

ASSESSMENT OF CARBON EMISSION SOURCES AND SUGGESTIONS FOR REDUCING CO₂ IN SMART CITIES

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Abstract : Rapid urbanization has intensified the need for sustainable solutions in developing smart cities that minimize environmental degradation. Carbon dioxide (CO₂) emissions are among the major contributors to global climate change, arising from transportation, industry, and energy use. This paper presents the key sources of carbon emissions within the urban framework and evaluates strategies to mitigate CO₂ levels. The study utilizes secondary data from the Central Pollution Control Board (CPCB) and NITI Aayog to analyze emissions across energy, industrial, agricultural, and waste sectors. Findings reveal that the energy sector contributes approximately 2.23 billion tonnes of CO₂ annually, followed by agriculture (0.40 billion tonnes), industry (0.23 billion tonnes), and waste (0.07 billion tonnes). The research further explores the potential of renewable energy, electric vehicles, carbon trading, and afforestation as effective carbon reduction measures. Implementation of sustainable energy systems, green mobility, and urban reforestation are recommended as key pathways to achieve low-carbon smart city development.

IndexTerms - Carbon emissions, Smart city, Renewable energy, Sustainable development.

I. INTRODUCTION

Smart cities represent a convergence of technology, infrastructure, and sustainability designed to improve urban living while minimizing environmental impacts. However, with technological advancement comes the challenge of increased energy consumption and CO₂ emissions. Cities account for 80% of global greenhouse gas emissions, with energy and transport being primary sources. This study focuses on assessing carbon emissions in the Indian context, particularly for Kolhapur city, and suggests mitigation strategies through renewable, electric mobility, and carbon offset mechanisms.

II. OBJECTIVE

1. Identify the primary sources of carbon emissions in urban areas.
2. Analyze emission patterns across different sectors.
3. Develop strategies to reduce CO₂ emissions using renewable energy and urban greening.
4. Propose sustainable frameworks like carbon trading and electric mobility for smart cities.

III. METHODOLOGY

The methodology includes secondary data collection from CPCB and NITI Aayog for national emissions, and local data from Kolhapur city for case analysis. A comparative approach was used to analyze CO₂ contributions from sectors: Energy, Agriculture, Industrial Processes, and Waste. Formulas were applied for vehicular CO₂ estimates:

Total CO₂ = (Number of Vehicles) × (Average CO₂ Emission per Vehicle)

Average CO₂ per vehicle (150 g/km) was used to calculate cumulative emissions for Kolhapur.

IV. RESULTS AND ANALYSIS

Table 1. Sector-wise CO₂ Emissions in India

Sector	CO ₂ Emissions (Tonnes)
Energy	2,238,408,890
Agriculture	405,983,210
IPPU (Industry)	238,555,840
Waste	75,641,070

Table 2. Kolhapur City Emission Sources (PM and CO₂)

Source	PM ₁₀ (Kg/day)	CO ₂ Contribution (%)
Industries	864.56	61.96
Vehicular Flow	241.02	17.27
Building Construction	77.20	5.53
Domestic	39.91	2.86
Others	172.62	12.38

Table 3. Registered Vehicles and Estimated CO₂ Emissions in Kolhapur

Year	Total Vehicles	Average CO ₂ (g/km)	Estimated CO ₂ (Ton/km)
2019-20	1,434,332	150	215.15
2020-21	1,521,642	150	228.25
2021-22	1,609,252	150	241.39

Table 4. Estimated CO₂ Emissions Avoided by Renewable Energy in India (FY 2024–25)

Category	Generation (TWh)	CO ₂ Avoided (Million Tonnes)	% of Power Sector CO ₂ Avoided
RE excl. Hydro	268.5	165.4	11.8%
Large Hydro	149.1	91.8	6.5%
Total	417.5	257.2	18.3%

CO₂ Consumption and O₂ production by trees:

Trees consume carbon dioxide (CO₂) and produce oxygen (O₂) through photosynthesis, converting light, water, and CO₂ into sugars for growth and releasing O₂ as a byproduct during the day. While trees release some CO₂ at night through respiration, their net effect over a 24-hour period is a significant consumption of CO₂ and a large production of oxygen. The amount of CO₂ absorbed and O₂ produced varies depending on factors like a tree's species, age, health, and surrounding environment.

Tree Groups and CO₂/O₂ Data:

1. Evergreen Trees (Broadleaf / Tropical)

Examples: Neem, Banyan, Mango, Peepal, Jamun, Mahogany

- CO₂ absorption: 20–35 kg/year
- O₂ production: 14–25 kg/year

Notes: Active year-round; high leaf area; excellent air purifiers.

