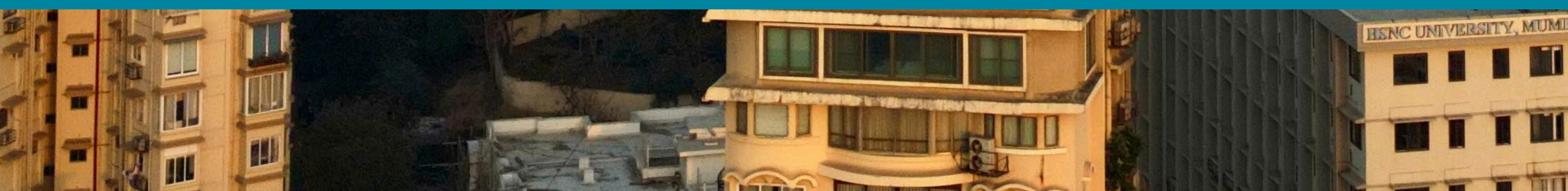
CLEAN AIR FUND

Dalberg

# The Business Case for Clean Air

## Unlocking Economic Opportunities for India





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# Acknowledgements

This is an independent report commissioned by the Clean Air Fund and developed by Dalberg Advisors between April and November 2025. The Clean Air Fund is a leading philanthropic initiative that brings together funders, researchers, policymakers, and campaigners to tackle the air pollution crisis worldwide.

The report aims to demonstrate how clean air can serve as a catalyst for India's economic growth and public well-being. It examines how air pollution mitigation is not merely a cost to be managed, but a high-return economic opportunity that advances development priorities.

This report aims to quantify the economic benefits of implementing India's top air quality solutions across five dimensions—investment potential, job creation, economic value generated, co-benefits, and cost-savings. Further, the report builds upon the Clean Air Fund's earlier study, The Silent Pandemic: Air Pollution and its Impact on Business (2021), to assess the impact of air pollution on business profitability through four pathways: reduced consumer spending at a domestic and tourist level, premature deaths, lower working productivity, and lost labour days due to sickness.

This report is based on techno-economic analysis, supported by secondary research and expert interviews with key stakeholders to validate insights and ground recommendations in real-world context. This report is not intended as a rigorous analytical study, rather, this report identifies key opportunities where air quality action in India can generate economic gains.

**The report received valuable research insights, direction and feedback from the Clean Air Fund team. The report was further informed by contributions from a wide range of knowledge partners, including teams from Air Pollution Action Group (A-PAG), CEEW, CSE, Chintan, Confederation of Indian Industry (CII), Envirocatalysts, iForest, Intellecap – The Aavishkar Group, International Council on Clean Transportation (ICCT), Iora Ecological Solutions and TERI. We are sincerely grateful for their inputs, which strengthened the analysis and framing across sections.**

THE BUSINESS CASE FOR CLEAN AIR: UNLOCKING ECONOMIC OPPORTUNITIES FOR INDIA

# About the Report

This report aims to position air quality management as a catalyst for India's economic transformation. It seeks to reframe the narrative around air pollution—from a challenge of loss mitigation to an opportunity for growth, jobs, and innovation. The report identifies and quantifies the economic opportunities arising from improved air quality, highlights high-impact solutions across key polluting sectors, and outlines pathways for policymakers, financiers, and private sector actors to realise these opportunities.

This report is intended as a **strategic and directional assessment,** not an academic or exhaustive quantitative study. Its purpose is to **guide policy and investment decisions** by highlighting areas where air quality action can yield significant economic, environmental, and social returns. It draws on secondary research, expert consultations, and estimation frameworks to provide indicative magnitudes of opportunity and cost, rather than detailed econometric modelling.

While the report uses the best available data and validated assumptions, **it is not designed to provide precise economic valuations or sectoral projections.** The estimates are **indicative and directional,** intended to spark dialogue, inform strategy, and catalyse cross-sector collaboration. The analysis focuses on measurable outcomes such as investment potential, job creation, and macroeconomic gains, and does not include a comprehensive accounting of all air pollution mitigation measures in India. Further, the report measures the **gross effects** and is not rigorous to calculate the overall net impacts of air pollution solutions.

Additionally, this report focuses on direct air pollution mitigation solutions (non-exhaustive) that can be implemented across key sectors such as industry, transport, construction, and residential energy use. Broader enabling factors—such as improvements in power supply reliability, adoption of renewable energy, or reduction of diesel generator (DG) emissions—are recognised as important for sustaining long-term air quality gains but fall outside the quantitative scope of this analysis.

# List of Abbreviations

| Abbreviation | Definition |
|---|---|
| A-PAG | Air Pollution Action Group |
| ADB | Asian Development Bank |
| AI | Artificial Intelligence |
| APCD | Air Pollution Control Devices |
| APM | Ambient Particulate Matter |
| AQI | Air Quality Index |
| BEST | Brihanmumbai Electric Supply and Transport |
| BS-6 | Bharat Stage VI (vehicle emission standard) |
| CAAQMS | Continuous Ambient Air Quality Monitoring Systems |
| C&D | Construction and Demolition |
| CBG | Compressed Biogas |
| CCTV | Closed Circuit Television |
| CEEW | Council on Energy, Environment and Water |
| CEMS | Continuous Emissions Monitoring Systems |
| CII | Confederation of Indian Industry |
| CNG | Compressed Natural Gas |
| $CO_2$ | Carbon Dioxide |
| COPD | Chronic Obstructive Pulmonary Disease |
| CPCB | Central Pollution Control Board |
| CSR | Corporate Social Responsibility |
| CSE | Centre for Science and Environment |
| CSO | Civil Society Organisations |
| DALY | Disability-Adjusted Life Year |
| DAP | Diammonium Phosphate |
| DFC | Development Finance Corporation |
| DTC | Delhi Transport Corporation |
| EMI | Equated Monthly Instalment |
| EPA | Environmental Protection Agency |
| EPC | Engineering, Procurement, and Construction |





| Abbreviation | Definition |
|---|---|
| EPIC | Energy Policy Institute at the University of Chicago |
| EPR | Extended Producer Responsibility |
| EV | Electric Vehicle |
| FAME | Faster Adoption and Manufacturing of Hybrid and Electric Vehicles |
| FCBTK | Fixed Chimney Bull's Trench Kiln |
| FGD | Flue Gas Desulphurisation |
| FOM | Fermented Organic Manure |
| GDP | Gross Domestic Product |
| GHG | Greenhouse Gas |
| GOBARdhan | Galvanising Organic Bio-Agro Resources Dhan |
| HAP | Hazardous Air Pollution |
| HDT | Heavy-Duty Truck |
| ICCT | International Council on Clean Transportation |
| ICE | Internal Combustion Engine |
| IEA | International Energy Agency |
| IRENA | International Renewable Energy Agency |
| IRR | Internal Rate of Return |
| LCS | Low-Cost Sensors |
| LPG | Liquefied petroleum gas |
| LTV | Loan-to-Value |
| MDB | Multilateral Development Bank |
| MDT | Medium-Duty Truck |
| MFI | Microfinance Institutions |
| MNRE | Ministry of New and Renewable Energy |
| MoEFCC | Ministry of Environment, Forest and Climate Change |
| MRF | Material Recovery Facilities |
| MRS | Mechanised Road Sweepers |
| MSME | Micro, Small, and Medium Enterprises |
| MSW | Municipal Solid Waste |
| MW | Megawatt |
| NAAQS | National Ambient Air Quality Standards |

| Abbreviation | Definition |
|---|---|
| NABARD | National Bank for Agriculture and Rural Development |
| NAMP | National Air Quality Monitoring Programme |
| NBFC | Non-bank Financial Institution |
| NCAP | National Clean Air Programme |
| NECP | National Efficient Cooking Program |
| NCR | National Capital Region |
| NITI Aayog | National Institution for Transforming India Aayog |
| NOX | Nitric Oxide & Dioxide |
| NTPC | National Thermal Power Corporation |
| OECD | Organisation for Economic Co-operation and Development |
| OEM | Original Equipment Manufacturer |
| PFI | Public Financial Institutions |
| PLI | Production-Linked Incentive |
| PM2.5 | Particulate Matter ≤ 2.5 micrometres |
| PMUY | Pradhan Mantri Ujjwala Yojana |
| PNG | Piped Natural Gas |
| R&D | Research & Development |
| RBF | Results-Based Financing |
| RWA | Resident Welfare Associations |
| SATAT | Sustainable Alternative Towards Affordable Transportation |
| SEWA | Self-Employed Women's Association |
| SHG | Self-Help Group |
| SIDBI | Small Industries Development Bank of India |
| $SO_2$ | Sulphur Dioxide |
| SPCB | State Pollution Control Boards |
| TCO | Total Cost of Ownership |
| TPD | Tonnes per Day |
| TPH | Tonne per Hour |
| TPP | Thermal Power Plant |
| ULB | Urban Local Bodies |
| VGF | Viability Gap Funding |





| Abbreviation | Definition |
|---|---|
| VSBK | Vertical Shaft Brick Kiln |
| WRI | World Resources Institute |
| WTE | Waste-to-Energy |
| ZET | Zero Emission Trucks |
| ZZK | Zig-Zag Kiln |

# I. Executive Summary

**Over the last decade, India has made notable progress on air quality management, yet pollution levels remain above national standards, posing a serious threat to public health, productivity, and long-term economic resilience.** Air pollution remains a nationwide, systemic issue, driven by emissions from multiple sectors including transport, industry, residential combustion, agriculture, solid waste, power, construction, and road dust.

In 2019, as per the Lancet report 2021, 1.7 million deaths (18% of total annual deaths)[1] could be attributed to air pollution. A 2019 study by Dalberg and the Clean Air Fund in partnership with Confederation of Indian Industry, estimated the economic loss due to air pollution at $95 billion (or 3% of 2019 GDP) — primarily from productivity losses, reduced consumer footfall, absenteeism, and premature deaths.

The Government of India has made significant efforts through the National Clean Air Programme (NCAP), deploying ~US$ 900 million across 131 cities from FY 2019-20 through FY 2025-26. These efforts, along with other national and state-level measures, have contributed to a 13% decline in average annual PM2.5 levels, from 72.5 $\mu g/m^3$ in 2018 to 50.6 $\mu g/m^3$ in 2024[2], and 41 cities achieving the initial PM10 reduction target of 20-30% or more.[3] However, current levels still exceed the national standard (NAAQS) of 40 $\mu g/m^3$ by over 25%. Persistent high-pollution days continue to cause acute and long-term health and economic harm. Addressing this requires a shift from short-term fixes toward systemic, long-term solutions.

**Air quality management has traditionally been viewed as a way to avert loss of life and livelihood. However, it also offers a high-return economic opportunity that unfolds across three orders of outcomes.** (see Figure 1).

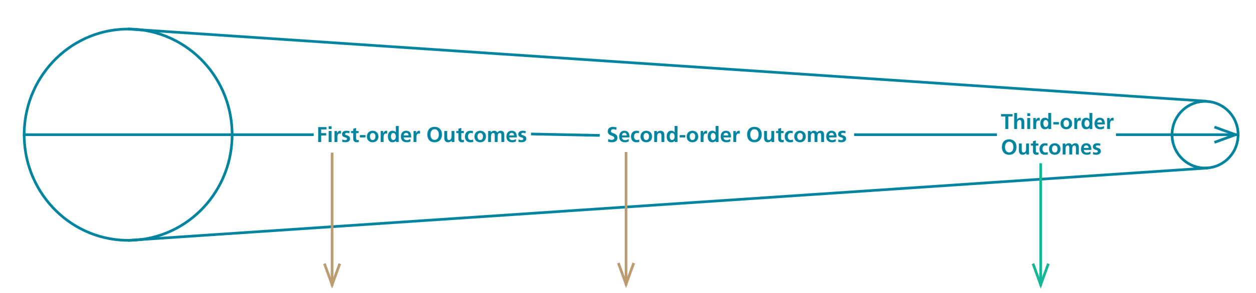
- First-order outcomes are effects of investments in initial catalytic capital, such as viability gap funding and capex subsidies, used to implement clean air solutions. They also include the revenue and employment generated when existing activities shift to greener alternatives (for example, ticket sales revenue from e-bus replacing diesel buses, or jobs from cleaner brick production replacing traditional brick kilns). These solutions primarily support the "brown to green" economy, where existing revenue streams continue but the underlying technology becomes cleaner, resulting in reduced pollution, lower emissions, and improved health outcomes.
- Second-order outcomes arise when initial capital crowds-in commercial capital, expanding and building new industries and value chains (for example, compressed biogas plants). They create additional revenue streams (for example, from biogas or recyclable sales), gross jobs across sectors and geographies, and cost savings for governments and consumers (such as lower ownership costs or reduced subsidies). These outcomes also deliver co-benefits across value chains, including improvements in health, social, and environmental outcomes.
- Third-order outcomes reflect system-level economic returns across businesses, extending beyond the direct solution areas. They are driven by improved worker productivity, increased consumer footfall, and reduced premature mortality, resulting from effective air quality management.





*Figure 1: Framework for measuring the economic opportunity of clean air in India*

| Solution-specific outcomes | Macroeconomics gains |
|---|---|
| Implementing air quality solutions will lead to economic outcomes at first and second order, while leading to a reduction in 20% PM2.5 | Reduction in PM2.5 will lead to improved health, thereby unlocking macroeconomic gains |

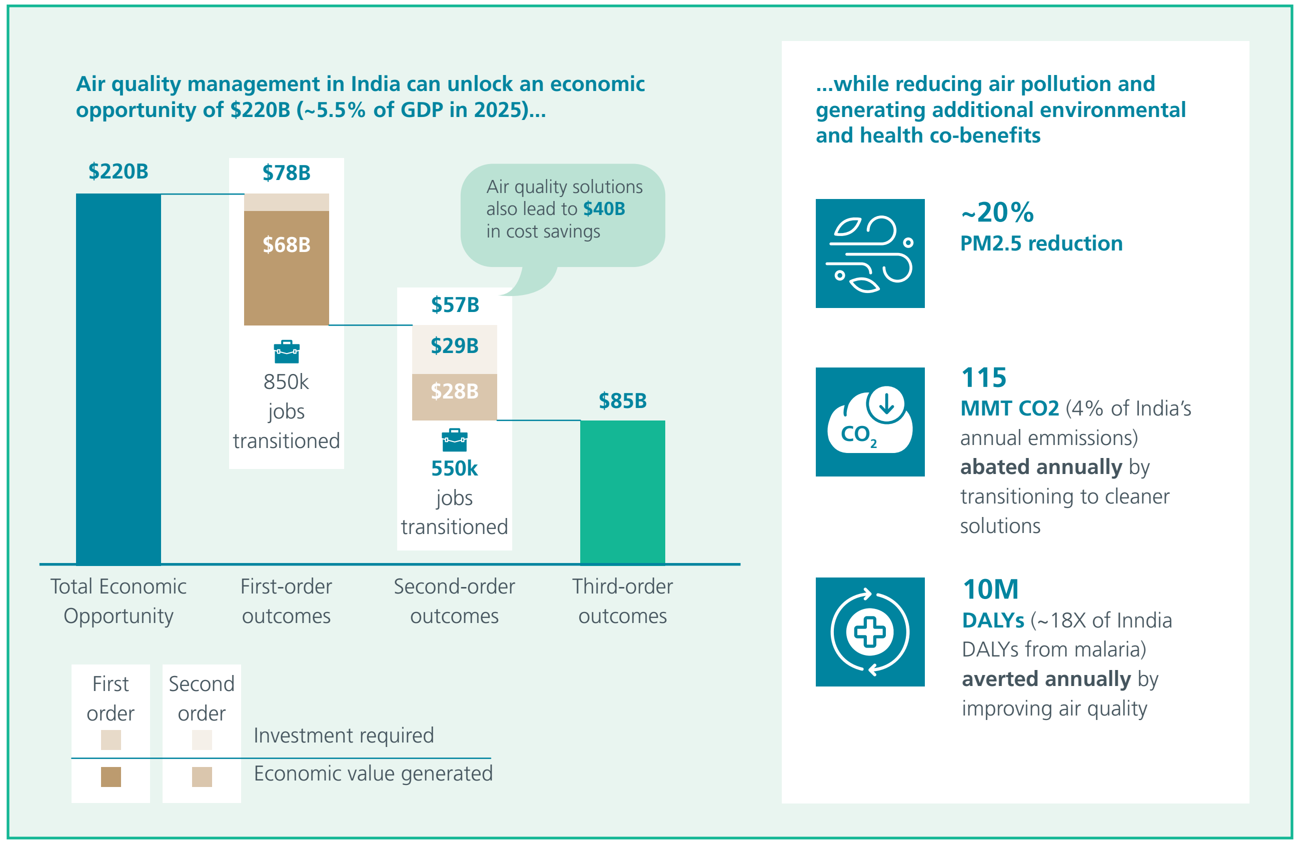



| Key Elements | Investment and economic gains from "brown to green" economy transition | Mobilising private capital and expanding the green economy (20% Reduction in PM2.5) | System-level gains due to improved health from better air quality |
|---|---|---|---|
| Investment required | **Initial catalytic capital** i.e. initial capital outlays to build necessary ecosystem | **Crowded in commercial capital** i.e. additional commercial capital mobilised as a result of catalytic capital under first order outcomes | Absenteeism |
| Job creation potential | **Job transition** i.e. reskilling and transition of gross jobs to cleaner alternatives | **Job creation** i.e. new gross jobs as a result of setting up of new value chains | Presenteeism |
| Annual economic value generated | **Existing revenue streams** i.e. the gross economic value produced due to transition of current value chains to cleaner alternatives | **New revenue streams** i.e. gross economic value produced due to setting up new value chains | Consumer Footfall |
| Cost savings | | **Gross cost savings in economy due to transitioning** (e.g., reduction in oil imports) or new value chains (e.g., reduction in fertiliser subsidy due to cheaper manure) | Healthcare Expenditure |
| Co-benefits potential | | **Health benefits,** e.g., DALYs averted<br>**Environmental benefits** e.g., GHG abated<br>**Social benefits** e.g., time saved by women | Premature Mortality |

The report evaluated 13 high-impact solutions i.e., interventions addressing key polluting sectors: transport, solid waste, agriculture, residential combustion, construction, road dust, power, industries and monitoring. While not exhaustive, these solutions were selected for their maturity, scalability, and ability to deliver near-term impact. The criteria for selection of these 13 key solutions across sectors can be found in the Methodology section of this report.

**These solutions, when implemented, can reduce ~20% of India's air pollution from current levels (measured as PM2.5) while generating a $220 billion economic opportunity, creating and transitioning 1.4 million jobs, reducing 115 million tonnes of annual CO2e emissions, and preventing 10 million annual Disability Adjusted Life Years[4] (DALYs).**

***Figure 2: Potential economic opportunity till 2030, which can be realised by reducing ~20% of air pollution in India***




- **First-order outcomes represent a large share of the economic opportunity—approximately $78 billion—driven by catalytic initial investment and value creation from the brown-to-green transition:**
  - **Investment required ($10 B):** Initial capital outlays such as viability gap funding, policy rebates to reduced capital costs and derisking funds to build the enabling ecosystem and attract commercial capital.
  - **Economic value generated ($68 B):** Gross economic value created as existing value chains transition to cleaner alternatives (for example, ticket-fare revenue generated from e-buses replacing diesel buses).
  - **Jobs transition (850 K):** Jobs reskilled or transitioned while switching to cleaner alternatives. (Figures represent gross employment transitions).

- **Second-order outcomes, valued at $57 billion, result from the multiplier effect of catalytic initial investments that crowd-in private capital and build new value chains:**
  - **Investment required ($29 B):** Additional commercial capital mobilised as a result of catalytic capital under first-order outcomes (for example, additional debt mobilised from the private sector through guarantees).
  - **Economic value generated ($28 B):** Gross revenue created from establishing new value chains (for example, compressed biogas) and/or new revenue streams (for example, carbon revenue and recyclables).
  - **Jobs created (550 K):** New gross jobs generated through the development of new industries and new value chains.
  - **Additional cost savings ($40 B):** Gross cost savings for the economy, achieved through both transitions (for example, lower oil imports) and new value chains (for example, reduced fertiliser subsidies due to manure produced through CBG).





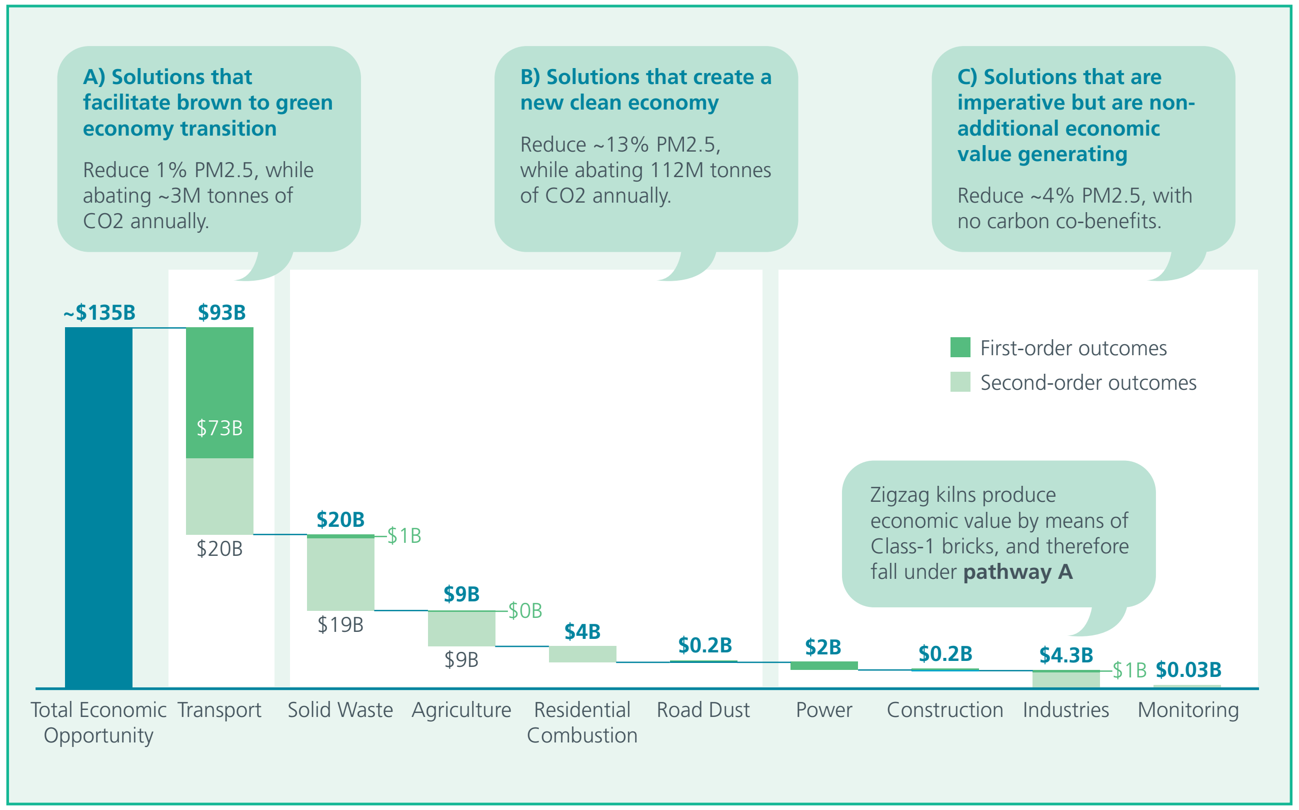
- **Additional Co-benefits:** Abatement of 115 million tonnes of CO2e (~4% of India's emissions) due to synergies between clean air and GHG emission solutions (for example, e-vehicles, biomass burning) along with health gains measured through reduced Disability Adjusted Life Years (DALYs).

- **Third-order outcomes valued at $85 billion,** capture macroeconomic gains across sectors driven by better worker health, higher productivity, reduced absenteeism, greater consumer activity, and lower health expenditure.

## Summary of Findings: Economic Outcomes Across Pathways and Selected Solutions

- **Air quality action delivers these economic outcomes through distinct pathways that describe how economic opportunity is created.** Each pathway represents a channel through which air pollution solutions can generate economic opportunity, such as by greening existing industries, building new clean value chains, or enabling compliance-driven improvements. Individual solutions can be mapped to each pathway, together quantifying the total scale of India's clean air opportunity (see Figure 3).

***Figure 3: Economic outcomes of implementing air quality management solutions across key polluting sectors***




**Pathway A: Solutions that facilitate brown to green economy transition:** This category covers solutions where existing revenue streams continue, but the underlying technology transitions from polluting to clean. The economic pie does not expand substantially, but it becomes greener, delivering emissions reductions and health gains. Combined, these solutions represent a $97 B economic opportunity while reducing 1% of PM2.5 (see Table 1).

