate finance to support decarbonization efforts also helps to find solutions. Strengthening existing policies like the Energy Conservation (Amendment) Act 2022, developing sector-specific carbon budget strategies for key emitting industries, considering carbon taxes, and incentivizing decarbonization will effectively regulate carbon emissions. Moreover, large-scale adoption of electric To boost electric vehicle adoption, the government should offer incentives like tax

rebates and subsidies, along with infrastructure development Kamboj et al. (2022). India needs to step up efforts to cut emissions from transport and industry, aiming for a 45% reduction in carbon intensity. It will be necessary to drastically reduce coal and crude oil use across all industries and replace them with more effective and clean alternatives like solar and hydrogen. Continuous research in carbon reduction technologies is required for a significant reduction in carbon emissions across all sectors.

Therefore, by emphasizing progress in carbon markets via establishing carbon credit systems and trading platforms substantial amount of emissions can be reduced considering the soaring population demands which aids towards a sustainable community. Adopting sustainable policies supporting climate adaptation such as NAPCC plays a vital role in responding to the climate crisis. Adhering to the Paris Agreement for reaching the goal of net zero emissions involves boosting renewable resource reservoirs, integrating innovative technologies for the effective management of its carbon budget, and promoting collaborations for sector-specific reforms. Moreover, a greater focus on environment-friendly approaches and implementing energy-efficient green technologies not only helps to mitigate carbon emissions but also enhances overall vegetation cover. A promising sustainable carbon budget framework could only be achieved by collaborative efforts of both government and society along with continuous transformation, funding and innovative discoveries.

10. CONCLUSION

The alarming rise in carbon dioxide concentrations in Indian cities necessitates immediate attention and action. As India continues to urbanize and industrialize, it is crucial to adopt sustainable measures to mitigate carbon emissions. Indian cities must prioritize carbon budgeting to mitigate the impacts of climate change. A combination of strategies, including urban forestry, carbon capture and storage technologies, and community-based initiatives, is necessary to reduce carbon emissions. Effective implementation of carbon budgeting initiatives requires government support, policies, and funding. Raising awareness and promoting community participation are crucial for the success of carbon reduction initiatives.

To achieve significant reductions in carbon emissions, Indian cities must establish clear targets and strategies for reducing carbon emissions. Urban planning should prioritize walkability, proximity, and sustainability to reduce carbon emissions. Cities should engage with citizens to raise awareness and promote participation in carbon reduction initiatives. Collaborations between government, private sector, and civil society are essential for securing funding and expertise to support carbon reduction initiatives. By adopting a multi-faceted approach to carbon budgeting, Indian cities can reduce their carbon footprint, promote sustainable development, and contribute to a climate-resilient future.

This article highlights the importance of carbon budgeting in Indian cities, discusses the current carbon emissions scenario, and explores strategies for reducing carbon emissions, including urban forestry, carbon capture and storage technologies, and community-based carbon reduction projects.

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