2. Deciduous Trees

Examples: Teak, Sal, Gulmohar, Amaltas, Arjun

- CO₂ absorption: 15–25 kg/year
- O₂ production: 10–18 kg/year

Notes: Shed leaves seasonally; Teak stores carbon well in wood.

3. Coniferous Trees

Examples: Pine, Deodar, Cypress, Ceda

- CO₂ absorption: 12–20 kg/year
 - O₂ production: 8–15 kg/year
- Notes: Slower photosynthesis but long-term carbon storage.

4. Fast-Growing Species

Examples: Eucalyptus, Subabul, Poplar, Cassia, Acacia auriculiformis

- CO₂ absorption: 30–50 kg/year
- O₂ production: 22–36 kg/year

Notes: High productivity; short rotation cycles; excellent for reforestation.

5. Fruit-Bearing Trees

Examples: Mango, Guava, Jackfruit, Coconut, Banana, Tamarind

- CO₂ absorption: 20–30 kg/year
- O₂ production: 15–22 kg/year

Notes: Dual benefit — food + environmental; good canopy cover.

6. Wetland / Mangrove Trees

Examples: Rhizophora, Avicennia, Sonneratia, Bruguiera

- CO₂ absorption: 50–80 kg/year
- O₂ production: 35–60 kg/year

Notes: Exceptional carbon sinks; crucial for coastal regions.

7. Shrubs and Small Trees

Examples: Bougainvillea, Hibiscus, Cassia fistula, Indian coral tree

- CO₂ absorption: 5–15 kg/year
- O₂ production: 3–11 kg/year

Notes: Smaller biomass but valuable for urban greening.

Data of E-Vehicles:

As of October 2025, India has witnessed a significant surge in electric vehicle (EV) adoption, with total sales reaching approximately 2.17 million units between October 2024 and September 2025. This marks a substantial increase from the previous year, reflecting a growing shift towards sustainable mobility.

EV Sales Breakdown by Category (FY 2024–25)

- Electric Two-Wheelers (E2Ws): Over 50% of total EV sales.
- Electric Three-Wheelers (E3Ws): Approximately 36% of total EV sales.
- Electric Passenger Vehicles (4Ws): Around 11% of total EV sales.

Monthly Sales Trends:

In September 2025, India recorded 181,760 EV sales, slightly down from 186,678 units in August 2025 but up from 159,425 units in September 2024, indicating a 14% year-on-year growth.

Data of E-Vehicles :

In One City, a total of 73,610 electric vehicles were registered in 2023, with December 2023 seeing a record 19.5% EV sales share of all vehicles sold. Sales in the first five months of 2024 totaled 4,016 EVs, though overall sales in the electric vehicle segment have declined.

- Total EV Sales in 2023: 73,610
- Record EV Sales in December 2023: 9,510 EVs, representing 19.5% of all vehicle sales for that month
- Total EV Sales (Jan-May 2024): 4,016

V. DISCUSSION

The analysis shows that India's emissions are energy-dominant, with transport and industries adding substantial local burdens. Kolhapur's foundry sector, vehicular density, and energy use are significant contributors. Adoption of renewable energy, electric vehicles, and tree plantation can mitigate emissions effectively. Reforestation of 82,600 hectares of unused cultivable land could sequester approximately 1.8 million tonnes of CO₂ annually.

VI. SUGGESTION FOR CO₂ REDUCTION

1. Carbon Trading Systems: Implement carbon markets like 'Vantara' to offset industrial and vehicular emissions.
2. Electric Mobility Expansion: Subsidize EVs, install city-wide charging stations, and promote e-public transport.
3. Urban Green Infrastructure: Develop rooftop gardens, green corridors, and urban forests.
4. Renewable Energy Integration: Mandate solar rooftops in commercial and residential zones.
5. Waste-to-Energy Systems: Encourage methane capture and energy recovery from waste.
6. Public Participation: Launch awareness campaigns for sustainable living and green commuting.
7. Policy Reinforcement: Align municipal plans with India's National Clean Air Programme (NCAP).

VII. CONCLUSION

This study concludes that smart cities must balance technological growth with environmental responsibility. Energy and transportation dominate emission profiles; hence, integrating renewables, promoting EVs, adopting carbon trading, and restoring green spaces can significantly reduce CO₂ emissions. Kolhapur's model demonstrates how localized interventions can scale to national sustainability goals.

VIII. REFERENCES

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