*Table 1: Pathway A: Solutions that facilitate brown to green economy transition*

| Sector | Total Opportunity \| Investment required, Economic Value produced | Solution | Scale & Description | Economic Value Created |
|---|---|---|---|---|
| **Transport** | ~$93B \| ~$25B investment required, ~$68B annual economic value | E-buses ($90B) | Electrify ~200 thousand e-buses (25% of government targets under FAME) in urban, high-emission cities. | Value to OEMs from sale of e-buses and to fleet operators from passenger ticket revenue. |
| | | E-trucks ($3B) | Deploy ~10,000 e-trucks (<1% of all trucks) across medium- and heavy-duty freight. | Value to OEMs from sale of e-trucks and to operators from freight transport revenue. |
| **Industry** | ~$4B \| ~$0.5B investment, ~$3.5B annual economic value | Zigzag Kilns ($4B) | Retrofit ~13,000 traditional kilns (~38% of remaining mandated kilns). | Revenue to kiln owners from additional bricks produced. |





**Pathway B: Solutions that create a new clean economy:** This category comprises solutions that catalyse the development of new industries and value chains, generate fresh revenue streams from products and services that previously did not exist. Combined, these solutions represent a $33B economic opportunity while reducing 13% of PM2.5 (see Table 2).

*Table 2: Pathway B: Solutions that create a new clean economy*

| Sector | Total Opportunity \| Investment required, Economic Value produced | Solution | Scale & Description | Economic Value Created |
|---|---|---|---|---|
| **Solid Waste** | ~$20B \| ~$6B investment, ~$14B annual economic value | MRFs ($12.5B) | Establish ~1,000 centralised MRFs (processing 33% of India's waste), 150 TPD capacity each. | Value from sale of recyclables, plastic credits, and EPR revenue. |
| | | CBG Plants ($7.5B) | Set up ~200 large plants (~95% of SATAT targets) processing 500 TPD. organic municipal solid waste. | Value from sale of CBG and manure to off-takers. |
| **Agriculture** | ~$9B \| ~$3B investment, ~$6B annual economic value | CBG Plants ($7B) | Set up ~90 large plants (~20% of SATAT targets) processing 300 TPD crop residue. | Value from sale of CBG and manure to off-takers. |
| | | Bio pellet Plants ($2B) | Establish ~200 plants (~20% of co-firing mandates) processing 60 TPD stubble. | Value from sale of bio pellets to thermal power plants. |
| **Residential Combustion** | ~$4B \| ~$1B investment, ~$3B annual economic value | Improved Cooking Solutions ($4B) | Scale improved/electric cookstoves among ~50M households using solid fuel (35% of total). | Value to manufacturers from sale of cookstoves and carbon credits. |

**Pathway C: Solutions that are imperative but do not generate substantial economic value:** These solutions are essential for ensuring industries meet environmental standards, but unlike other solutions, they do not lead to any additional economic value generation. Their primary contribution is in safeguarding health and ensuring regulatory compliance. Combined, these solutions represent a ~$2.5B economic opportunity while reducing 4% of PM2.5 (see Table 3).

*Table 3: Pathway C: Solutions that are imperative but do not generate substantial economic value*

| Sector | Total Opportunity \| Investment required, Economic Value produced | Solution | Scale & Description | Economic Value Created |
|---|---|---|---|---|
| **Industry** | ~$0.3B \| ~$0.3B investment | Air Pollution Control Devices & Continuous Emissions Monitoring Systems ($0.3B) | Install APCDs in 50,000 small boilers (100% coverage) and CEMS in ~700 red-category industries (100% mandated). | No additional economic value beyond investment. |
| **Power** | ~$2B investment | Flue Gas Desulphurisation ($2B) | Install FGDs in 72 Category A & B TPP units (100% mandated). | Reduces $SO_2$ and PM2.5; no additional economic value beyond investment. |
| **Construction & Road Dust** | ~$0.2B \| ~$0.1B investment, ~$0.1B annual economic value | Mechanised Road Sweepers ($0.1B) | Deploy ~3,000 MRS in ~150 cities (100% NCAP cities). | Value to MRS manufacturers from sale. |
| | | Construction Safeguards ($0.1B) | Deploy PM2.5 sensors, CCTV, protective sheets, enclosed setups at ~5,500 sites in ~150 cities. | Value to manufacturers from sale of safeguards. |
| **Monitoring** | ~$0.03B \| ~$0.01B investment, ~$0.02B annual economic value | Low-cost Sensors (LCS) ($0.03B) | Deploy ~11,000 LCS across ~150 cities (100% NCAP cities). | Value to manufacturers from sale of LCS. |

**The implementation of these air quality solutions across the 3 pathways delivers significant environmental and health co-benefits alongside economic gains.** Collectively, the solutions can abate over 115 million tonnes of $CO_2$ annually, while reducing PM2.5 emissions by nearly 20%. As a result, an estimated 10 million DALYs can be averted each year, leading to major reductions in disease burden and premature mortality.





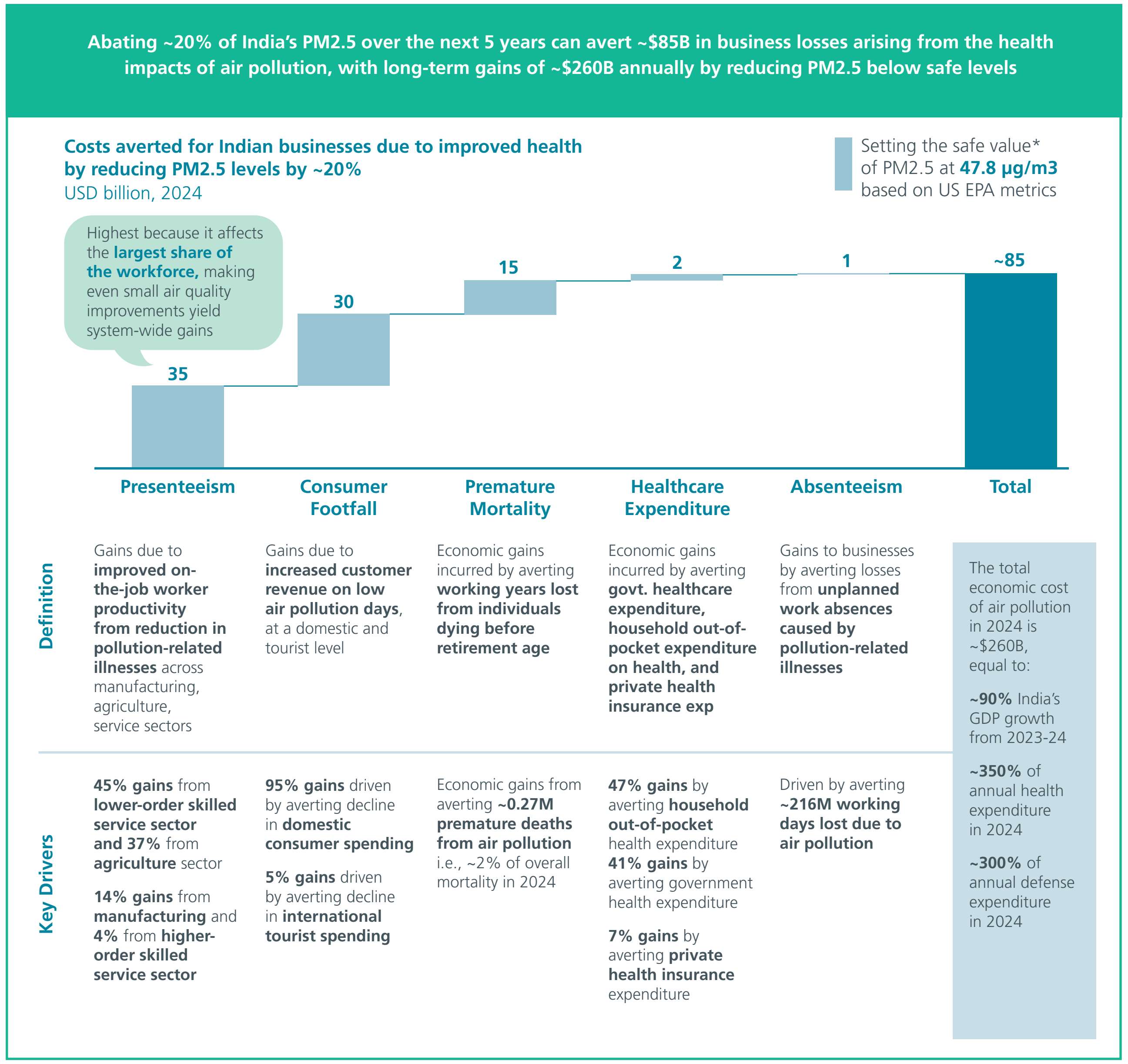
# Summary of Findings: Macroeconomic Gains

**By improving air quality through these solutions by just ~20%, India can generate ~$85B in economic gains by 2030.** Air pollution above safe levels,[5] costs Indian businesses ~$95B[6] each year (3% of India's GDP) largely due to its health and productivity impacts. In a worst-case scenario, this cost could rise to ~$260B annually (~6% of current GDP).

This cost is driven by 5 metrics of air pollution's impact on health i.e., losses in labour productivity from (i) unplanned pollution-related absences and (ii) reduced worker output, (iii) decrease in consumer footfall, (iv) increase in premature mortality, and (v) added healthcare expenditure.

Implementing the 13 identified air pollution solutions can reduce PM2.5 levels (from current levels) by ~20% within five years, averting almost $85B of these annual losses by 2030. The largest gains come from improved worker output ($35B) and consumer footfall ($30B). In the long run, achieving safe PM2.5 levels could unlock ~$260B in annual economic gains (see Figure 4).

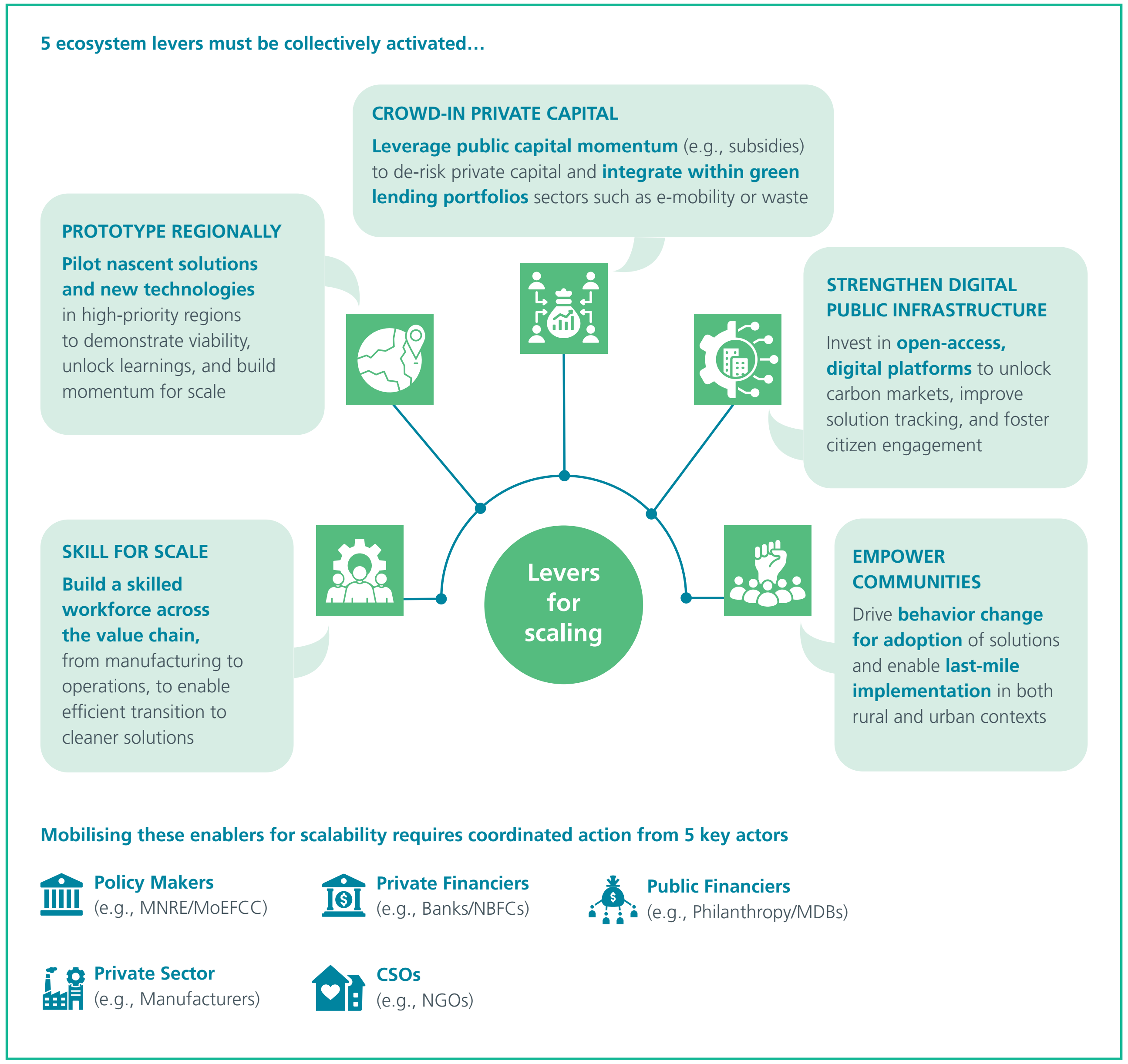
*Figure 3: Economic gains unlocked across 5 metrics of air pollution's impact on health, by improving air quality*



# Way Forward

**Scaling air pollution solutions to realise India's clean air economic opportunity hinges on mobilising private capital, prototyping solutions regionally, building a skilled green workforce, driving behaviour change within communities and strengthening digital public infrastructure.**

*Figure 4: Levers to unlock India's clean air economic opportunity*








**Mobilising these ecosystem enablers will require coordinated action across five key actors:**

- Policymakers must strengthen legal frameworks and enforcement mechanisms, set mandates to generate demand, and de-risk early markets through instruments like subsidies, procurement, and digital infrastructure (for example, carbon credit marketplaces and open data).
- Private financiers need to expand green lending portfolios and provide concessional loans for clean air solutions by leveraging public momentum and participating in blended finance structures.
- Public financiers can deploy catalytic capital, including guarantees, grants, and results-based finance tied to measurable activities (vs. PM2.5 reduction, which is difficult to measure) such as deployment of key solutions or proven outcomes such as carbon—to crowd in private investment and scale high-impact solutions.
- Private sector players need to continue to invest in R&D, build manufacturing capacity, strengthen supply chains, and upskill workers to deploy clean technologies at scale.
- Civil society can drive public awareness and behavioural change, support informal workers' inclusion and training, and monitor implementation outcomes through community-led feedback loops and accountability mechanisms.

**India's approach to achieving clean air must now move beyond a focus on mitigating losses toward realising economic opportunity. Reframing clean air as a driver of growth and resilience can mobilise new coalitions, attract capital flows, and embed clean air as a cornerstone of India's green development agenda.**

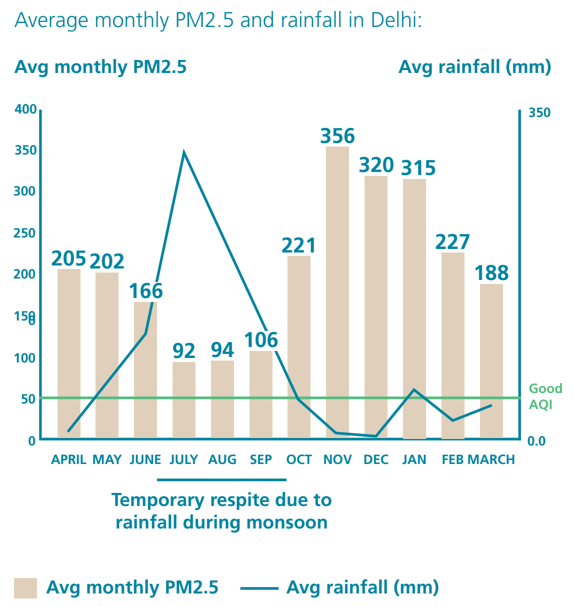
**By viewing air quality management not as a cost but as a catalyst for progress, India can advance public health, strengthen economic competitiveness, and demonstrate climate leadership.**

# II. Context: Air Pollution as an Economic Opportunity

**Air pollution is a persistent, year-round concern that poses a dual threat to both public health and the economy in India.** In 2024, India ranked as the fifth most polluted country,[7] with PM2.5 levels exceeding the WHO's recommended limit by over ten times.[8] In 2019 alone, air pollution was linked to 1.7 million deaths, with disproportionate impacts on children, the elderly, pregnant women, and immunocompromised individuals.[9] The economic impact is equally alarming; air pollution drives millions in annual healthcare costs and billions in productivity losses due to premature deaths, unplanned sick leave, and reduced worker efficiency. Poor air quality has also severely damaged India's tourism, costing the industry $1.7 billion each year.[10] Other costs, such as indirect impacts on unpaid work, caregiving, and community contributions remain unquantified, despite being significantly disrupted by pollution-related illness and disability.

### *Figure 6: The year-round impact of air pollution on health and the economy*

**Air pollution is a year-round issue, which remains high across the year, despite spikes during winter**




**Dalberg and CAF's previous study highlights the staggering impact of air pollution on India in 2019**

**1.7 million** — **Annual deaths in India due to air pollution in 2019**[1] (18% of total deaths in India in 2019)

**54 million** — **Annual DALYs in India due to air pollution in 2019**[1] (12% of total DALYs in India in 2019)

**$95 million** — **Annual cost of air pollution on Indian economy in 2019**[2] (3% of GDP in 2019)

**1.3 billion** — **Working days lost due to absenteeism in 2019**[2] (6% of total air pollution impact in 2019)

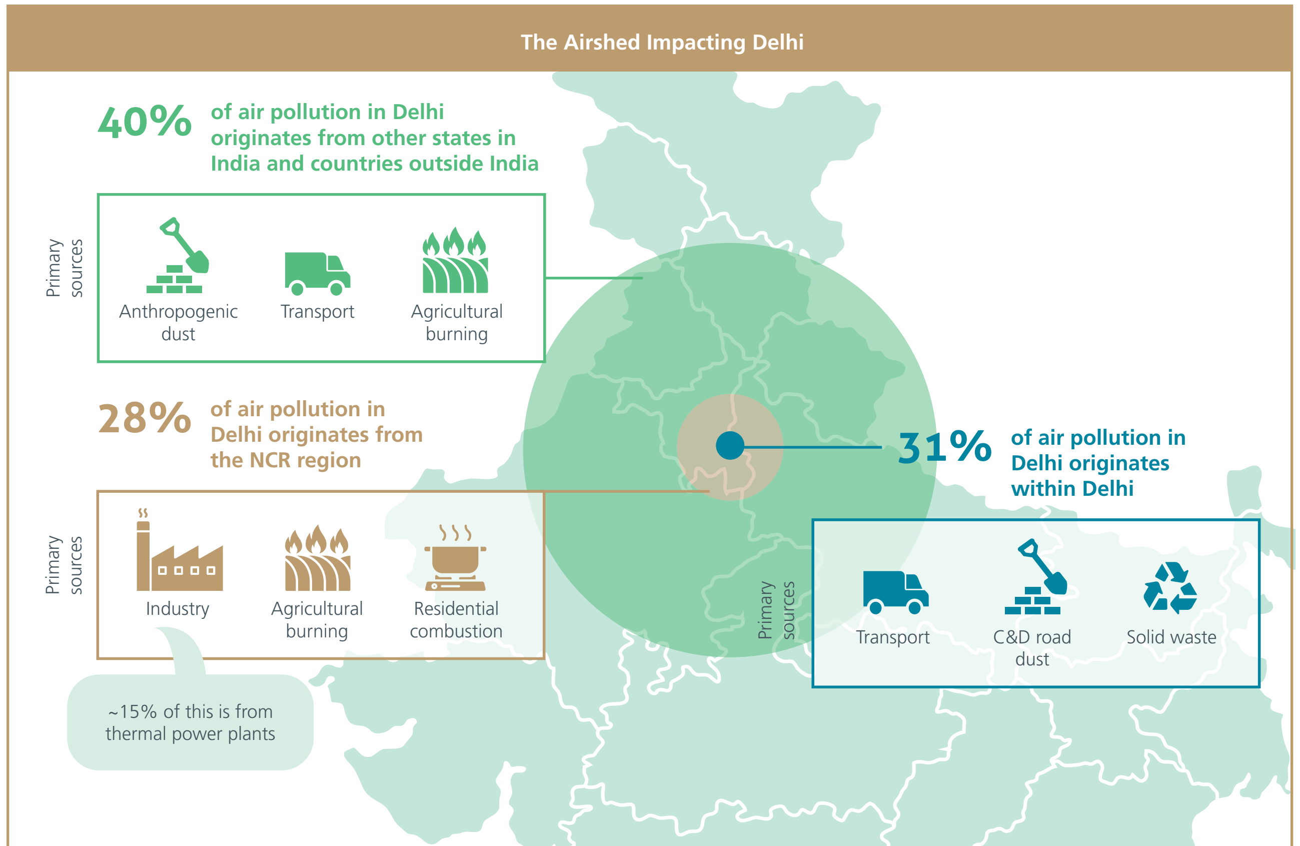
Sources: 1. The Lancet, 2021; 2. Dalberg and CAF, 2021

**Further, air pollution is not a localised issue but a regional airshed problem, with various high-emitting sectors driving majority of the pollution in India.** In Delhi, for instance, only ~30% of the pollution originates within the city, with the remainder transported from surrounding areas, driven by the anthropogenic dust from surrounding states, seasonal burning of crop residues in Punjab and Haryana, and industrial emissions from thermal power plants in neighbouring districts. A concentrated set of high-emitting sectors account for the majority of India's PM2.5 burden, including industrial emissions, crop residue burning, residential combustion, urban construction and others. Industry is the largest contributor, contributing >35% to PM2.5 levels in India, followed by residential cooking and heating at 27%[11]. Other large contributing sectors include agricultural residue burning and combustion of solid waste, producing 13% and 9% of India's PM2.5 respectively. Increasing construction activities in urban areas, tailpipe emissions from the transport sector and emissions from thermal power plants further compound the problem.



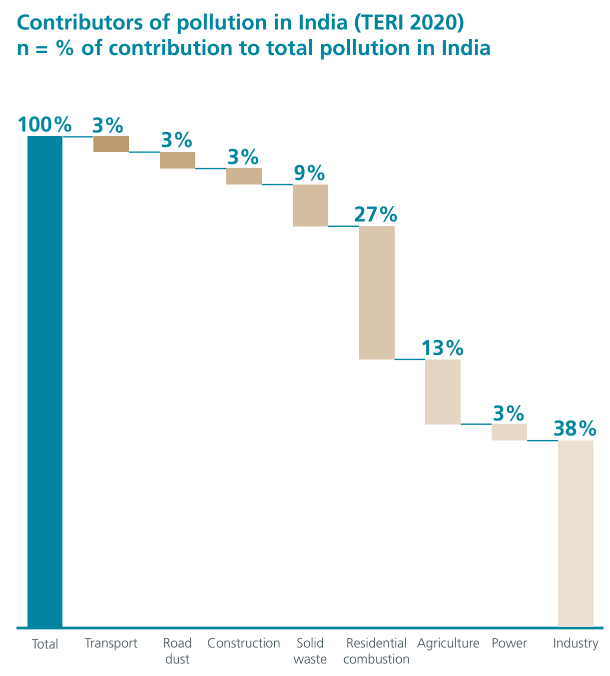


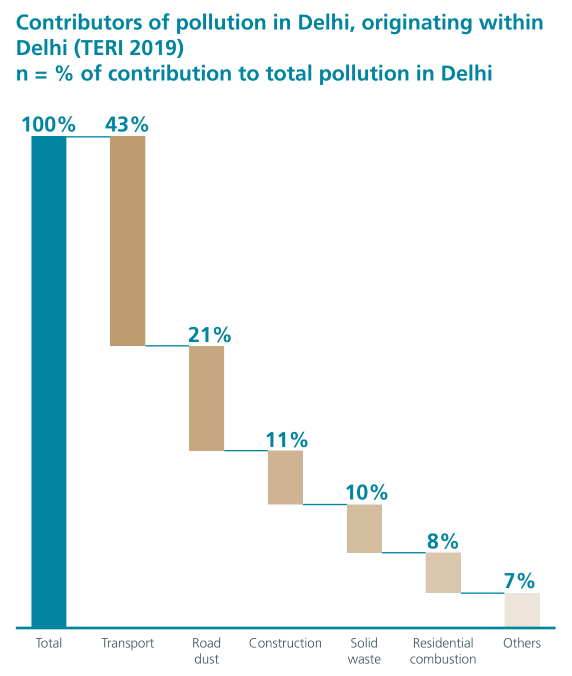
### *Figure 7: Air pollution is a regional airshed problem; ~70% of Delhi's air pollution arises from surrounding areas*




Source: Estimated from (1) World Bank. 2023. Striving for Clean Air: Air Pollution and Public Health in South Asia. [: Calculations using GAINS model developed by the International Institute for Applied Systems Analysis (IIASA) (2) TERI. 2021, Cost effectiveness of interventions for control of air pollution in Delhi, New Delhi: The Energy and Resources Institute (3) Khanna, I., Sharma, S., 2020. Could the National Capital Region serve as a control region for effective air quality management in Delhi?, Policy Brief, CCAPC/2020/02, Collaborative Clean Air Policy Centre, New Delhi

### *Figure 8: Contribution of different sectors to air pollution in India and Delhi*

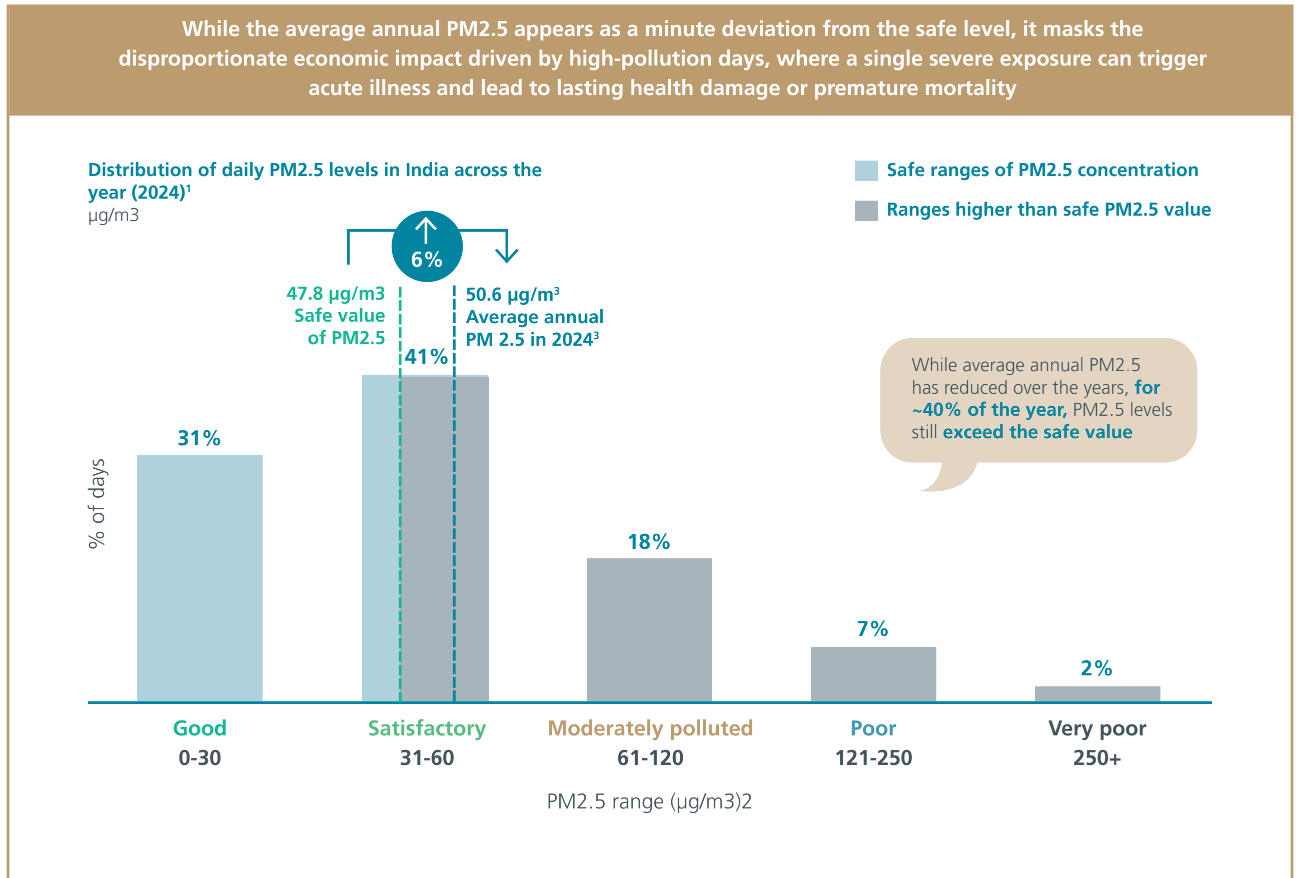


**Since 2019, national efforts such as the National Clean Air Programme (NCAP) have driven nationwide action, driving improvements in air quality.** Covering 130 cities in India and targeting a 40% PM reduction by 2026 from 2017 levels, NCAP has deployed US$ 890 million from 2019–2025 across priority sectors such as road dust, vehicles, and waste burning. 44 cities have conducted source apportionment studies, and manual monitoring capacity has grown by 40%.[12] These measures, alongside other national and local initiatives, have contributed to a 13% reduction in India's annual average PM2.5 between 2019 and 2024,[13] with 40% of cities now meeting the NAAQS PM2.5 standard.[14] Additionally, 41 of the 131 NCAP cities have met the initial target of 20-30% reduction in PM10 levels as of 2024-25.[15]

**Despite these gains, high-pollution days continue to drive severe health and economic impacts, underscoring the need for sustained, year-round action.** In 2024, the national average PM2.5 was 50.6 µg/m³. While only 6% higher than the safe limit, ~40% of the days exceeded the safe levels and ~30% of days recorded unhealthy PM2.5 levels (see Figure 9). With even short-term exposure on such high-polluting days triggering acute illness and causing lasting damage or premature death, there is a need for sustained air pollution action.[16]

### *Figure 9: Distribution of PM2.5 in India*



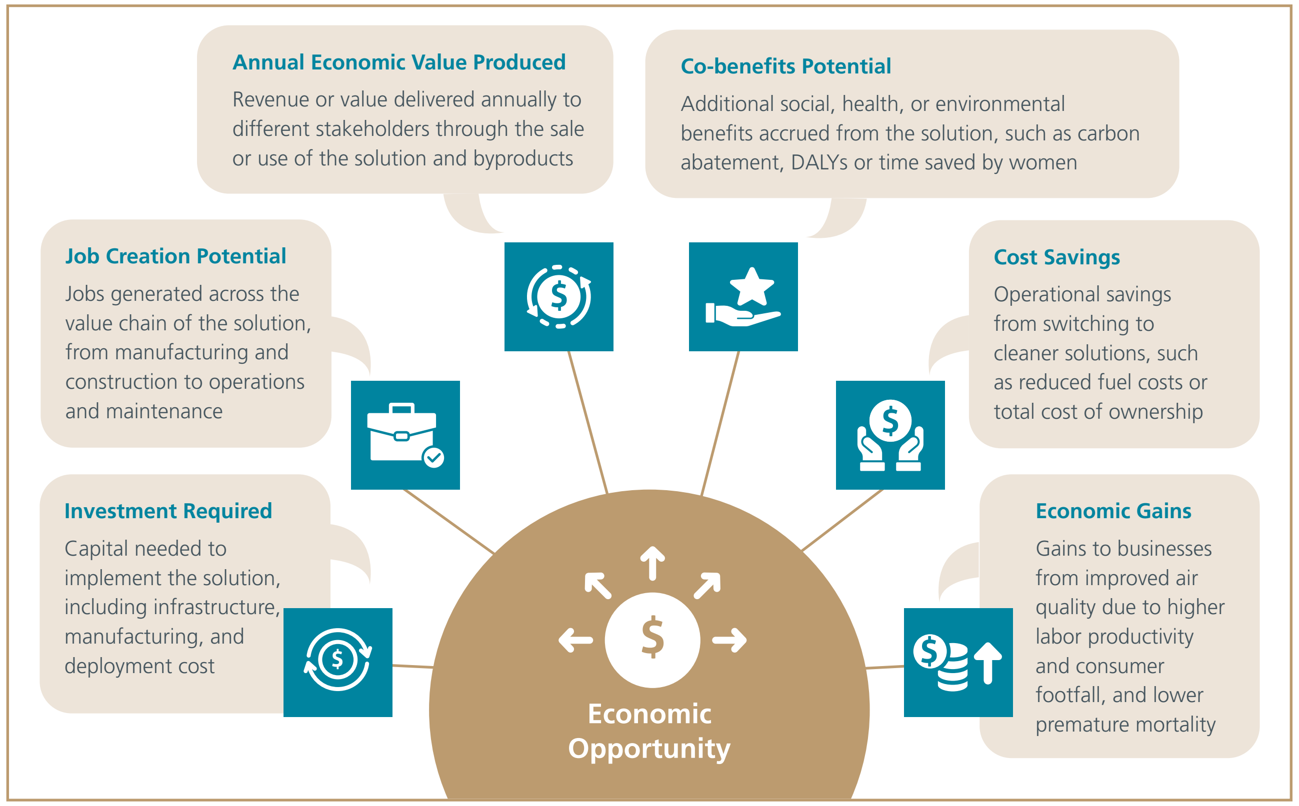

Sources: 1. Projected based on weighted PM2.5 distribution data from sensors in urban and rural areas; 2. WYND, 2023; 3. IQAIr

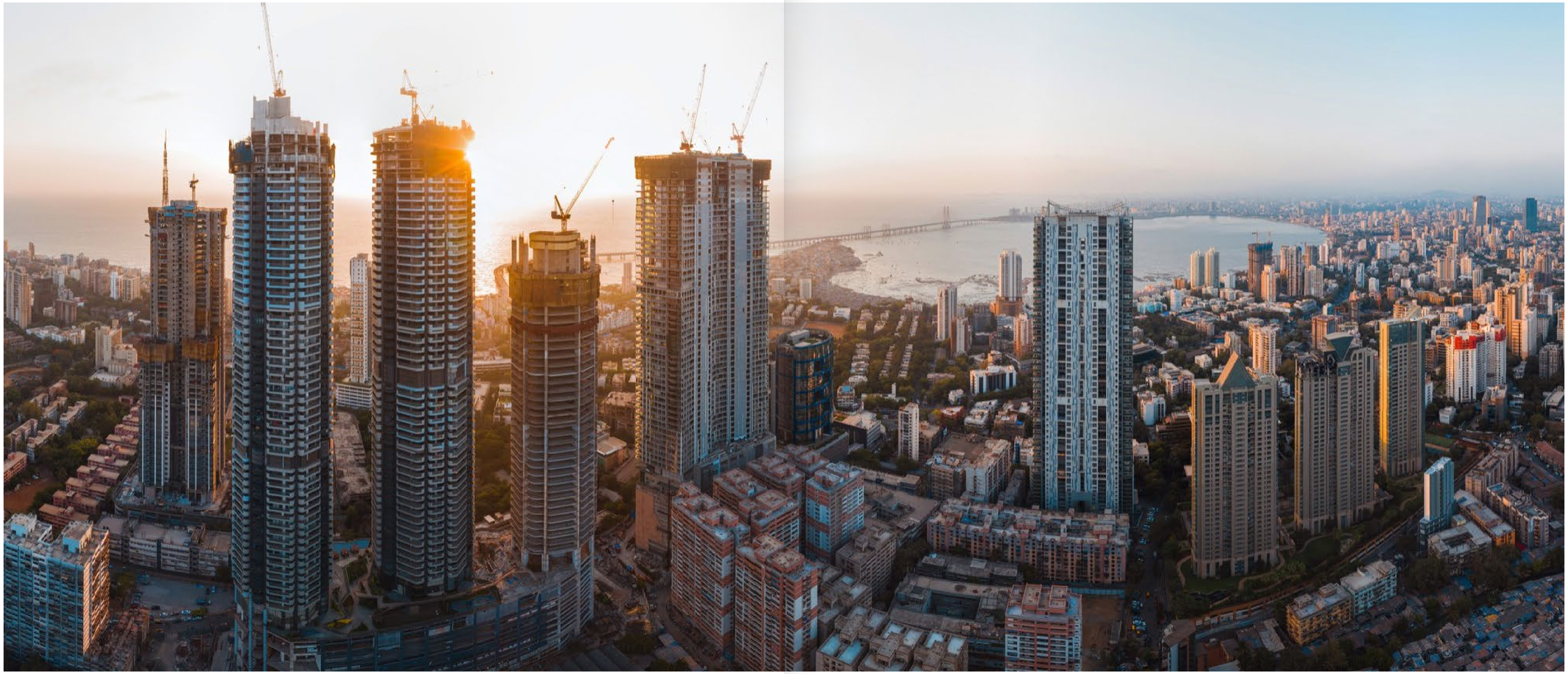




**However, solving for air pollution must be viewed as an untapped economic opportunity that can drive investment, generate economic value, create jobs, and unlock co-benefits.** Clean air solutions offer high-impact investment potential while generating economic value through new revenue streams and reducing costs for governments, businesses, and households. They also generate employment across the value chain, from manufacturing and plant construction to last-mile service delivery, strengthening both urban and rural livelihoods. In parallel, these solutions deliver measurable climate, health, and social dividends, including reductions in GHG emissions, DALYs, and tangible time savings for women, particularly through clean cooking access.

### *Figure 10: Solving air pollution can drive 6 economic benefits*





**Solutions to improve air quality across key sectors already exist in India, ranging from electric vehicles (EVs) to crop residue management, solid waste to clean cooking solutions, and when deployed at scale, can serve as engines of economic growth.** India's rapidly growing EV sector, for example, presents a major opportunity to attract investments across the value chain—from battery manufacturing to charging infrastructure and vehicle assembly—while enabling cost savings and reduced dependence on fossil fuels. The compressed biogas (CBG) sector is also gaining momentum, with major private investments like Reliance's US$ 580 million commitment[17] and strong policy backing through the SATAT scheme,[18] which targets 5,000 plants nationwide.[19] Solid waste solutions such as material recovery facilities (MRFs) can create jobs across from manufacturing, operations and collection to processing, while formalising informal labour and enabling circular economy outcomes. Beyond economic gains, clean-air solutions bring powerful co-benefits—reducing harmful emissions, improving respiratory health, and delivering time savings particularly for women through access to clean cooking.

**The objective of this report is to strengthen the case for investment in clean air by quantifying the economic opportunity, while also highlighting the social and environmental value of solving for air pollution in India.** The report conducts a rigorous analysis of 13 air pollution solutions to understand the economic opportunity of air quality management in India i.e., investment potential of the clean-air sector, job creation potential, economic value generated, co-benefits produced, cost-savings created, and economic gains from improved air quality. Drawing upon diverse data sources, including industry projections, investment forecasts, and emissions data, the report translates broad commitments into tangible, measurable outcomes. While prior research has addressed individual aspects of these solutions in isolation, this report provides a comprehensive assessment of their combined economic potential and socio-economic benefits. By quantifying these benefits, the report aims to position clean air solutions as compelling economic opportunities, enabling policymakers, investors, and industry leaders to direct capital towards high-impact solutions that deliver maximum returns.

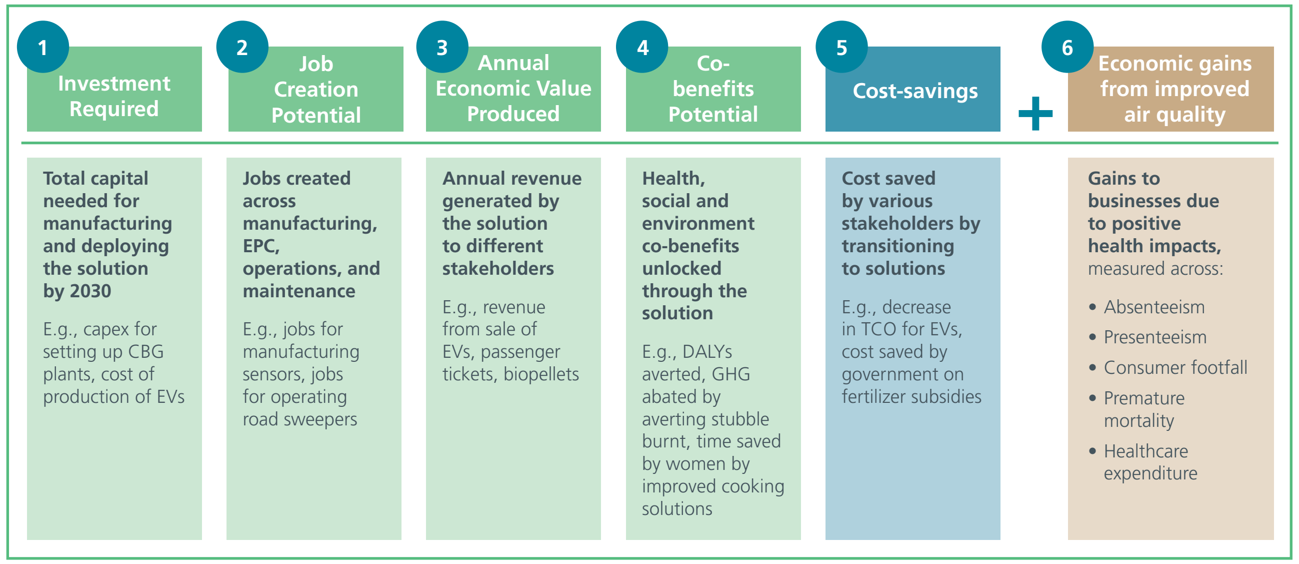
**Further, this report focuses on direct air pollution mitigation solutions that can be implemented across key sectors such as industry, transport, construction, and residential combustion. Broader enabling factors—such as improvements in power supply reliability, adoption of renewable energy, or reduction of diesel generator (DG) emissions—are recognised as important for sustaining long-term air quality gains but fall outside the quantitative scope of this analysis.**

# III. Measuring the Opportunity: Methodology

**This analysis evaluates the full economic impact of clean air solutions in India through two key measures: the economic opportunity from deploying air pollution solutions nationwide, and the economic gains from avoiding pollution-related business costs through reduced PM2.5 exposure.** The report first assesses the direct economic opportunity of air pollution solutions by quantifying five key metrics: i) investment required across a 5-year-period, (ii) job creation by 2030, (iii) annual economic value produced, (iv) annual co-benefits and (v) annual cost-savings. Second, the report computes the broader macroeconomic gains that can be accrued through improved air quality, across higher workforce productivity, reduced health burdens, stronger consumer demand and increased work attendance (see Figure 11). Together, these benefits highlight how clean air can deliver immediate economic returns while strengthening long-term growth and resilience.

The methodology for assessing the direct economic opportunity of air pollution solutions draws on rigorous secondary research and was refined through expert consultations to ensure real-world accuracy. The report reviewed landmark publications quantifying the economic impact of environmental solutions, including IRENA (2017) on renewable energy,[20] WRI (2018) on land restoration,[21] and IEA (2020) on clean energy investments,[22] to identify relevant metrics to the Indian context. These studies informed a set of the five key evaluation metrics. These global benchmarks were then validated through expert consultations across 8 key sectors: agriculture, residential cooking, transport, solid waste, industry, power, construction, and monitoring – to ensure that the methodology reflects both international rigor and on-ground realities.

***Figure 11: Framework for measuring the economic opportunity of clean air***








## 1. Investment Required

**This metric captures the total capital required to implement each solution by 2030, including capex for equipment, installation, and supporting infrastructure.** For each solution, we estimate the total number of units to be newly installed or retrofitted based on projected sectoral demand or national targets for 2030. This is combined with unit-level capital costs to calculate the total investment needed. For some solutions, additional parameters such as installation margins, deployment scale, and manufacturing overheads are incorporated to reflect real-world cost structures.

**Initial catalytic capital:** Initial catalytic capital refers to the investment required to kick-start the deployment of a solution. This includes early-stage funding such as subsidies, concessional finance, or seed capital needed to set up blended finance instruments such as risk sharing debt facility. In this report, "initial catalytic capital" captures the resources needed to overcome entry barriers, de-risk the solution, and demonstrate its viability. This measure emphasises the foundational role of early capital in enabling pilot projects, establishing proof of concept, and creating the conditions for subsequent large-scale investment.

**Crowded-in commercial capital:** Crowded-in commercial capital refers to the investment that is unlocked as a result of the multiplier effect generated by the initial catalytic capital. These are market-based funds mobilised from commercial banks, institutional investors, private developers, or other mainstream financiers once the solution demonstrates commercial viability and risk levels fall. In this report, "crowded-in commercial capital" captures the larger pool of follow-on resources that flow into scaling, replication, and long-term deployment. This measure emphasises the leverage potential of catalytic funding in attracting sustainable private capital at scale.

## 2. Job creation potential

**This estimate reflects the gross jobs created over a 5-year-period for each solution across three main stages: (i) equipment manufacturing; (ii) engineering, procurement, and construction (EPC); and (iii) long-term operations and maintenance.** Employment is calculated by applying sector-specific multipliers to the number of units deployed. These factors reflect the typical workforce required for each solution, drawing on industry benchmarks and comparisons with conventional alternatives, while accounting for differences in labour intensity and technological complexity.

**Job transition:** Job transition refers to the existing roles that shift from one type of work to another as the solution is deployed, without adding to the overall number of jobs in the economy. These are typically positions where workers remain employed but their tasks, tools, or required skills are altered to align with the new system. In this report, "jobs transitioned" captures the number of workers who would move from the incumbent system into equivalent roles in the new system, often with upskilling or reskilling. For example, when the fleet of ICE buses transitions to e-buses, existing drivers, depot staff, and mechanics largely retain employment but adapt to new responsibilities, equipment, and skills requirements. This measure emphasises continuity of employment while highlighting the adaptation required from the workforce to operate effectively in a changing technological and organisational environment.

**Job creation:** Job creation refers to entirely new roles that emerge as a direct result of the solution, expanding overall employment in the economy. These jobs do not exist in the incumbent system but are generated by the establishment of new value chains, industries, or services. In this report, "jobs created" captures the number of workers newly employed in functions such as construction, operations, supply chains, or downstream services associated with the solution. For example, deploying a CBG plant generates new employment opportunities in plant construction and operations—jobs that would not have existed in the absence of the solution. This measure emphasises the expansion of employment opportunities and the generation of additional economic activity that goes beyond the redeployment of the existing workforce.

## 3. Annual economic value produced

**This metric captures the direct gross annual revenue generated by each solution through the sale of goods, services, and carbon credits produced during its operation.** Many air quality solutions directly produce steady revenue streams, for example, brick sales from improved kilns, farebox revenues from e-buses, or biogas and compost sales from CBG plants. We estimate the revenue using assumptions on operational scale, utilisation potential, market prices, and technology lifespan. The result is a grounded view of income potential, particularly critical for private investors, local enterprises, and state actors to assess the long-term income potential and commercial viability of each solution.

**Existing revenue streams:** Existing revenue streams refer to the continuation of income sources that already exist in the incumbent system and remain relevant under the deployment of the solution but are delivered through a different technology or operational model. These are typically revenues linked to ongoing activities such as vehicle sales, fare collection, or other established market transactions that persist. In this report, "existing revenue streams" capture the revenue generated from functions that remain structurally similar, such as the sale of buses or farebox income from passengers, emphasising the continuity of economic flows even as the underlying system evolves.

**New revenue streams:** New revenue streams are the income sources that emerge exclusively due to the deployment of the solution, representing value chains and markets that did not exist in the incumbent system. These revenues are generated through the creation of new goods, services, or by-products that arise as part of the solution. In this report, "new revenue streams" capture revenue generated from outputs from newly established processes, or sale carbon credits as a result of the solution, highlighting the expansion of economic activity and diversification of income potential driven by the solution.

## 4. Co-benefits potential

**Beyond air quality improvements, these solutions deliver health, environmental and social benefits such as annual DALYs reduction, GHG abatement and time saved by women**. DALYs averted per year are calculated based on DALY reduction per PM2.5 % reduced by the specific solutions. We quantify annual greenhouse gas (GHG) abatement potential by comparing emissions factors of baseline and improved technologies, using India-specific energy-use data. Where relevant, social co-benefits such as time savings for women per year through cleaner household energy solutions, are valued based on secondary research. This metric highlights the broader developmental surpluses of clean air solutions, reflecting their contributions to climate, equity, and overall wellbeing.

Carbon credit values are included as an indicative measure of potential co-benefits from verified GHG abatement. Carbon credit prices in the voluntary carbon market vary widely—typically between **USD 1 and 10 per tonne,** depending on credit quality, project type, and verification standards. After consultations with sector experts, who indicated that most traded credits for similar mitigation solutions fall within the USD 2–3 range, this report adopts a uniform value of USD 3 per tonne for consistency and comparability across solutions. These are not compliance-market credits and are intended to reflect plausible, conservative revenue potential rather than guaranteed monetisation. Actual issuance and sale of credits will depend on project eligibility, certification standards, and verification processes. While this report assumes the full potential for carbon credit generation, it is possible that only a subset of abatement may ultimately qualify for issuance and sale under voluntary market standards.

## 5. Cost-savings

**This metric models the annual savings created by clean air solutions by comparing the total cost of ownership and operation in comparison to business-as-usual alternatives.** This includes user level savings such as reduced spending on fuel and maintenance, and public savings such as lower government expenditure on subsidies and services. For instance, we estimate fuel cost savings from improved stoves and e-trucks at a user-level and avoided fertiliser subsidies due to organic waste valorisation as a public sector saving.

## 6. Economic gains from improved air quality

**This metric builds on the study by the Clean Air Fund, Confederation of Indian Industry (CII), and Dalberg Advisors which estimated the cost of air pollution on the Indian economy.** This includes costs arising from 5 key sub-metrics: (i) presenteeism, (ii) absenteeism, (iii) consumer footfall, (iv) premature mortality, and (v) healthcare expenditure. The detailed methodology for the computation can be found below, under sub-section "Macroeconomic Gains".

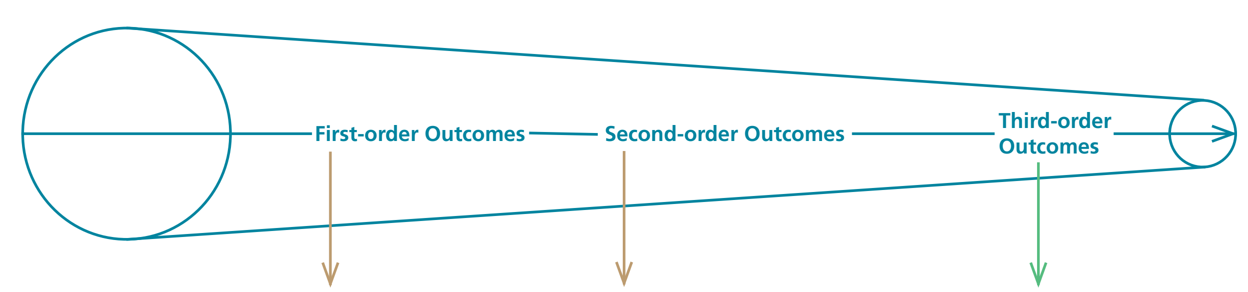




**These 6 key elements of the framework interact in 3 orders of outcomes:**

***Figure 12: Three orders of outcomes from implementing air quality solutions***

| Solution-specific outcomes: Implementing air quality solutions will lead to economic outcomes at first and second order, while leading to a reduction in 20% PM2.5 | | | Macroeconomics gains: Reduction in PM2.5 will lead to improved health, thereby unlocking macroeconomic gains |
|---|---|---|---|




| Key Elements | Investment and economic gains from "brown to green" economy transition | Mobilising private capital and expanding the green economy (20% Reduction in PM2.5) | System-level gains due to improved health from better air quality |
|---|---|---|---|
| Investment required | **Initial catalytic capital** i.e. initial capital outlays to build necessary ecosystem | **Crowded in commercial capital** i.e. additional commercial capital mobilised as a result of catalytic capital under first order outcomes | Absenteeism |
| Job creation potential | **Job transition** i.e. reskilling and transition of gross jobs to cleaner alternatives | **Job creation** i.e. new gross jobs as a result of setting up of new value chains | Presenteeism |
| Annual economic value generated | **Existing revenue streams** i.e. the gross economic value produced due to transition of current value chains to cleaner alternatives | **New revenue streams** i.e. gross economic value produced due to setting up new value chains | Consumer Footfall |
| Cost savings | | **Gross cost savings in economy due to transitioning** (e.g., reduction in oil imports) or new value chains (e.g., reduction in fertilizer subsidy due to cheaper manure) | Healthcare Expenditure |
| Co-benefits potential | | **Health benefits,** e.g., DALYs averted<br>**Environmental benefits** e.g., GHG abated<br>**Social benefits** e.g., time saved by women | Premature Mortality |

- First-order outcomes are effects of investments in initial capital (e.g., viability gap funding, capex subsidies, seed capital) deployed to implement solutions, and revenue and jobs transitioned from shifting existing activities to greener alternatives (e.g., ticket sales from e-buses, cleaner brick production). This is predominantly seen in solutions that directly support the transition from a "brown to green" economy, where existing revenue streams continue, but the underlying technology transitions from polluting to clean technology. The economic pie doesn't expand substantially, but it becomes greener, delivering emissions reductions and health gains.

- Second-order outcomes are a result of leveraging initial catalytic capital to crowd-in commercial capital, thereby supporting development of expanding and building of new industries and value chains (e.g., compressed biogas plants). Associated with these are new revenue streams (e.g., from biogas or recyclable sales), new gross jobs across sectors and geographies, and the cost savings realised by governments and consumers (such as lower ownership costs or subsidy reductions). In addition, across value chain there are co-benefits, including improvements in health, social, and environmental outcomes.

- Third-order outcomes are macroeconomic gains across various businesses (not limited to the solution areas), which occur when the country successfully deploys air quality management solutions, and are driven by improved productivity, increased consumer footfall, reduced premature mortality, and reduced healthcare expenditure.





# Selected Air Quality Management Solutions and Economic Pathways

**A set of 13 high-impact solutions were evaluated across key polluting sectors like transport, solid waste, agriculture, residential combustion, construction, road dust, power, industries and monitoring.** While not exhaustive, these solutions were selected for their maturity, scalability, and ability to deliver near-term impact.

*Figure 13.1: Sectors with key air-pollution solutions (1/2)*

| | Transport | Agriculture | Residential Combustion | Solid Waste Management |
|---|---|---|---|---|
| Prioritised Solutions | **1 Electric buses**<br>**2 Electric trucks**<br>• Electric 2-wheelers<br>• Electric 3-wheelers<br>• Electric 4-wheelers | **3 Compressed Biogas Plants (CBG)**<br>**4 Bio-pellets for co-firing in TPPs**<br>• Other ex-situ solutions (e.g., *biopellets for industrial boilers*)<br>• In-situ solutions (e.g., *happy seeders*) | **5 Improved cooking solutions (e.g., biomass stove, electric stove)**<br>• Liquefied Petroleum Gas (LPG)<br>• Electric heaters | **6 Compressed Biogas Plants (CBG)**<br>**7 Material Recovery Facilities (MRF)**<br>• Decentralised solutions (*e.g., decentralised CBG, MRFs, composting*) |
| Rationale for prioritisation | Electric **2W, 3W, and 4W already comprise >95% of EV sales** in FY25, with steady growth (~15% YoY) from strong policy push1<br>**E-buses** (<1% share, 4% YoY) and **e-trucks** (only ~550 units sold since 2023) **remain nascent,** requiring targeted efforts to move the needle[1] | **CBG and biomass co-firing** for TPPs are **backed by strong mandates** (e.g., SATAT targets; 7% biomass co-firing mandate) and have high economic value (e.g., sale of CBG, manure, bio-pellets)<br>Demand for **bio-pellets** is **likely to shift** from industrial boilers **to TPPs**<br>**In-situ is declining in preference,** with adoption declining from 80 to 60% in two years[2] | **~75% of India's PM2.5 from residential combustion** is from solid fuel for cooking,[3] requiring targeted focus on **clean cooking solutions**<br>**LPG,** while the cleanest option, is **unaffordable or inaccessible** for many households<br>**Improved cooking** solutions can **cut PM2.5 by 60–80%,** and **cost ~95% less** to scale universally than LPG4 | **Large, centralised CBG and MRFs** can process large volume and enable **city-wide scaling**<br>**Decentralised solutions** such as community-level CBG, MRFs, and composting have **limited scalability** due to low processing capacity and fragmented deployment |

Note: TPP stands for thermal power plants
Sources: 1. VAHAN data, 2025; 2. CSTEP, 2024; 3. TERI, 2021; 4. Expert interviews

1. **Transport:** Within transport, the report prioritises electric buses and electric trucks as the most catalytic solutions to deliver large-scale emissions reduction and economic value creation. While India's electric 2-, 3-, and 4-wheeler segments have already benefited from a strong policy push and rapid adoption—together accounting for over 95% of EV sales with steady annual growth of ~15%—the heavy-duty segment remains nascent.[23] E-buses (less than 1% of total bus stock) and e-trucks (only ~550 units sold since 2023) offer significant potential for emissions reduction and market development but require targeted public investment and policy support to scale. In contrast, two-, three-, and four-wheeler segments are already commercially viable and advancing through market momentum.

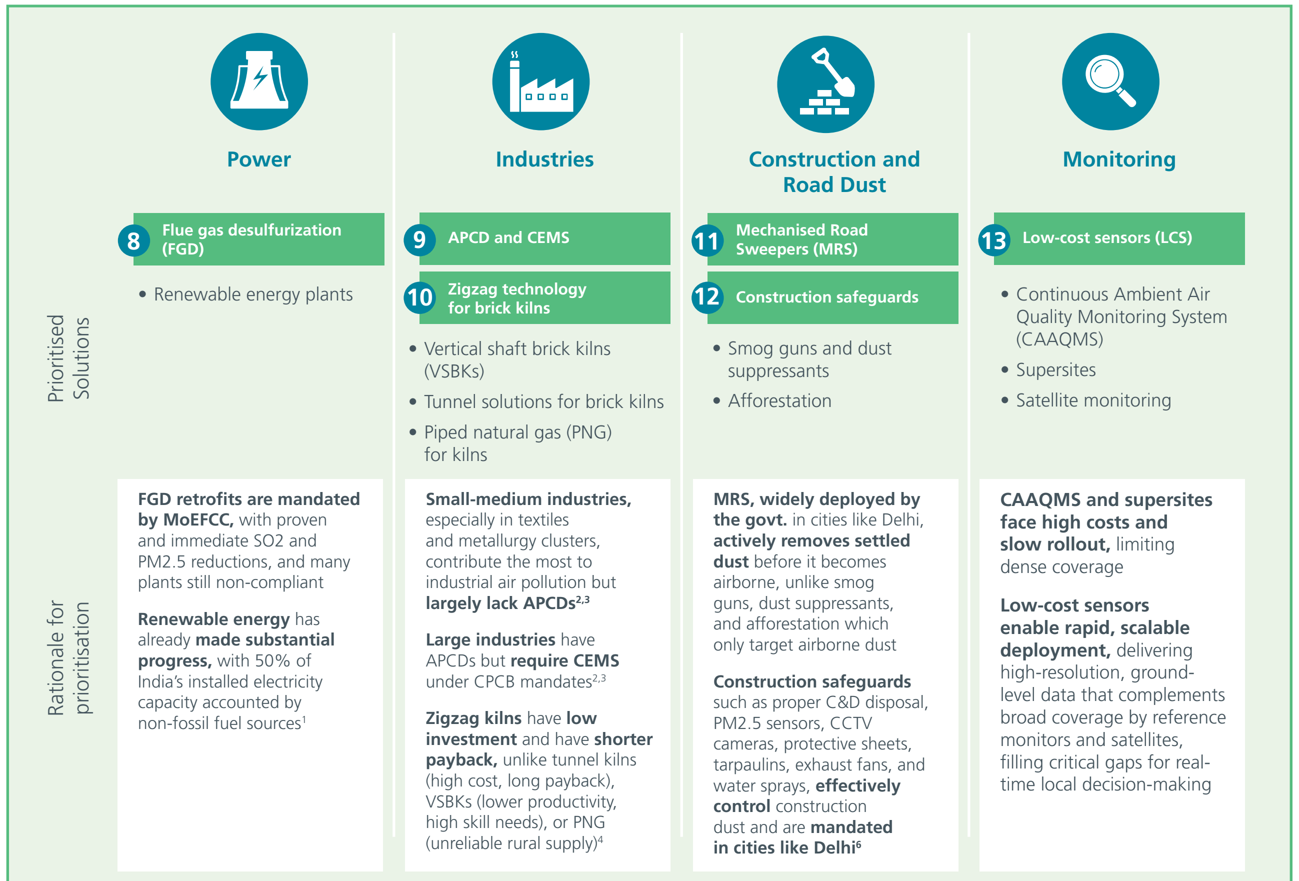
2. **Agriculture:** In agriculture, Compressed Biogas (CBG) plants and bio-pellets for co-firing in thermal power plants (TPPs) were prioritised for their strong policy backing, commercial potential, and capacity to reduce stubble burning. CBG and biomass co-firing are supported by national mandates such as SATAT and biomass co-firing targets, and they create valuable byproducts like manure and bio-pellets. Demand for bio-pellets is also expected to rise as TPPs shift away from industrial boilers. In contrast, in-situ crop residue management solutions like happy seeders have shown declining adoption—from 80% to

60% in two years[24]—making ex-situ solutions more scalable and economically sustainable. Nutrient management was also not included as it targets ammonia ($NH_3$), which has a non-linear relationship with ambient air quality and requires major reductions to yield modest gains.[25]

3. **Residential combustion:** The report prioritises improved cooking solutions (e.g., biomass and electric stoves) as a critical solution to curb emissions from residential fuel use. Nearly 75% of India's PM2.5 emissions from residential combustion sector stem from the use of solid fuels for cooking, underscoring the need to accelerate clean cooking transitions. While LPG remains the cleanest option, it is unaffordable or inaccessible for many households, particularly in rural areas. Improved cooking solutions can reduce PM2.5 emissions by 60–80%, are significantly more cost-effective to scale, and offer a practical bridge toward universal access to clean cooking.[26]

4. **Solid waste management:** Large-scale Compressed Biogas (CBG) plants and Material Recovery Facilities (MRFs) were prioritised for their ability to process high waste volumes and enable city-wide impact. Centralised CBG plants align with SATAT goals and can convert municipal organic waste into biogas and manure, while MRFs provide infrastructure for recycling and resource recovery. Decentralised solutions such as community-level composting or small-scale CBG and MRF units were deprioritised due to limited processing capacity, fragmented deployment, and higher per-unit costs—making centralised models more viable for large-scale pollution reduction and economic returns.

***Figure 13.2: Sectors with key air-pollution solutions (2/2)***




Note: APCDs stands for Air pollution control devices; CEMS stand for Continuous Emissions Monitoring Systems
Sources: 1. Reuters, 2025; 2. Expert interviews; 3. TERI, 2021; 4. Shakti Foundation, 2012; 5. DPCC

5. **Power:** In the power sector, the report prioritises flue gas desulphurisation (FGD) as the key solution to address emissions from thermal power plants. FGD retrofits are mandated by the MoEFCC (for certain specific plants, in lieu of the notification in July 2025), yet many plants remain non-compliant—making this a high-impact, compliance-driven solution. Renewable energy, while critical for the long-term transition, was deprioritised for this report as the sector has already made substantial progress, with over 50% of India's installed capacity now from non-fossil sources.[27]

6. **Industries:** Within industries, the report prioritises Air Pollution Control Devices (APCDs) and Continuous Emission Monitoring Systems (CEMS), along with zigzag kiln technology for brick manufacturing.[28] These solutions target the most polluting subsectors—particularly small and medium industries that often lack pollution control systems despite contributing heavily to ambient air pollution. Large industries already have APCDs in place but need improved enforcement and monitoring under CPCB mandates, justifying CEMS prioritisation. Alternative kiln technologies such as tunnel kilns, VSBKs, or piped natural gas (PNG) were deprioritised due to high capital costs, shorter payback periods, and unreliable or limited fuel supply.[29]

7. **Construction and road dust:** The report prioritises Mechanised Road Sweepers (MRS) and construction safeguards as effective, scalable solutions for reducing PM2.5 from dust and construction activity. Electric-operated mechanical sweepers were considered but deprioritised for this analysis, as their higher upfront costs and limited operational availability in Indian cities currently constrain large-scale deployment. MRS are already widely deployed by municipal bodies in cities like Delhi and directly remove settled dust before it becomes airborne—unlike other measures such as smog guns or dust suppressants, which only address suspended dust. Construction safeguards, including C&D sensors, protective sheets, and exhaust fans, effectively control on-site emissions and are mandated in key urban centres, making them actionable and enforceable solutions.[30] Other approaches such as afforestation and smog guns were deprioritised given their localised or limited pollution control impact. Wall-to-wall paving was also not included, as achieving full coverage across urban areas entails significant logistical and fiscal challenges, making it impractical as a primary dust control measure whereas MRS offers dust reduction benefits within hours of implementation at significantly lower operational costs.[31]

8. **Monitoring:** For the monitoring sector, the report prioritises low-cost sensors (LCS) as the most scalable and cost-effective solution to improve air quality data coverage. Conventional CAAQMS and supersites, though highly accurate, are expensive and slow to roll out, limiting dense monitoring networks. LCS provide high-resolution, ground-level data that complement satellite and reference monitors, helping indicate relative pollution levels across locations and filling critical gaps for real-time local decision-making – despite some gaps in accuracy and calibration. While supersites remain important for calibration and benchmarking, their high costs make them less suitable for widespread deployment in India's urban and rural areas.

**The implementation of these solutions is expected to have cascading benefits across sectors, amplifying overall impact on air quality and emissions reduction.** Actions in one domain—such as electrification, waste valorisation, or monitoring—can enable or amplify outcomes in others, creating a system-wide ripple effect. For instance, the transition from internal combustion engine (ICE) trucks to electric trucks in the transport sector will also decarbonise solid waste logistics, as many urban waste collection and transfer vehicles fall within this category—reducing emissions throughout the waste management value chain. Similarly, improved air quality monitoring through low-cost sensors will enhance targeting and evaluation of solutions across all sectors. These interlinkages create a systemic multiplier effect, where progress in one area reinforces gains in others, accelerating India's transition toward cleaner and more efficient growth.

**These 13 solutions manifest themselves across 3 distinct pathways that describe how economic opportunity is created.** Each pathway represents a channel through which air pollution solutions can generate economic opportunity, such as by greening existing industries, building new clean value chains, or enabling compliance-driven improvements. Individual solutions can be mapped under each pathway, together quantifying the total scale of India's clean air opportunity.

## Pathway A

**Solutions that facilitate brown to green economy transition:** This category covers solutions where existing revenue streams continue, but the underlying technology transitions from polluting to clean. The economic pie doesn't expand substantially, but it becomes greener, delivering emissions reductions and health gains. This pathway includes:

- E-buses
- E-trucks
- Zigzag kilns

## Pathway B

**Solutions that create a new clean economy:** This category comprises solutions that catalyse the development of new industries and value chains, generate fresh revenue streams from products and services that previously did not exist. This pathway includes:

- CBG for agricultural residue
- Co-firing bio-pellets
- CBG for solid waste
- Material Recovery Facilities
- Mechanised Road Sweepers
- Improved cooking solutions

## Pathway C

**Solutions that are imperative but do not generate substantiate economic value:** These solutions are essential for ensuring industries meet environmental standards, but unlike other solutions, they do not lead to any additional value generation. Their primary contribution is in safeguarding health and ensuring regulatory compliance.

- FGD
- Air Pollution Control Devices and Continuous Emissions Monitoring Systems
- Construction safeguards
- Low-cost sensors

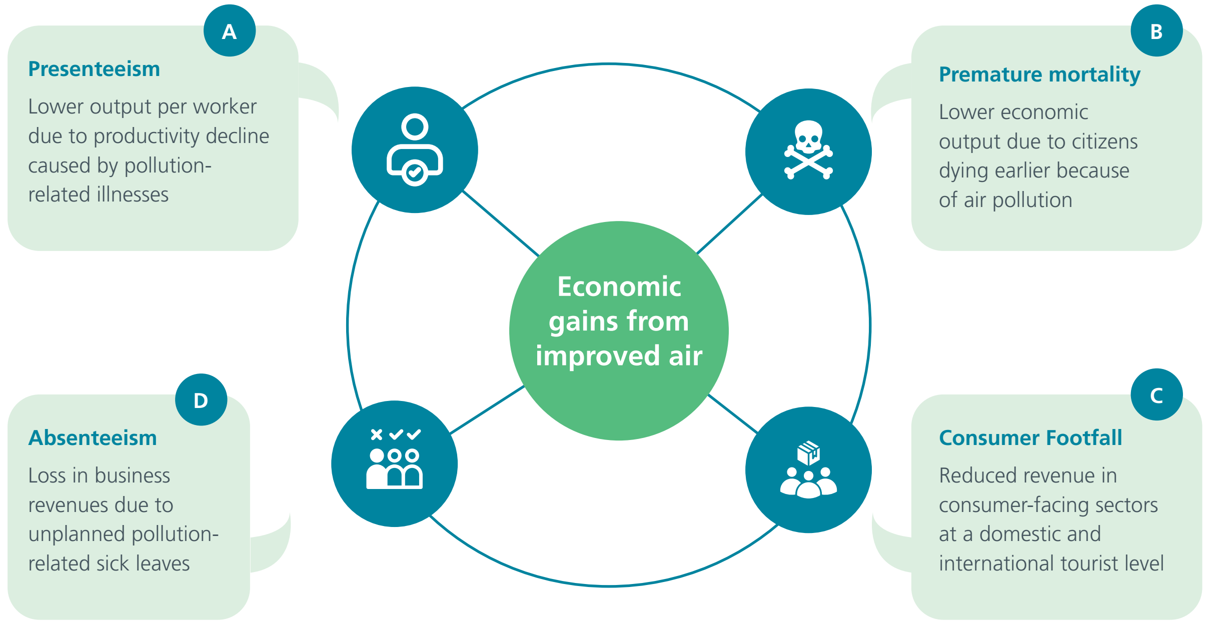




## Macroeconomic Gains

**In 2021, a study by the Clean Air Fund, Dalberg Advisors and CII, estimated that air pollution costs the Indian economy USD 95 billion, or 3% of the annual GDP, by assessing its impact across four key metrics.** Each metric captured a distinct channel through which air pollution affected businesses, including: (i) presenteeism – the reduced productivity when employees work while ill due to pollution-related health issues, (ii) premature mortality – the economic loss from early deaths, creating lost working years, (iii) consumer footfall - the diminished consumer spending in outdoor-facing sectors due to avoidance on high-pollution days, and (iv) absenteeism – the lost labour days when workers are unable to report to work due to illness caused by poor air quality.

***Figure 14: Economic gains from air quality are measured across 4 metrics***




Sources: (1) Graff-Zivin et al., "The Effect of Pollution on Worker Productivity: Evidence from Call-Center Workers in China", 2012; (2) Sustainable Food Trust, "The impact of air pollution on crops", 2019; (3) Holub et al., "Air pollution and labor supply: Evidence from social security data", 2016; (4) The World Bank, "The cost of air pollution: strengthening the economic case for action", 2016; (5) OECD, "The economic consequences of outdoor air pollution", 2016; (6) DEFRA, "Valuing the Impacts of Air Quality on Productivity", 2014

## A. Presenteeism

**This metric reflects the diminished productivity when employees attend work but underperform due to under high pollution conditions, leading to lowered total output.[32]** Despite being present, workers are incapable of performing to normal standards due to suffering from pollution-linked morbidities. A micro-level study performed on manufacturing sector workers in India revealed a 1.45% productivity decrease for every 1% PM2.5 increase.[33] Indian call centres depicted a similar output decline of 0.17% for a unit PM2.5 increase,[34] while software developers displayed a 0.3% decline in total actions completed per day.[35]

## B. Premature mortality

**This metric represents the economic losses incurred from lost working years due to individuals dying before retirement age.** These losses account for the lifetimes lost due to pre-natal and neo-natal mortalities. A study displayed that India's economy lost $55.39B due to forgone labour output from all premature deaths in 2013[36].

## C. Consumer footfall

**This metric captures the revenue loss in consumer-facing sectors due to reduced footfall during high pollution periods.** Poor air quality discourages people from travelling, visiting shops, restaurants etc., directly impacting spending.[37] Studies show that In India, poor air quality has led to a 33% drop in footfall across Delhi's commercial hubs, costing the tourism sector ~US$ 135 million annually.[38] Similarly, Mumbai's Linking Road market saw a 5% fall in consumer traffic during polluted winter months, underscoring how smog directly dampens urban spending.[39]

## D. Absenteeism

**This metric accounts for the loss of productive workdays when employees are unable to attend work and take unplanned sick leaves due to pollution-linked illness.** Rising particulate matter levels lead to workers either falling sick themselves or staying at home to take care of unwell dependents.[40] In 2018, 490 million work absence days were recorded in India due to air pollution related reasons.[41]

**The 2021 analysis drew on real-world evidence and a structured methodology to quantify the impact of each driver:**

- **Literature reviews sourced credible data to capture impact of PM2.5 on each metric.** The data was gathered ensuring the analysis accurately reflects real-world behavioural and economic responses to pollution in various sectors and geographies.
- **Mathematical extrapolation was carried out to align the base data from literature (typically from pre-2019 studies) with a 2021 context.** This involved accounting for changes in sector-specific GDP, population-growth, and year-wise changes in PM2.5 levels to ensure accurate reflection of Indian 2021 conditions.
- **A conservative PM2.5 threshold was applied to accurately quantify exposure-driven impacts for a 2021-pollution context.** The safe value was derived from US EPA's daily safe levels, and adjusted for India's sensitive population across children, the elderly, and individuals with asthma and COPD[42].

**The current analysis builds on the 2021 study by assessing economic gains across five metrics of air pollution's health impact in a 2024 context, with key methodological updates to reflect new data and exposure patterns.** Although average PM2.5 levels have declined in recent years, air pollution remains a significant economic concern due to persistent high exposure in certain regions, and during peak winter months. This report shows that air quality mitigation still offers substantial economic returns in today's context. To maintain the conservative approach taken, the analysis applies a PM2.5 safe value based on US EPA standards, weighted for updated distributions of India's sensitive populations.





**To estimate the economic gains in the 2024 context, the five metrics of air pollution's impact on health were quantified by identifying and modelling their key indicators:**

a. **Presenteeism:** This metric refers to when employees attend work but underperform due to symptoms such as fatigue, illness, and difficulty concentrating. For this analysis, we factor in two metrics across the manufacturing, service, and agricultural sectors:
   - **Decrease in worker productivity:** Sustained exposure to air pollution can impair worker concentration, physical performance, and decision-making
   - **Average sectoral economic output:** The reduction in individual efficiency accumulates across the workforce, leading to lower overall output

b. **Premature Mortality:** This metric refers to the loss of working-age individuals, reducing labour participation and economic productivity, due to premature air-pollution linked deaths. For this analysis, the cost of premature mortality is calculated using two main indicators:
   - **Working years lost due to air pollution:** Long-term exposure to air pollution increases the risk of fatal illnesses, leading to early deaths, often during peak productive years
   - **Economic value of a working year:** As GDP grows, so does the average annual income contribution of a worker, which is lost to the economy with each premature death

c. **Consumer Footfall:** This metric refers to the loss in consumer spending and tourism revenue driven by people avoiding shopping, dining, travel, and other outdoor activities during periods of poor air quality. For this analysis, the cost of consumer footfall is calculated across two sub-pathways:
   - **Loss in domestic spending:** High air pollution discourages people from stepping out, leading to reduced visits for the retail and hospitality sectors, affecting their annual revenues
   - **Loss in tourist spending:** Poor air quality makes destinations less appealing, leading to fewer tourist arrivals, shorter stays, and lower spending overall

**d. Absenteeism:** This metric refers to the loss of productive workdays when employees are unable to attend work due to pollution-linked illness or related disruptions. For this analysis, we estimate the cost of absenteeism through two major metrics:

- **Number of workdays lost due to unplanned sick leaves:** Rising air pollution worsens the severity and duration of illness, leading to longer recovery times and more workdays missed
- **Economic value of a workday:** Each lost workday results in permanent loss of revenue, while also creating hidden costs from disrupted workflows and time wastages

**e. Health expenditure:** This metric refers to the healthcare costs incurred by various stakeholders due to air-pollution related diseases. For this analysis, we estimate the cost of healthcare expenditure through three main metrics:

- **Government health expenditure:** Spending under all schemes funded and managed by the Union, state, and local governments on air pollution–related illnesses
- **Household expenditure:** Direct payments at the point of care and indirect prepayments (e.g., health insurance premiums) made by households for air pollution–linked diseases
- **Private health insurance expenditure:** Share of treatment costs for air pollution–related diseases paid by private insurers

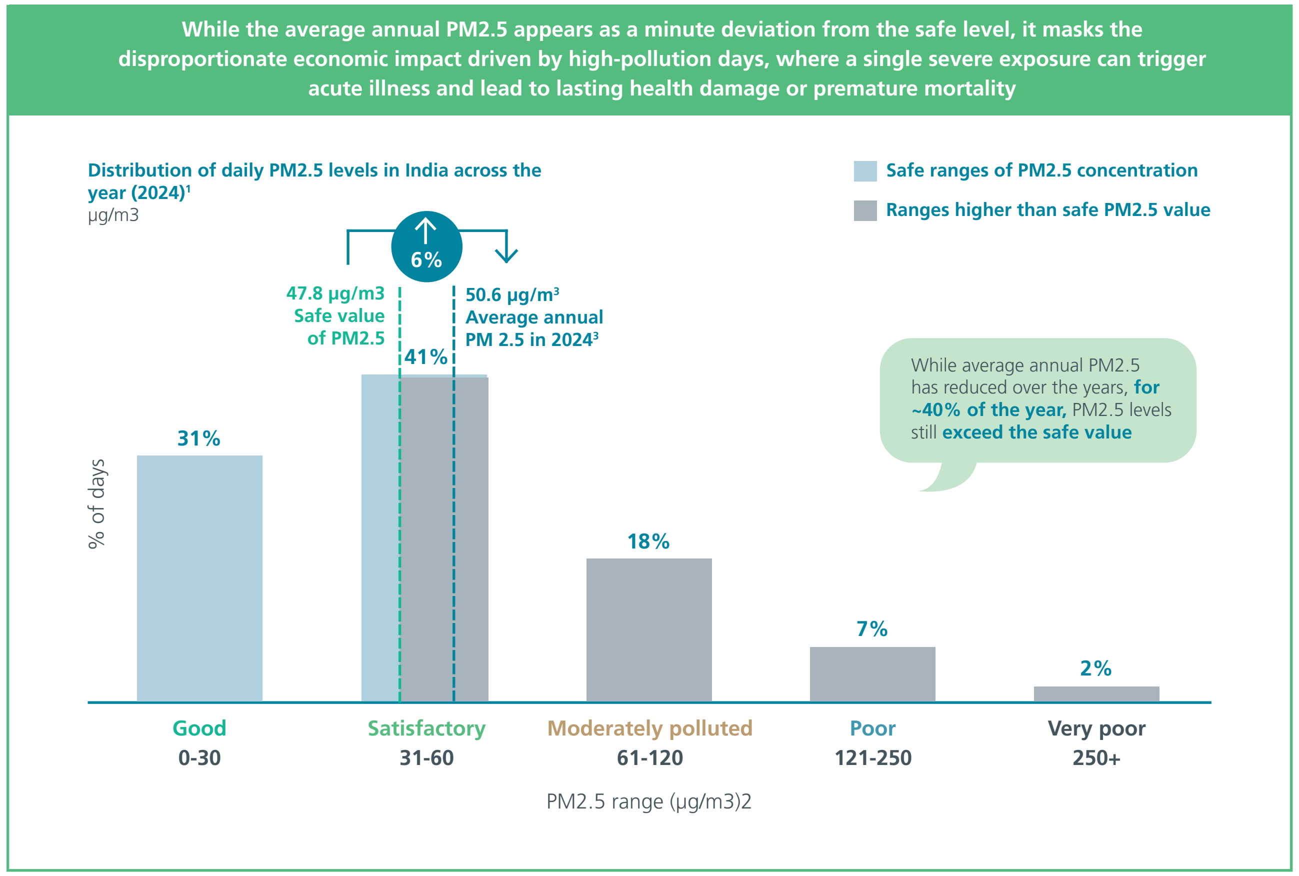
**The report further introduces certain refinements to strengthen the robustness of the analysis and reflect emerging data:**

- **The report uses daily PM2.5 averages instead of annual means for enabling greater sensitivity to real-world impacts.** Daily average values better capture the day-to-day effects of pollution, which are often masked by annual averages. These short-term impacts significantly influence annual business performance, but are averaged out in annual data, leading to an underestimation of actual costs.
- **To capture an accurate distribution for India, this report takes urban and rural daily averages into account.** As sources of pollution span both urban and rural geographies, incorporating a combination of settings captures the full extent of India's daily PM2.5 variation.





***Figure 15: Distribution of daily PM2.5 levels in India across the year, based on the safe value of PM2.5[43]***




- The report uses updated base data to reflect recent research and prioritises studies conducted in India. This ensures costs reflect current conditions, sector trends, and exposure patterns. India-specific research also captures pollution-sensitivity more accurately by accounting for genetic, environmental, and socio-economic factors influencing health and productivity.
- The report introduces an additional productivity metric, accounting for the agricultural sector. As a predominantly outdoor occupation, agricultural workers are especially vulnerable to pollution exposure, further compounded by activities such as stubble burning that majorly release particulate matter.
- The report introduces an additional health metric, capturing healthcare expenditure linked to air pollution-related diseases. This includes the costs borne by government, households, and private insurers for diagnosis, treatment, and long-term management of health impacts due to air pollution.

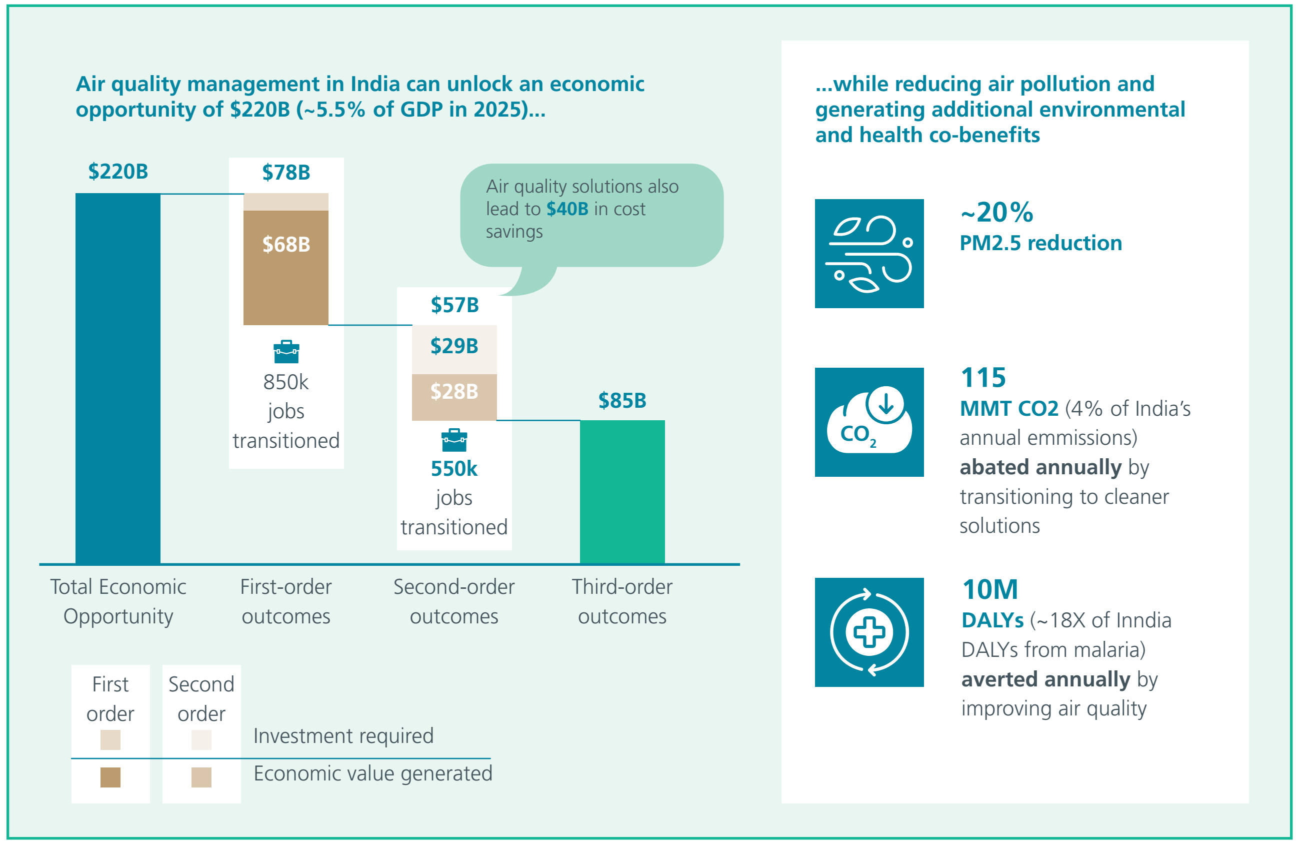
# IV. Analysis of Opportunities Across Sectors and Solutions

**Air pollution solutions in India can unlock a $220 billion economic opportunity by solving for ~20% of India's PM2.5, while creating 1.4 million jobs, abating 115 million tonnes of annual CO2 emissions, and averting 10 million annual DALYs.** This would happen through the implementation of clean air solutions across 8 sectors of agriculture, transport, solid waste, residential combustion, industries, thermal power plants, construction and road dust, and monitoring. An investment of ~$35 billion in the solutions can generate an economic value of ~$100 billion over five years to different stakeholders. This improvement in air quality could drive an additional ~$85 billion in economic gains to businesses from improved health, productivity, and consumer spending.

These solutions can generate additional economic, environmental, and health co-benefits by

- Creating 1.4 million jobs over five years, equivalent to ~6% of India's total unemployed population,[44]
- Abating 115 million tonnes of CO2e per year, equivalent to ~4% of India's current annual CO2e emissions,[45] and
- Averting ~10 million DALYs per year, equivalent to ~18X of India's DALYs from malaria.[46]

***Figure 16: Economic opportunity of air pollution in India***




**The economic opportunity of these solutions can be unfolded in three orders of outcomes.** Initial investments activate implementation, followed by new value chains as capital crowds in, and ultimately resulting in economy-wide gains in health.

- **First-order outcomes represent a large share of the economic opportunity—approximately $78 billion—driven by catalytic initial investment and value creation from the brown-to-green transition:**
  - **Investment required ($10 B):** This refers to the initial capital outlays such as viability gap funding, policy rebates to decrease cost of capex, and initial capital for derisking, to build the necessary ecosystem and catalyse commercial capital.



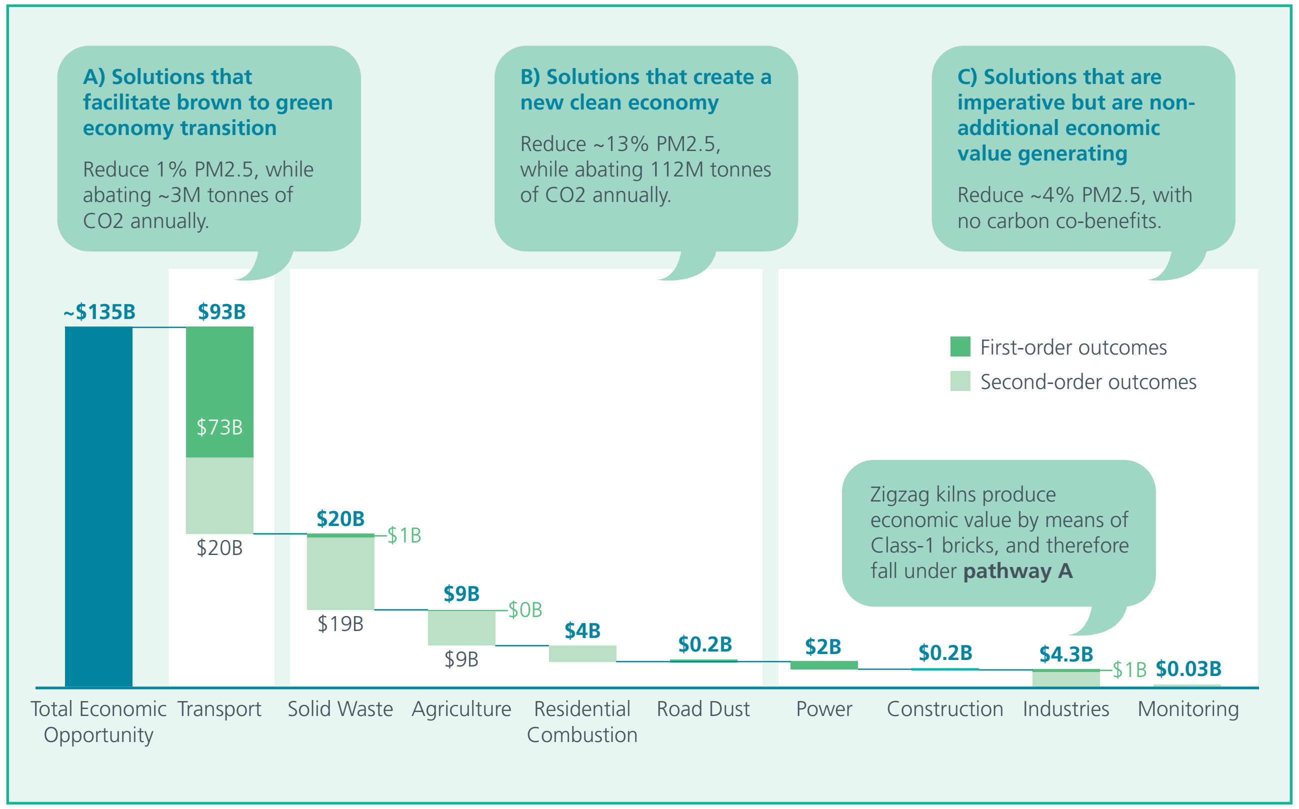


  - **Economic value generated ($68 B):** This refers to the gross economic value produced due to the transition of current value chains to cleaner alternatives (for example, ticket-fare revenue generated due from e-buses instead of diesel buses).
  - **Jobs transition (850 K):** This refers to the reskilling and transition of jobs to cleaner alternatives. Note that the number refers to gross jobs.
- **Second-order outcomes, valued at $57 billion, arise from the multiplier effect of catalytic initial investments that crowd-in private capital and unlock new value chains:**
  - **Investment required ($29 B):** This refers to the additional commercial capital mobilised as a result of catalytic capital under first-order outcomes (for example, additional debt mobilised from the private sector due to guarantees).
  - **Economic value generated ($28 B):** This refers to the gross revenue produced from setting up new value chains (for example, compressed biogas) and/or new streams of revenue (for example, carbon revenue, recyclables).
  - **Jobs created (550 K):** This refers to the creation of new gross jobs as a result of setting up new value chains.
  - **Additional cost savings ($40 B):** This refers to the gross cost savings in economy because of either transitioning (for example, reduction in oil imports) or setting up of new value chains (for example, reduction in fertiliser subsidy due to FOM produced by CBG).
  - **Additional co-benefits** generated due to the abatement of 115 million tonnes of CO2e (~4% of India's emissions) due to synergies between clean air and GHG emission solutions (for example, e-vehicles, biomass burning) and better health outcomes such as reduction in disability-adjusted life years (DALYs).
- **$85 billion of third-order outcomes** are realised across businesses, at a macroeconomic level, due to better worker health and productivity, reduced absenteeism, increased consumer footfall and lower health expenditure

**These economic outcomes are delivered through three distinct pathways.** Each pathway represents a channel through which the solutions can generate economic opportunity. Individual solutions can be mapped under each pathway, together quantifying the total scale of India's clean air opportunity (see Figure 17).

- **Pathway A: Solutions that facilitate brown to green economy transition:** This category covers solutions where existing revenue streams continue, but the underlying technology transitions from polluting to clean. The economic pie does not expand substantially, but it becomes greener, delivering emissions reductions and health gains. **Combined, these solutions represent a $97 B economic opportunity while reducing 1% of PM2.5.**
- **Pathway B:** Solutions that create a new clean economy: This category comprises solutions that catalyse the development of new industries and value chains, generate fresh revenue streams from products and services that previously did not exist. **Combined, these solutions represent a $33B economic opportunity while reducing 13% of PM2.5.**
- **Pathway C:** Solutions that are imperative but do not generate substantial economic value: These solutions are essential for ensuring industries meet environmental standards, but unlike other solutions, they do not lead to any additional economic value generation. Their primary contribution is in safeguarding health and ensuring regulatory compliance. **Combined, these solutions represent a ~$2.5B economic opportunity while reducing 4% of PM2.5.**

*Figure 17: Sector-wise breakdown of India's clean air economic opportunity*




## Pathway A

**Includes solutions that facilitate brown to green economy transition:** This category covers solutions where existing revenue streams continue, but the underlying technology transitions from polluting to clean. The economic pie doesn't expand substantially, but it becomes greener, delivering emissions reductions and health gains.

### 1. Transport

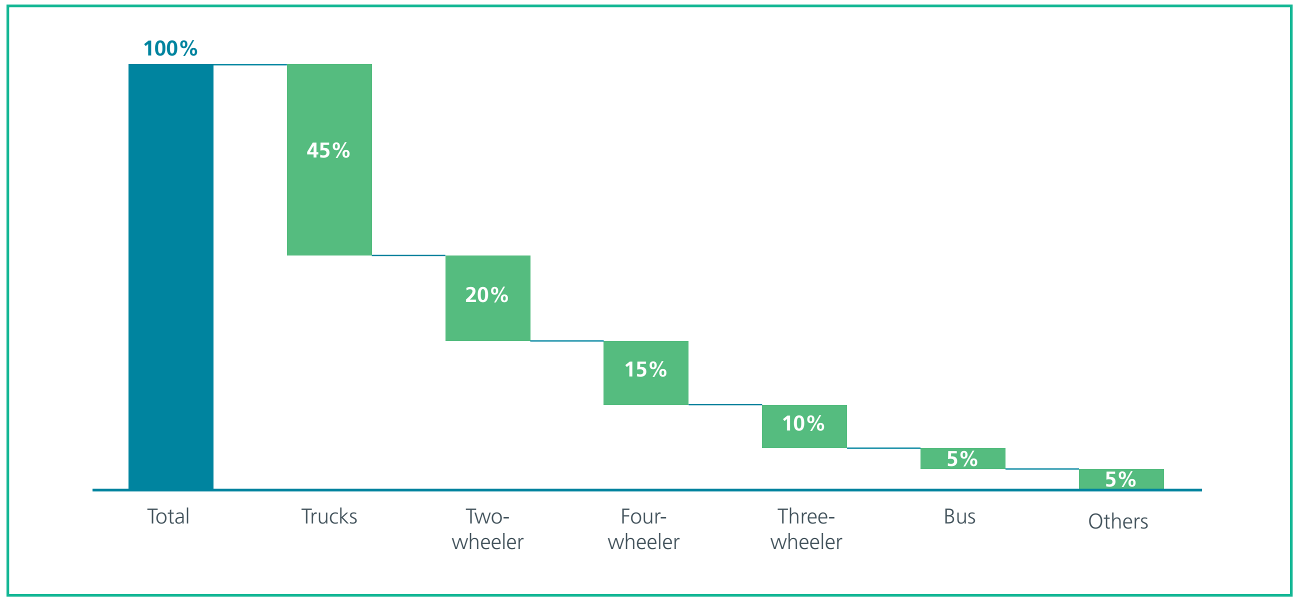
**Transportation is a key contributor to air pollution and greenhouse gas emissions, particularly in urban areas.** The transport sector is responsible for more than 40% of total NOX emissions, 12% of energy-related CO2e emissions, and around 7% of combustion-related PM 2.5 emissions.[47,48] In India, tailpipe emissions from transport contribute to 3% of India's total PM2.5 but the contribution is much larger in urban, metropolitan cities. In Delhi, for instance, transport is the single largest contributor of PM 2.5 at 43%.[49]

Within the transportation sector, trucks, two-wheelers, three-wheelers, and four-wheelers are the largest contributors to air pollution and GHG emissions. Nationally, freight trucks account for ~45% of total transport-related emissions, followed by two-wheelers (~20%), four-wheelers (~15%), and three-wheelers (~10%). Among passenger modes, buses contribute ~5%, while domestic air travel (~1%) and passenger rail (~1.5%) have relatively smaller shares. Freight modes such as rail (~2%) and domestic shipping (~0.5%) contribute modestly.[50]





*Figure 18: Breakdown of contribution to transport-linked air pollution in India by vehicle type*




**The government has taken various steps across both national and state levels that integrate addressing transport-linked air pollution and India's climate goals.** Under its Panchamrit commitments, India aims to achieve energy independence by 2047 and reach net-zero emissions by 2070.[51] The government has recognised EVs as a key lever in this transition and aims to achieve 30% EV penetration by 2030 which translates to approximately 102 million EVs on the road. To support this shift, at the national level, the Ministry of Heavy Industries has launched the PM E-DRIVE scheme which provides subsidies (with a US$ 12.8 billion outlay)[52] for EVs and the Production-Linked Incentive (PLI) scheme which offers financial incentives up to ~US$ 3 billion[53] to manufacturers of EVs and advanced chemistry battery cells to promote domestic production. Newer schemes such as the PM e-Bus Sewa aim to deploy 10,000 e-buses across cities through a public-private partnership model, while the PM e-Drive initiative supports demand and supply-side incentives for electric two-wheelers and three-wheelers. At the state level, EV policies offer additional incentives.[54] The policies of Delhi, Tamil Nadu, Karnataka, and Andhra Pradesh, for example, offer up to US$ 350 purchase subsidy for two-wheelers[55] and the policies of Delhi, Maharashtra, and Karnataka[56] offer between a ~US$ 60 and a ~US$ 120 incentive for scrapping petrol two-wheelers and CNG three-wheelers.[57]

**While these efforts have helped create a relatively mature EV market for two-wheelers, three-wheelers, and four-wheelers, the adoption of electric buses and trucks remains at a nascent stage.** In FY25, two- and three-wheelers dominated the EV market, accounting for over 90% of total sales, with annual growth rates of 10–20%. Four-wheelers—primarily light motor and passenger vehicles—made up around 5% of EV sales, marking a growth rate of 15%. In contrast, electric buses represented less than 1% of total sales and grew by just 4% year-on-year.[58] Similarly, e-truck sales began only in 2023, with ~550 e-trucks sold in 2023 and 2024.[59]

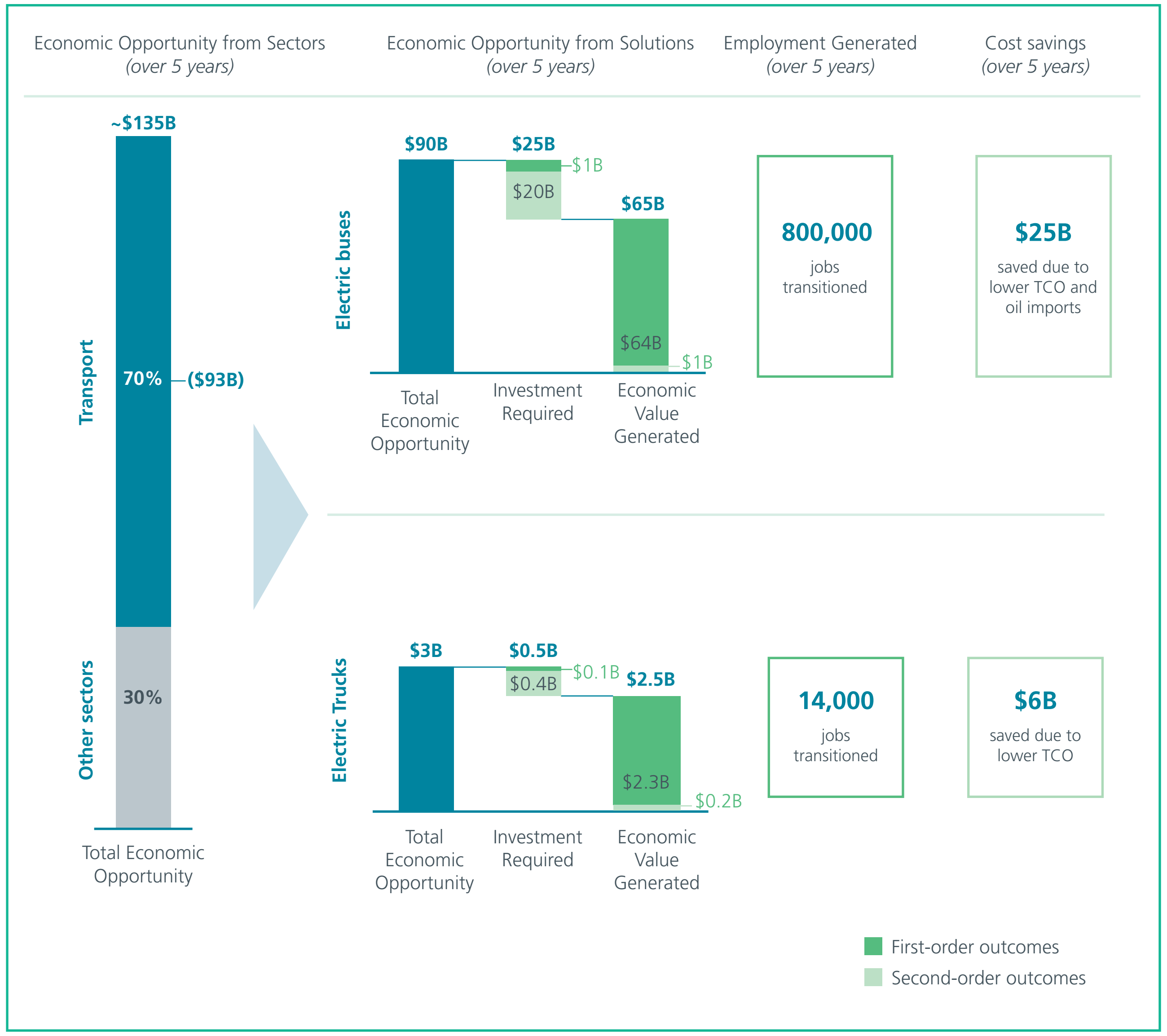
**A few challenges remain in scaling e-bus deployment across cities.** High upfront costs—often requiring operators to contribute up to ~US$ 36,000 per bus—continue to constrain smaller fleet operators, while commercial lenders remain cautious given limited repayment histories.[60] Depot and charging infrastructure also lag demand, restricting reliable operations and fleet utilisation. Most incentives under PM E-DRIVE and PM e-Bus Sewa remain directed toward public operators, limiting broader private participation and slowing scale-up.

**Similarly, e-truck adoption faces early-stage challenges around cost, financing, and infrastructure.** E-trucks currently cost 2–4× more than comparable diesel models, making them unaffordable for most small fleet operators.[61] Access to finance is limited, as lenders view the technology as high-risk, and charging infrastructure—just ~12,000 public stations nationwide—remains inadequate for long-haul operations. Combined with low model availability and weak compliance with scrappage norms, these factors continue to slow the sector's early growth.

**Given the nascent stage of e-bus and e-truck adoption, the government can prioritise near-term transitions to cleaner vehicle categories through targeted scrappage incentives and fuel-switching mandates.[62]** For freight, replacing old diesel trucks with BS-6 vehicles remains a feasible interim strategy, supported by state-level scrappage policies offering tax and registration rebates. For public transport, governments can accelerate the shift to cleaner fuels such as CNG by mandating diesel bus phase-outs, supported by financial grants. As an additional lever, introducing a green tax, to deter entry of older, polluting commercial vehicles into sensitive airsheds like Delhi NCR, enabled by monitoring technology and vehicular stack of databases can further strengthen the transition.

**However, accelerating bus and truck electrification at scale can unlock a massive economic opportunity.** India plans to electrify 800,000 diesel buses over the next 6-7 years,[63] with e-bus sales likely to grow ~4x within the next 2 years itself.[64] Similarly, the number of trucks in India is expected to more than quadruple from 4 million in 2022 to ~17 million by 2050, indicating a vast market for electrification.

***Figure 19: Solutions combatting PM2.5 emissions in the transport sector contribute 70% ($93B) to the total economic opportunity, distributed across e-buses and e-trucks***









## (i) E-buses

**Deploying ~200,000 E-buses by 2030 can generate over US$ 13 billion in direct gross annual revenues across e-bus sales, fare collections, and carbon credit sales. This roll-out is projected to transition ~800,000 direct gross jobs over 5 years and create US$ 25 billion in cost savings, while abating ~3 million tonnes of GHG annually and reducing PM2.5 emissions by 0.1% by 2030.[65]**

There is a need to deploy ~200,000 additional e-buses in India by 2030, marking a 16-fold expansion over today's fleet. While the government originally set an ambitious target of deploying 800,000 e-buses, this analysis adopts a more pragmatic estimate of 200,000 buses by 2030,[66] given the supply chain constraints. As of 2025, 12,100[67] e-buses are operational across the country. To meet the target by 2030, an additional ~200,000 buses must be deployed in the next five years. Of this target, the National Electric Bus Programme (2022) and PM e-Bus Sewa Scheme (2024) together aim to enable the deployment of over 88,000 e-buses over the next few years[68]. At this level, the transition signals a transformative shift in India's public transport landscape and demands parallel expansion in infrastructure, finance, and workforce capacity. The immediate focus should be on using these e-buses to replace aging and high-emission diesel HDVs, ensuring that fleet electrification first offsets the most polluting vehicles.

**First-order outcomes:**

The deployment of approximately 200,000 electric buses is expected to generate significant first-order outcomes, including:

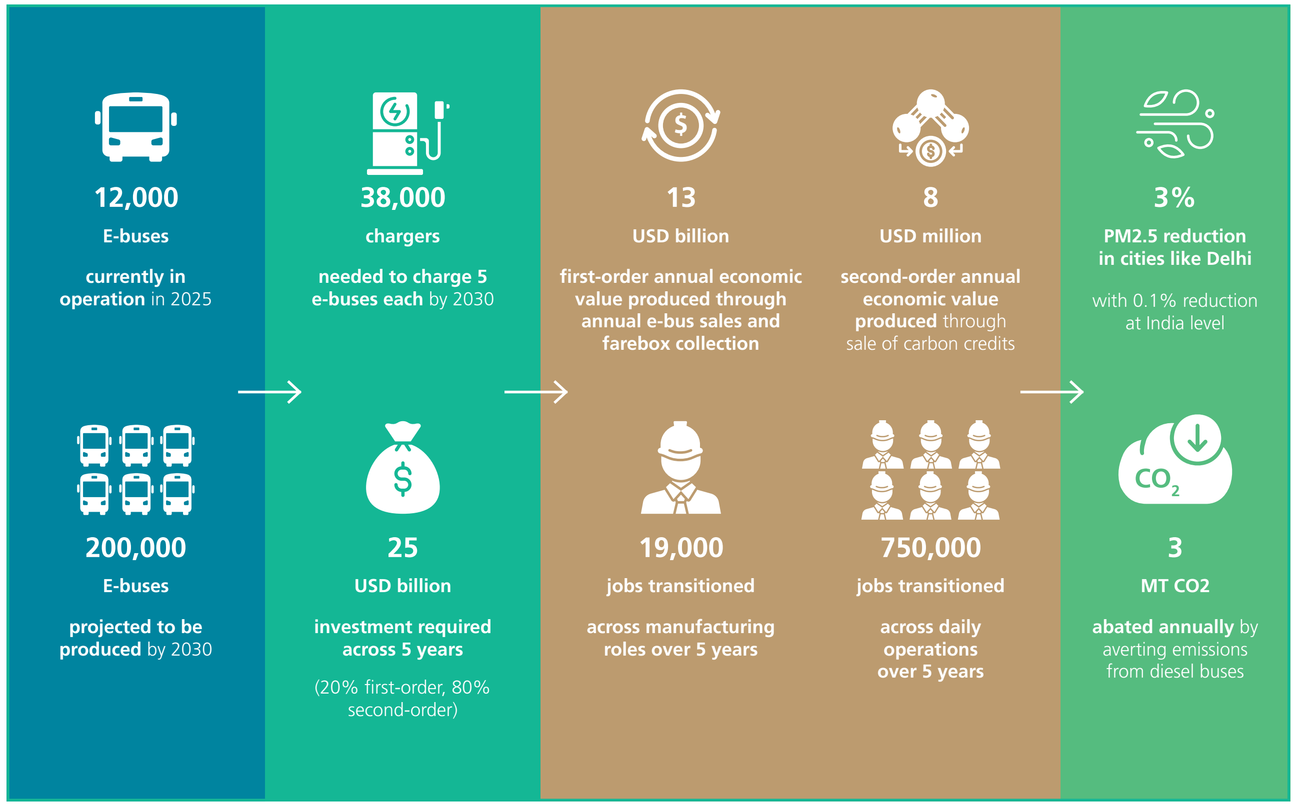
- **Catalytic investment** enabled through the PM e-DRIVE Scheme and seed capital required to set up blended finance instruments
- **Transition of nearly 800,000 jobs,** across manufacturing and operations of these e-buses.
- **USD 13 billion in annual economic value generated** from revenue through sale of e-buses and passenger ticket fares

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the deployment of electric buses will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to deploy and sustain e-bus fleets
- **USD 8 million annually from carbon credits,** generated through verified emissions reductions
- **USD 25 billion in cost savings,** particularly due to the lower total cost of ownership (TCO) compared to ICE buses and savings on oil imports
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 20: Investing $25 billion in e-bus production can unlock $13 billion in economic value annually, delivering significant employment, health, and environmental benefits***








## Investment required

**India will need to invest ~$25 billion by 2030 to deploy the additional ~200,000 e-buses and build the supporting charging infrastructure.** This projection assumes a 20% production margin, pegging the average manufacturing cost of an e-bus at US$ 120,000.[69] An additional ~40,000 chargers will be required, at an average unit cost of US$ 35,000,[70] driving US$ 1.3 billion in infrastructure capital expenditure.

25% of this capital could potentially be financed from first-order public catalytic capital, including government subsidy as well as capital needed to set up blended finance instruments such as a risk sharing debt facility. Government support is already in motion: the National Electric Bus Program has earmarked USD 10 billion,[71] and schemes like PM E-DRIVE are facilitating deployment through demand aggregation and incentives, including ~US$ 120 per kWh subsidies that cover up to 20% of vehicle costs.[72] PM E-DRIVE aims to deploy over 14,000 e-buses by 2026, and the PM e-Bus Seva will support over 38,000 buses through FY 2028-29 with a focus on reducing financial risk via payment security mechanisms.

This public share of investment is expected to unlock the remaining 75% from private and commercial capital.[73] Financial institutions are beginning to extend loans that can cover most project costs, while blended finance mechanisms such as ADB's (Asian Development Bank) US$ 40 million package for GreenCell show how concessional instruments can de-risk private investment.[74] These innovations allow government commitments to act as a catalyst, crowding in significant volumes of private finance and ensuring the viability of large-scale deployment. This can further be supported by green financing, with financial institutions providing loans for up to ~70% of project cost.[75,76] Expanding green financing can accelerate solution implementation, while also unlocking an economic opportunity for financiers through interest and repayment earnings.

## Job creation potential

**The e-bus transition is expected to transition ~800,000 gross jobs across 5 years, with over 95% in long-term operations.** Every e-bus adds approximately four operation-phase jobs and 0.1 jobs in manufacturing.[77,78] Across the 200,000 new buses, this translates to ~19,000 manufacturing jobs and ~750,000 operation jobs such as drivers, conductors, and maintenance.

These jobs represent a shift from diesel to electric bus fleets, meaning they are primarily replacement jobs, but the overall impact remains substantial. They also lead to the re-skilling and re-employment of people engaged in the fleet before the transition.

## Annual economic value-add

**The expanded e-bus fleet can generate about US$ 13 billion in gross revenues every year.** This includes approximately US$ 6 billion from annual bus sales and US$ 7 billion from fare collections (based on 333 operating days, a US$ 120 daily fare estimate per bus), both of which are established, first-order revenue streams that will continue under electrification.

In addition, e-bus deployment opens a new, second-order revenue stream from carbon credits. This is expected to generate about US$ 8 million annually (US$ 3 per carbon credit[79]), representing incremental value that arises directly from reduced emissions. This robust revenue potential, anchored in established demand patterns, demonstrates strong commercial viability for operators and city transit agencies.

## Co-benefits potential

**Adding ~200,000 e-buses to India's fleet can eliminate ~3 million tonnes of GHG emissions annually, supporting both national and sectoral climate targets.** Each e-bus cuts emissions by ~14 tonnes/year, even at today's 30% renewable grid mix.[80,81]

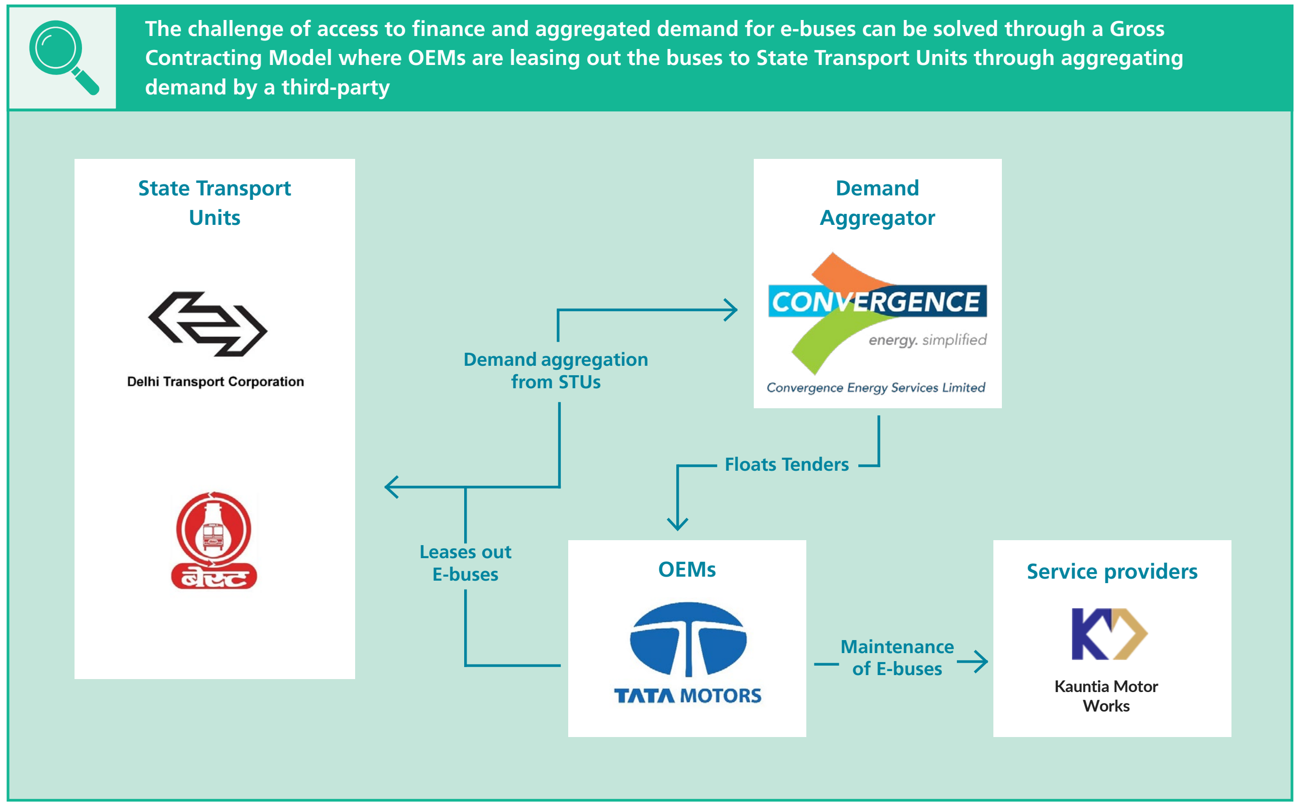
## PM2.5 and DALYs reduction

**Deploying e-buses can reduce PM2.5 by ~3% in urban, metropolitan cities by 2030 and avert ~30,000 DALYs annually.** While buses contribute just ~0.7% to India's PM2.5 levels, they account for nearly 10% of pollution in metro cities, indicating large air pollution gains from e-bus deployment. Deploying the ~200,000 e-buses can additionally avert ~30,000 DALYs in India,[82] represent a significant public health gain, particularly for vulnerable urban populations exposed to high-traffic corridors.

## Cost savings

**Second-order outcomes from the e-bus shift also include annual cost savings of total US$ 1.6 billion due to lower total cost of ownership (TCO) and US$ 3.5 billion in oil import savings.**[83] The TCO of an average e-bus is ~15% lower than its diesel counterpart; intra-city e-buses (70% of the fleet) save US$ 4,100/year each, while inter-city e-buses save over US$ 19,000/year, driven by lower fuel and maintenance costs.[84] These direct operational savings, combined with macroeconomic relief from reduced oil dependence, strengthen the long-term financial case for electric mobility.

*Figure 21: Case Study: Existing Gross Cost Contracting Model for e-buses*[85,86]




## (ii) E-trucks

**Deploying 10,000 e-trucks by 2030 can generate ~US$ 500 million in direct gross annual revenues including vehicle sales, freight revenues, and carbon credits. This roll-out is projected to transition 14,000 direct gross jobs across 5 years and create US$ 6 billion in cost savings, while abating 0.2 million tons of GHG annually and reducing PM2.5 levels by 0.004% by 2030.**[87]

**There is a need to target the deployment of 10,000 electric trucks**[88] **in India by 2030 as a realistic first step to minimise freight-driven air pollution.** This number reflects a practical and necessary ambition, grounded in policy-backed scenarios that emphasise charging infrastructure readiness, financial incentives, and toll waivers. The PM E-DRIVE program launched its first dedicated e-truck policy in July 2025, offering incentives of up to US$ 11,300 per vehicle.[89] While this marks a significant step forward, the scheme remains in its early stages, with a maximum of ~5,500 e-trucks expected to be operational by 2026. A substantial ramp-up will therefore be required over the next five years to meet the 2030 target. Of this target, 70% are expected to be medium-duty trucks (MDTs) and 30% heavy-duty trucks (HDTs),[90] based on application viability and existing logistics patterns. The transition to e-trucks should prioritise phasing out the oldest and most polluting diesel freight vehicles, ensuring that early electrification efforts deliver the greatest air quality and climate benefits. Even though this scale is modest relative to India's total fleet of ~200,000 trucks,[91] it marks a critical starting point to decarbonise one of the most polluting and energy-intensive sectors of the economy.





### First-order outcomes:

The deployment of 10,000 e-trucks is expected to generate significant first-order outcomes, including:

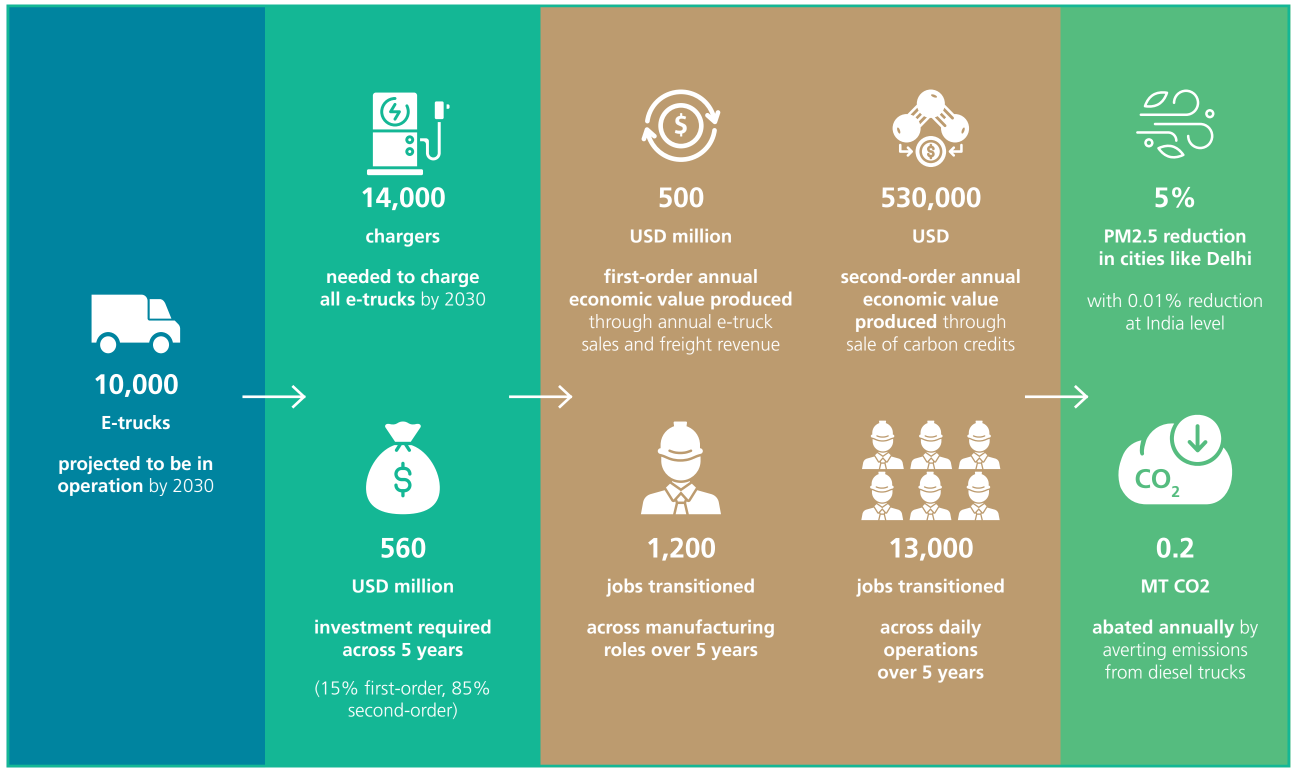
- **Catalytic initial investment** enabled through the PM e-Drive Scheme and seed capital required to set up blended finance instruments
- **Transition of nearly 14,000 gross jobs,** across manufacturing and operations of these e-trucks
- **USD 4.5 million in annual gross economic value generated** from revenue through sale of e-trucks and freight income

### Second-order multiplier outcomes:

Building on the multiplier effect of these first-order outcomes, the deployment of e-trucks will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to deploy and sustain e-bus fleets
- **USD 0.5 million annually from carbon credits,** generated through verified emissions reductions
- **USD 1.2 billion in annual cost savings,** due to the lower total cost of ownership (TCO) compared to diesel trucks and savings on oil imports
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 22: Investing US$ 560 million in e-truck production can unlock US$ 500 million in economic value annually, delivering significant employment, health, and environmental benefits***




## Investment required

**To meet the projection of 10,000 e-trucks by 2030, investment worth ~US$ 560 million is required across 5 years to deploy the vehicles and build supporting infrastructure.** The total includes US$ 510 million in vehicle production costs and US$ 50 million in charging infrastructure, based on a mix of depot and en-route chargers. Manufacturing costs are estimated at US$ 30,000 per MDT and US$ 99,000 per HDT[92], with a 35% margin built into market prices.[93] A total of ~14,000 charging units will be needed, with 90% deployed at depots and 10% en-route, requiring a capex of US$ 900 and US$ 21,000 per charger respectively.[94] While the investment is moderate compared to other clean mobility transitions, the returns are significant in terms of emissions, fuel savings, and freight efficiency.

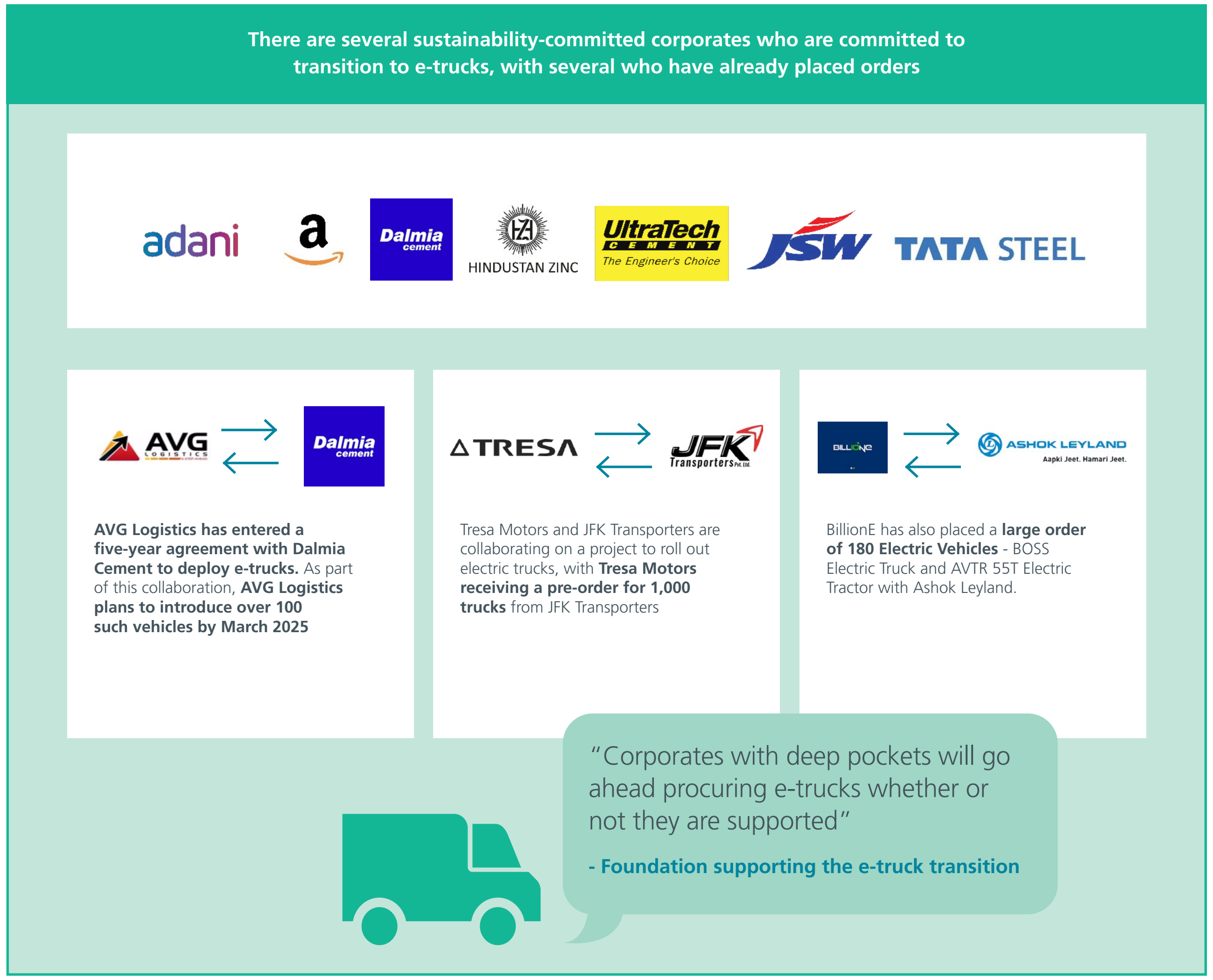
15% of this capital could potentially be financed from first-order public catalytic capital, including government subsidy as well as capital needed to set up blended finance instruments such as a risk sharing debt facility. The launch of the PM Electric Drive Revolution in Innovative Vehicle Enhancement (PM E-DRIVE) Scheme marks a transformative step, introducing the country's first dedicated funding for electric and zero-emission trucks (ZETs). With US$ 58 million allocated to accelerate adoption,[95] this initiative underscores India's commitment to reducing the transportation sector's environmental footprint, but its impact remains unclear due to unspecified truck numbers. The E-FAST initiative by NITI Aayog fosters industry collaboration, piloting for e-trucks but is still in its early stages.

This government support can act as a catalyst to potentially unlock the remaining 85% through commercial sources and needs to be complemented by green financing. Currently, very few commercial loans for e-trucks are available, underscoring the need for banks and NBFCs to expand their EV portfolios to include e-trucks. Scaling such financing not only advances e-truck deployment but also opens a growing market for lenders. Innovative financing solutions are also emerging in India to finance the e-truck transition; major logistics fleet players have begun piloting electrification of their fleet.





***Figure 23: Examples of private capital supporting the electrification of truck fleets[96,97]***




## Job creation potential

**The e-truck rollout could transition over 14,000 gross jobs in the truck fleet by 2030.** Every e-truck is expected to require ~1.5 direct jobs, including manufacturing and operational roles.[98] This translates to 1,000+ jobs in vehicle production and 13,000 in long-term fleet operations. This employment is a second order outcome, as it is the replacement of existing diesel trucking jobs; these jobs are especially relevant in logistics hubs and industrial corridors, offering new opportunities for reskilling and clean transport workforce development.

## Annual economic value-add

**E-trucks can generate ~US$ 500 million in annual gross economic value.** This includes first-order gross annual revenue from e-truck sales at ~US$ 160 million and gross annual freight income from the additional e-truck fleet at ~US$ 300 million, with an average of US$ 16,000 per MDT and US$ 61,000 per HDT.

Additional second-order revenue of US$ 530,000 is expected from carbon credit sales, based on a value of US$ 3 per credit.[99] With established demand for road freight and rising pressure to decarbonise supply chains, e-trucks can offer high return potential to logistics operators.

## Co-benefits potential

**The transition to e-trucks could reduce annual GHG emissions by 0.2 million tonnes.** Each e-truck eliminates approximately 18 tonnes of $CO_2$-equivalent emissions per year, even with a 30% renewable grid.[100] While this currently accounts for just ~0.03% of emissions from the transport sector and a smaller share of total national emissions, it lays the groundwork for deeper decarbonisation as battery technologies and grid clean-up improve.

## PM2.5 and DALYs reduction

**E-trucks can reduce India's PM2.5 by ~5% by 2030 in metro cities like Delhi by reducing tailpipe emissions from ICE trucks, with deployment of 10,000 e-trucks averting ~2,500 DALYs annually.** Trucks contribute to ~0.8% of India's PM2.5, although numbers are much larger (~20%) in urban metropolitan cities such as Delhi. Electrifying 10,000 trucks can reduce India's PM2.5 by 0.004%, with larger benefits in urban cities, thereby averting ~2,500 DALYs[101] linked to air pollution.

## Cost savings

**Annual total cost of ownership (TCO) savings from e-truck adoption could exceed US$ 1.1 billion, while oil import savings could amount to around US$ 35 million per year.** Each medium-duty e-truck saves over US$ 6,100 annually, while a heavy-duty truck saves more than US$ 39,000 per year, primarily due to lower fuel and maintenance costs.[102] At fleet scale, these operational savings amount to US$ 1.15 billion per year. Further, the transition to 10,000 e-trucks could lead to ~US$ 35 million in savings on oil imports annually, with each e-truck saving ~US$ 3500 annually. This enhances business viability for logistics operators and makes a strong financial case for electrifying freight movement.

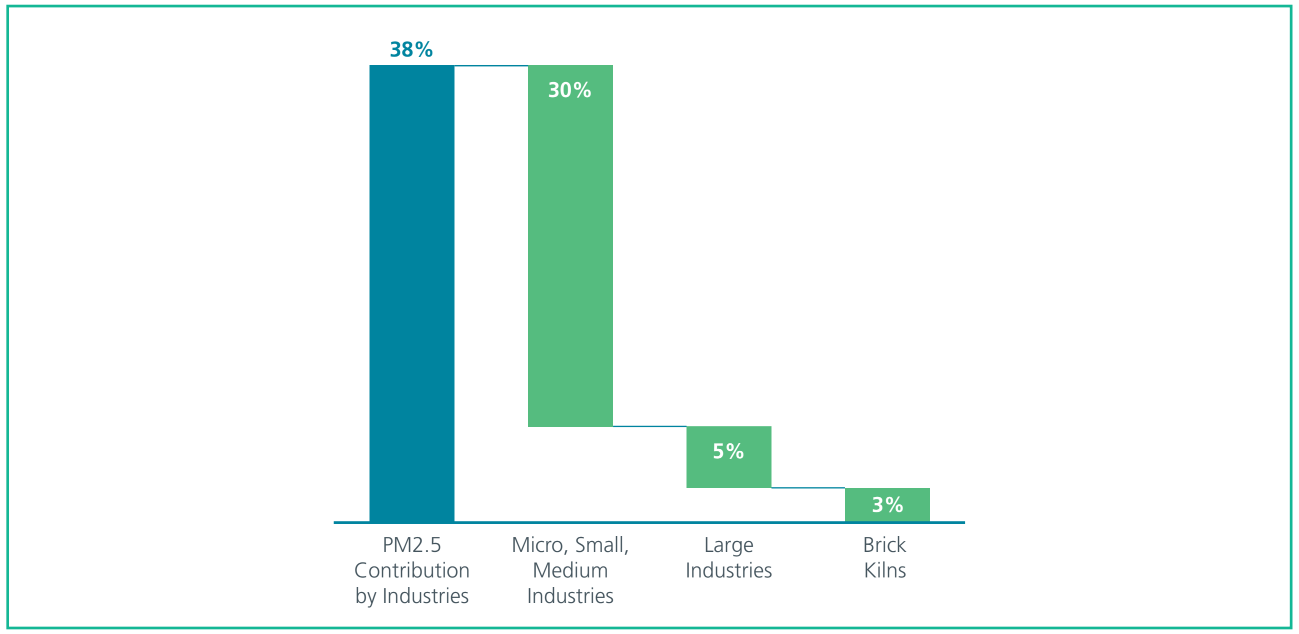
## 2. Industry: Brick kilns

**Brick kilns are a distinct and significant source of air pollution in India, contributing about 3% of national PM2.5 emissions.** Concentrated largely in peri-urban and rural clusters, these kilns rely heavily on coal, biomass, and other low-grade fuels, often burned in inefficient traditional designs such as Fixed Chimney Bull's Trench Kilns (FCBTKs). The combination of poor combustion efficiency, lack of emission control equipment, and absence of regulatory oversight leads to dense, localised air pollution affecting both ambient air quality and public health.[103]





*Figure 24: Contribution of different types of industries to India's PM2.5*




**Cleaner production technologies are increasingly available and promoted to transform this sector.** The zigzag kiln design, enhances air circulation, ensures more uniform heating, and significantly improves combustion efficiency. This transition results in a 30–40% reduction in PM2.5 emissions compared to traditional kilns.[104] Other emerging technologies include tunnel kilns (high efficiency but capital-intensive), vertical shaft brick kilns (VSBKs) with lower fuel use but higher skill requirements, and gas-fired kilns using PNG where supply is reliable. For most small operators, zigzag kilns represent the optimal balance between emission reduction, cost, and ease of transition.

**Brick kilns must transition to zigzag kiln technology to reduce emissions and comply with government mandates.** Traditional kilns in peri-urban and rural clusters operate with outdated designs and poor combustion efficiency, contributing heavily to local air pollution. The MoEFCC has mandated that all new and existing brick kilns transition to zigzag designs or cleaner alternatives. Zigzag kiln technology offers lower PM2.5 emissions through better airflow and fuel use. It also offers lower investment costs and shorter payback periods compared to alternatives such as tunnel kilns (high cost, long payback), VSBKs (lower productivity, high skill needs), or PNG-based kilns (unreliable rural supply).[105] State Pollution Control Boards (SPCBs) are increasingly enforcing location-specific norms, particularly in high-density clusters near cities, where cumulative emissions from hundreds of small kilns contribute to regional air pollution.

**However, systemic challenges continue to slow progress.** Many small kiln operators lack access to affordable credit and technical expertise to upgrade to zigzag or other cleaner technologies. Seasonal operations and informal ownership structures also discourage long-term investment. Inconsistent enforcement and limited capacity among local regulators further delay widespread adoption. Moreover, variations in brick demand and raw material availability make it difficult to maintain consistent kiln operations, which undermines technology efficiency.

Addressing these barriers through targeted financial incentives, training programs, and stronger institutional enforcement will be key to achieving full transition and emission reduction in the brick kiln sector.

***Figure 25: Zigzag kilns contribute 3% ($4B) to the total economic opportunity***


## Zig-zag kilns

**Transitioning existing brick kilns to zig-zag technology kilns can generate an annual gross economic value addition of ~US$ 800 million and transition ~38,000 gross jobs over the next 5 years and create US$ 750 million in cost savings, while reducing India's PM2.5 by 1% by 2030.**

**Retrofitting 13,000 traditional brick kilns to zigzag kilns in India by 2030 would be a pragmatic and high-impact pathway to reduce emissions from one of India's most polluting rural industries.** The Ministry of Environment, Forest and Climate Change (MoEFCC) has already mandated that all new brick kilns in India must use cleaner technologies such as zigzag kilns or vertical shaft kilns. Zigzag kilns use a natural draft mechanism to channel airflow in a zigzag pattern, ensuring uniform combustion. This method reduces coal consumption by 20%, cuts emissions of black carbon and particulate matter by 75% and lowers energy use by 20%[106]. However, only ~40% of all kilns have successfully been retrofitted till now.[107] Of the remaining 33,000+ non-clean kilns in India, 75% are likely to be converted to zigzag kilns given lower installation costs and simpler operational procedures compared to its other clean-kiln counterparts. A realistic target of retrofitting 50% of these kilns leaves 13,000 FCBTKs achievable for retrofit by 2030, based on historic momentum and supply-side feasibility. Even though this covers only a portion of the national kiln stock, it offers major gains in air quality, job creation, and energy efficiency with relatively low capital investment. This transition is especially beneficial for Indian states in the Indo-Gangetic Plain (Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal), which account for 65% of the brick production in India.





**First-order outcomes:**

Retrofitting 13,000 traditional brick kilns to zigzag kilns in India by 2030 can generate a **first-order outcome of initial investment,** financed by kiln owners and operators. Currently, while the government has mandated the transition of all kilns to clean kilns, it does not provide any financial incentive or support to do so.

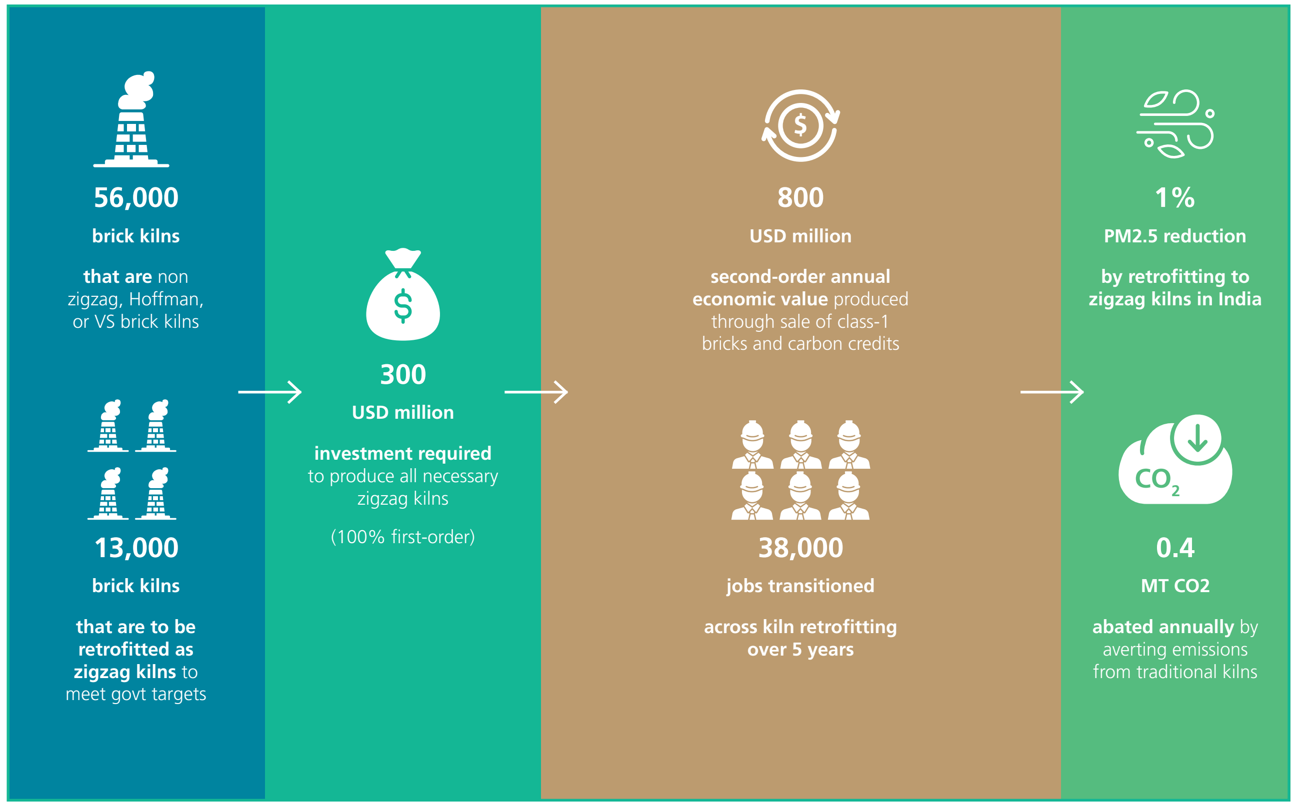
This transition will also lead to the **transition of nearly 38,000 gross jobs,** across transition and operations of these zigzag kilns.

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the transition to zigzag kilns will catalyse a range of second-order impacts, including:

- **USD $760 million in gross annual economic value generated** from sale of additional Class-1 bricks and carbon credits
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 26: Investing $300 million in the production of zigzag kilns can drive $800 million and deliver significant employment, health, and environmental benefits***



## Investment required

**Retrofitting 13,000 kilns will require ~US$ 300 million in capital investment across the next 5 years, with an average cost of US$ 20,600 per kiln.**[108] This is modest compared to other industrial decarbonisation pathways and does not require the creation of new production sites, only upgrading existing ones. Given the availability of local contractors and workforce familiarity with kiln operations, implementation is technically and logistically feasible at scale. However, currently there is no financial support or incentives provided by the government to implement these retrofits, and thus this entire first-order investment would come from kiln operators.

Barring a few large brick kiln owners, most small- and medium-sized operators would need access to external capital for retrofitting, which can be derived from green financing across philanthropies, private capital and financial institutions, unlocking an economic opportunity for these players. For example, ADB's Financing Brick Kiln Efficiency Improvement Project in Bangladesh catalysed domestic capital through a USD $50 million credit facility that successfully enabled the replacement of 50% of highly polluting fixed-chimney kilns with more energy-efficient alternatives including zigzag kilns, Hoffman kilns and others.[109]

## Job creation potential

**The retrofitting effort will transition ~38,000 gross full-time equivalent jobs over a 5-year period.** Each kiln retrofit employs ~30 workers over 45 days, translating into nearly 60 million person-days of employment.[110] Additionally, the same workers employed at traditional kilns can be upskilled to operate zig-zag kilns. Since this marks a transition of jobs from traditional kilns to zigzag kilns, this classifies as a first-order outcome. As the same workers rotate across kiln sites, this solution offers a structured opportunity for semi-skilled rural labour and local masonry contractors, without requiring long-term displacement. This would also amplify employment for female workers, who represent ~13% of the workforce in the brick kiln industry.

## Annual economic value-add

**Zigzag kilns can generate US$ 760 million in additional annual revenue, classifying as second order outcomes, with the production of 20-30% more Class-1 bricks than traditional kilns.** Zigzag kilns can produce ~3.2 million additional Class-1 bricks per kiln per year due to better combustion efficiency and airflow, with an average sale price of US$ 0.1 per brick.[111] This upgrade not only improves profitability for kiln owners but also increases availability of high-grade building materials for India's growing construction demand.

## Co-benefits potential

**Retrofitting 13,000 kilns can abate 1 million tonnes of $CO_2$ emissions annually, around 4% of total emissions from India's brick sector.** Each kiln eliminates ~470 tonnes per year due to ~30% lower emissions than FCBTKs, collectively abating 1 million tonnes of CO2e emissions annually.

## PM2.5 and DALYs reduction

**These kilns can reduce India's PM2.5 by ~1% over a 5-year-period and reduce 450,000 DALYs annually.** Micro, small, and medium industries are the largest contributors of India's PM2.5 at 30%, with 3% coming from brick kilns. Retrofitting 13,000 kilns with zigzag technology can reduce India's PM2.5 by ~1%. This will further avert 450,000 million DALYs[112] attributable to air pollution.

## Cost savings

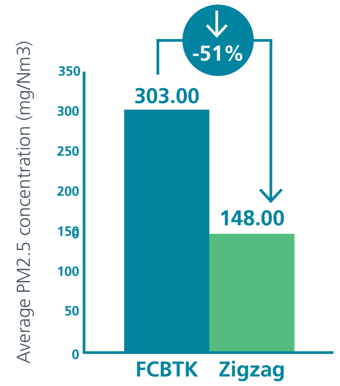
**The transition can save US$ 150 million annually in coal costs.** Zigzag kilns reduce fuel consumption by up to 20%, primarily through more efficient airflow and heat distribution. These savings directly improve the profitability of small kiln businesses, while reducing coal demand and associated emissions.[113]





***Figure 27: Difference between PM2.5 emissions by FCBTKs and ZZKs***

**Zigzag kilns have significantly lesser PM 2.5 concentrations in their emissions than Fixed Chimney Bull's Trench Kilns (FCBTK), irrespective of their type and fuel used**




Source: MDPI, Atmosphere: A Comparative Study of Stack Emissions from Straight-Line and Zigzag Brick Kilns in Nepal, 2019

***Figure 28: Case Study: Successful zigzag kiln transition in Baghpat, UP***

Zigzag kiln innovation in Baghpat, Uttar Pradesh

In Baghpat district of Uttar Pradesh, ~70% of FCBTKs had already retrofitted to zigzag technologies by 2019. This shift has not only reduced air pollution, but it has also improved brick quality and reduced coal consumption by 15–20% per kiln, demonstrating clear environmental and cost benefits. Therefore, brick kiln owners in Baghpat are now saving around 2 tonnes of coal, which amounts to savings Rs 22,000-23,000 per one lakh bricks.

> "We have benefited as we are saving fuel expenses by having to use less coal. **Quality of our bricks has also improved and pollution from our kilns have reduced significantly"**
>
> **- Brick kiln entrepreneur, Baghpat**

## Pathway B

**Includes solutions that create a new clean economy:** This category comprises solutions that catalyse the development of new industries and value chains, generate fresh revenue streams from products and services that previously did not exist.

## 1. Solid Waste Management

**Solid waste burning is a major contributor to air pollution in India.** India generates over 1,70,000 tonnes of municipal solid waste daily,[114] with burning of this waste contributing to 9% of India's PM2.5. In Delhi, solid waste burning contributes to 10% of total air pollution originating in the city.[115]

**This burning occurs at three points along the waste management value chain.** Burning of solid waste occurs during open burning in informal settlements, incineration at waste-to-energy (WTE) plants, and illegal burning to clear landfills, with each releasing harmful pollutants into the air. Inadequate waste collection leads to illegal dumping and a rise in garbage burning, for instance Hyderabad recorded ~30,000 tonnes of open garbage burning in 2022 alone.[116] Across cities in India, 2% to 24% of the municipal solid waste generated in the city gets burned.[117] WTE plants tend to exceed permissible pollution norms due to weak regulatory enforcement and methane-induced fires at landfills, exacerbated by dumping of fresh waste, continue to worsen air quality.

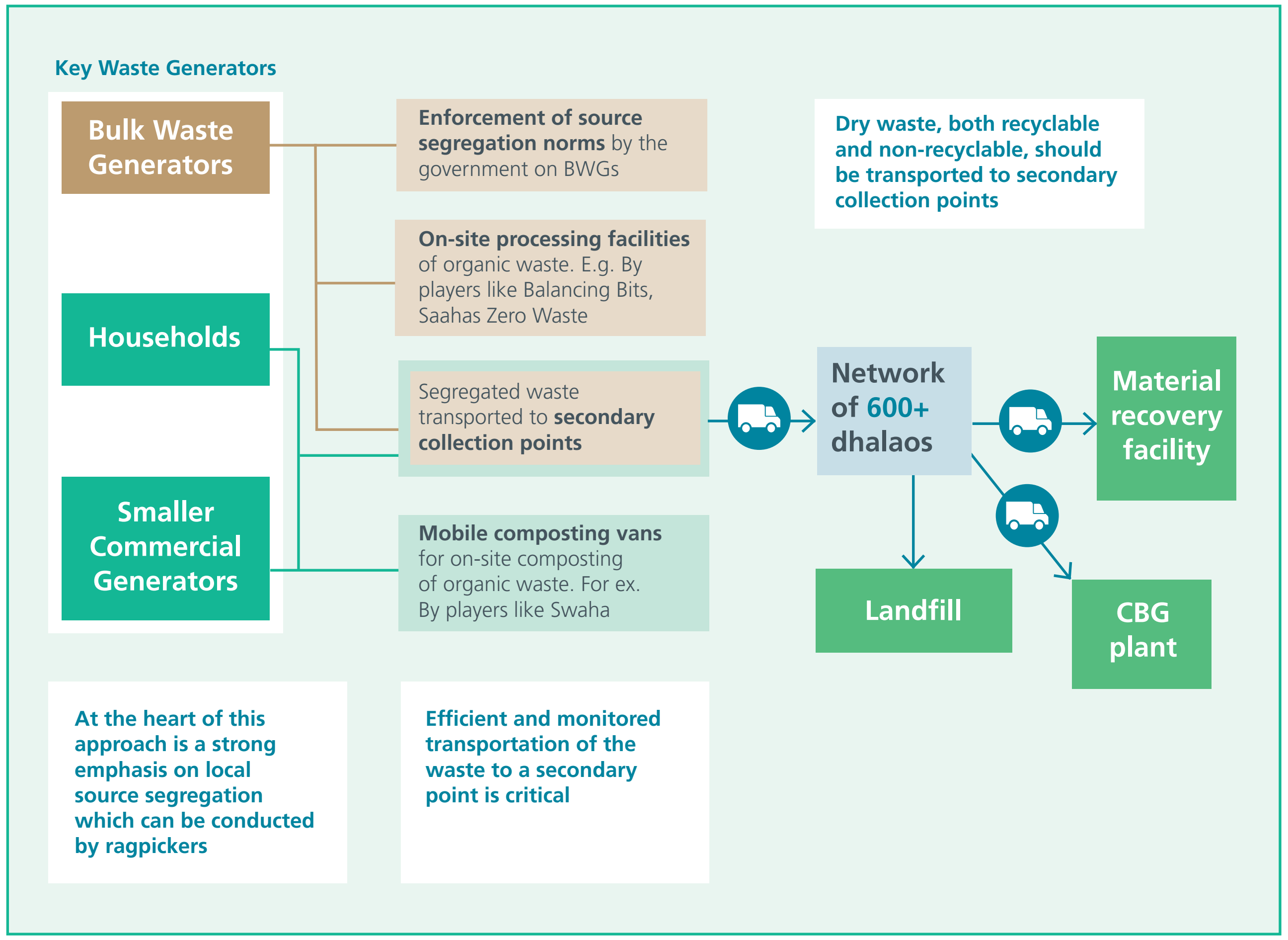
**India has a robust policy framework for solid waste management, which focuses on local accountability, scientific methods, and private sector involvement.** The 2016 Solid Waste Management Rules aim to improve waste management by mandating source segregation, extending local authorities' responsibilities, and promoting waste-to-energy plants. The 2021 Swachh Bharat Mission (Urban) 2.0 allocated US$ 4.6 billion to enhance urban waste management, with a focus on developing MRFs, door-to-door waste collection, and remediating dumpsites.[118] Additionally, the 2022 Extended Producer Responsibility (EPR) guidelines strengthened producer accountability, introduced recycling targets, and streamlined processes through an online portal, while encouraging reduced use of virgin plastics.[119]

**Centralised Material Recovery Facilities (MRF) and Compressed Biogas Plants (CBG) emerge as promising solutions to drive efficient waste management.** While source segregation is the foremost priority, after decentralised waste collection and segregation, dry waste, both recyclable and non-recyclable, can be transported to secondary collection points (e.g., *dhalaos* [120] in Delhi). From there, inorganic waste is directed to centralised MRFs, where it is sorted and baled, with recyclables sold to end-buyers. Organic waste is routed to CBG plants, where it is converted to biogas which can be used for transportation or pipeline networks. Only inert or contaminated waste that cannot be recovered is ultimately sent to landfills.





*Figure 29: Centralised and decentralised solid waste management*

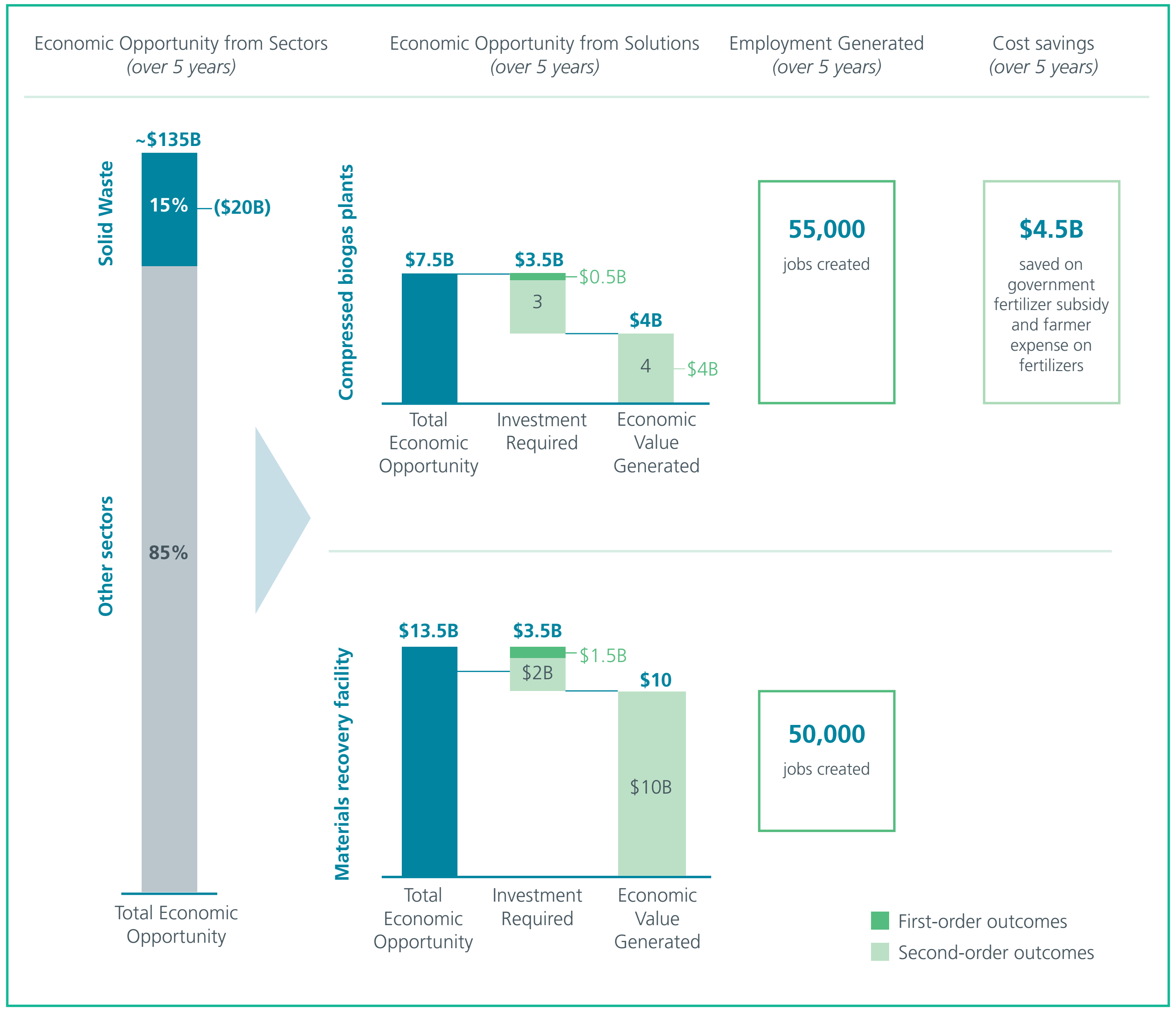



**While CBG plants present a strong opportunity for circular waste management, a few operational and financing challenges could affect scale-up.** Setting up a 100-TPD plant requires an investment of ~US$ 3–4 million, which limits participation to larger developers and dampens private interest.[121] Low plant utilisation which is often below optimal levels due to poor waste segregation (only ~55% in cities like Delhi)[122] reduces gas yields and operational efficiency, heightening lender risk perceptions. Further, fragmented coordination with urban local bodies delays land allocation and waste supply agreements, while underdeveloped carbon and plastic credit markets limit opportunities to enhance project returns.

**Similarly, while MRFs are a critical link in efficient solid waste management, structural barriers continue to constrain scaling.** Establishing a single facility can cost up to ~US$ 9.5 million, making private investment difficult without concessional capital.[123] Weak source segregation at collection points lowers processing efficiency and contaminates recyclable streams, while uncertain revenue flows from recycled material sales increase perceived financing risk. Limited operating track records and complex coordination with municipalities further slow implementation and reduce investor confidence in long-term viability.

**However, scaling efficient waste management systems presents a high-impact economic opportunity.** Targeted policy incentives, concessional finance, and assured waste supply can address current structural bottlenecks and accelerate private investment. Returns will materialise across multiple fronts, from direct economic value and job creation to fiscal savings and environmental benefits.

***Figure 30: Solutions combatting PM2.5 production in the solid waste sector contribute 15% ($20B) to the total economic opportunity, distributed across CBG plants and MRFs***




## (i) Compressed biogas plants

**Diverting ~20% of total waste generated daily in India to CBG plants can drive gross annual economic revenues of US$ 800 million, generating 55,000 direct gross jobs across construction and operations over 5 years and creating US$ 4.5 billion in cost savings, while abating 10 million tonnes of GHG annually, and reducing PM2.5 emissions by 4% by 2030.**

**To meet the projected CBG potential from municipal solid waste (MSW) by 2030, there is a need to set up ~200 large CBG plants, each processing 500 TPD.** SATAT targets and industry projections for 2030 highlight a potential of ~15 million tonnes of CBG per year, with 8% i.e., ~1.2 million tonnes annually from MSW. With CBG yields from MSW of ~4%, this indicates a need to set up a capacity of processing 100,000 TPD of MSW, equivalent to ~22% of the ~450,000 TPD generated daily in India by 2030.[124] Given that current CBG capacity from MSW is minimal at ~1,000 TPD,[125] meeting government targets and industry projections requires ~200 additional CBG plants of 500 TPD processing capacity. The SATAT scheme targets ~5,000 CBG plants, they are likely to be of smaller scale[126] to meet the full CBG potential from multiple feedstocks. However, the estimate of ~200 plants focuses on large-capacity CBG plants for MSW to meet 2030 demand. The construction of these plants will require strong government support, particularly in ensuring land concessions and access for plant sites.





**First-order outcomes:**

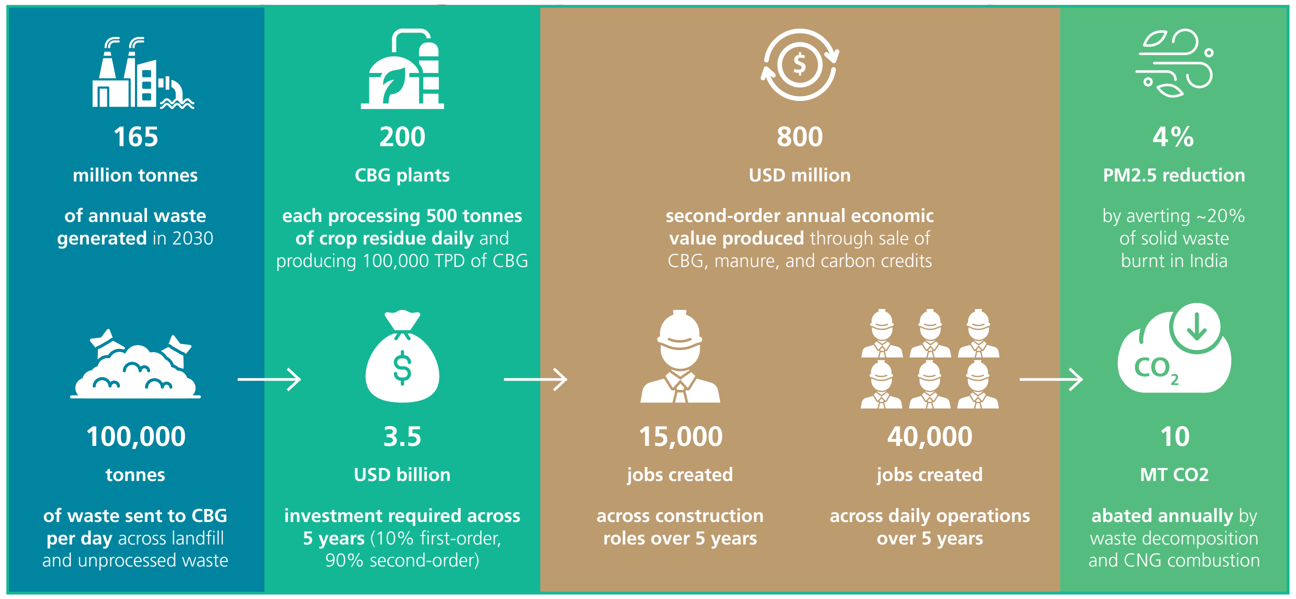
Diverting ~20% of total waste generated daily in India to CBG plants will generate a **first-order outcome of catalytic initial investment,** enabled through the SATAT Scheme and the MNRE Waste to Energy Scheme, and seed capital required to set up blended finance instruments. In this context, public investment is considered the only first-order outcome because CBG represents a completely new value chain: all revenues and jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the deployment of CBG plants for solid waste will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to construct and operate these plants
- **Creation of nearly 55,000 new jobs,** across manufacturing and operations of these CBG plants
- **USD 3.5 billion in annual economic value generated** from sale of CBG, manure and carbon credits
- **US$ 630 million in cost savings per year** in government fertiliser subsidies, with potential for an **additional US$ 270 million per year savings** for farmers at full scale CBG adoption
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 31: Investing $3.5 billion in the build-out of 200 CBG plants can drive $800 million annually while delivering significant employment and environmental benefits***



### Investment required

**Scaling CBG from solid waste will require US$ 3.5 billion in capital investment by 2030.** Each plant requires ~US$ 18 million in capex,[127] with first order government subsidies of ~10% per plant from the MNRE Waste to Energy Scheme.[128]

The remainder, second-order investment, is supported by 70% debt financing, resulting in a funding structure of US$ 11 million in debt and US$ 5 million in equity per plant, indicating ~70% of capital investment for CBG plants for MSW can be drawn from green financing across subsidies and financial institutions, unlocking an economic opportunity for lenders. E.g., under the Galvanising Organic Bio-Agro Resources Dhan (GOBARdhan) initiative by the Government of India, US$ 1.1 was allocated in the 2023 Union Budget to establish 500 "waste-to-wealth" plants, including 200 CBG facilities, of which 190+ plants were constructed in FY 2023–24.[129]

### Job creation potential

**Setting up the ~200 CBG plants will generate ~55,000 direct gross jobs across construction and operations over a 5-year-period, acting as a second-order outcome.** Each plant creates ~450 jobs,[130] split between 57% in construction and 43% in long-term operations.[131] With a construction period of 1.5 years, this translates to ~15,000 construction jobs and ~40,000 operation-phase jobs permanently across 5 years, supporting sustained livelihoods across in urban cities, with opportunities for informal waste workers.

### Annual economic value-add

**These plants can generate over US$ 800 million in annual gross revenue, largely driven by sale of CBG.** Each plant, operating at 70% capacity utilisation, produces ~18 TPD of CBG, generating ~US$ 3.5 million in annual revenue from its sale to transport and pipeline off-takers. An additional ~US$ 350,000 is generated by producing ~90TPD of FOM and ~US$ 150,000 from sale of carbon credits, with the diverse revenue streams enhancing plant viability.[132,133] These second-order economic benefits because they are incremental in nature and expand the total economic value generated, rather than replacing existing revenue streams.

### Co-benefits potential

**Additionally, by averting waste burnt, these CBG plants can avoid 10 million tonnes of GHG emissions annually.** Each plant avoids ~50,000 tonnes of $CO_2e$ per year by avoiding emissions from waste burnt and displacement of CNG combustion, reducing ~10% of total $CO_2e$ emissions from solid waste burning.[134]

### PM2.5 and DALYs reduction

**The plants can abate India's PM2.5 by ~4% by 2030 by diverting waste burnt, thereby averting ~2.5 million DALYs annually.** Solid waste burning in India contributes to ~9% of India's PM2.5, of which ~50% is organic, diverting which to CBG plants can reduce India's PM 2.5 by ~4%. This can further accrue health benefits by averting ~2.5 million DALYs[135] attributable to air pollution in.

### Cost savings

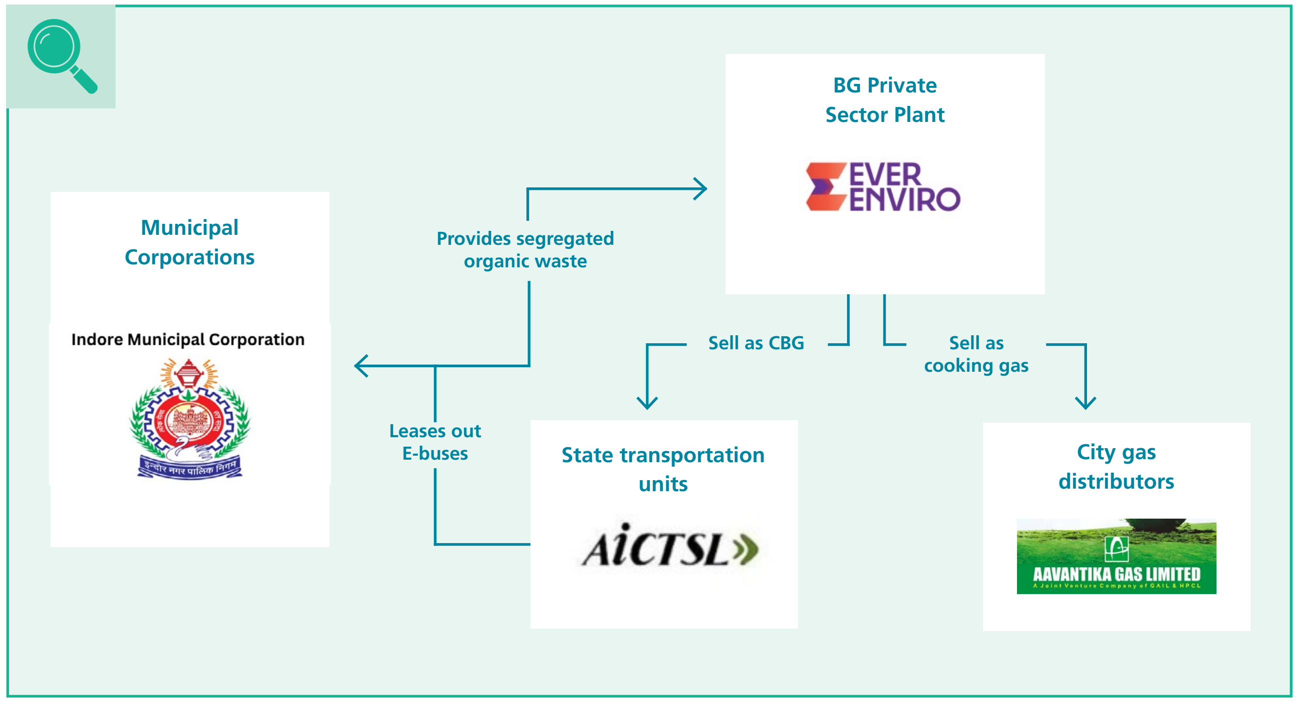
**CBG use from these plants will save up to US$ 630 million per year in government fertiliser subsidies, with potential for an additional US$ 270 million per year savings for farmers at full scale CBG adoption.** Each TPD processed by CBG plants can save the government US$ 1.7 million on fertiliser subsidies, cumulatively yielding savings of US$ 630 million per year. Additionally, full scale expansion of CBG across feedstocks can replace conventional DAP (diammonium phosphate) fertiliser with FOM, which is sold to farmers at 1/3rd of the subsidised DAP price, yielding cost savings of ~US$ 270 million annually to farmers.





**Successful solutions are emerging in India through government partnerships and private sector execution.** Indore has successfully piloted a circular model where the Indore Municipal Corporation provides segregated organic waste to EverEnviro's compressed biogas (CBG) plant. The plant processes this waste into biogas, which is then sold as compressed biogas to state transport units and as cooking gas to city gas distributors. As part of the integrated model, the municipal corporation also leases out electric buses to the state transport agency, creating a closed-loop ecosystem for clean mobility and waste management.

*Figure 32: Case Study: Indore's successful pilot for CBG operations*




## (ii) Material Recovery Facilities (MRF)

**Diverting 33% of daily waste generated in India to centralised MRFs can generate over US$ 2 billion in gross annual revenues, and create gross 50,000+ jobs across construction, operations and management by 2030. MRFs can also abate 2 million tonnes of $CO_2e$ annually and reduce PM2.5 emissions by ~3% by 2030.**

**To meet the projected waste processing needs for 2030, India will require ~1,000 MRF plants, collectively processing 150,000 tonnes of municipal solid waste per day.** India's total daily waste production in 2030 is projected at ~450,000 tonnes,[136] of which 30%+ can be diverted to MRFs.[137] A large-scale MRF can process 150 TPD, indicating a need for ~1,000 MRFs to meet the waste processing demand. While many cities currently operate decentralised MRFs, these facilities are often small, fragmented, and limited in their ability to process waste efficiently. There is therefore a need to establish large, centralised MRFs that can aggregate waste from multiple collection points and achieve greater operational efficiency and economies of scale. Centralised MRFs can process higher daily volumes, support mechanised sorting, and ensure higher material recovery rates, reducing duplication of infrastructure and logistical inefficiencies seen in scattered small units. At the same time, decentralised MRFs can continue to play a complementary role by managing localised waste streams in dense or peri-urban areas, feeding into a hub-and-spoke waste management model. The construction of these plants will require strong government support, particularly in ensuring land concessions and access for plant sites.

**First-order outcomes:**

Diverting 33% of daily waste generated in India to centralised MRFs will generate a **first-order outcome of catalytic initial investment,** enabled through 25% viability gap funding. In this context, public investment is considered the only first-order outcome because MRF creates a completely new value chain: all revenues and jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the creation of MRF will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to construct and operate these facilities
- **Creation of nearly 50,000 gross new jobs,** across manufacturing and operations of these MRF
- **USD 2 billion in gross annual economic value generated** from sale of recyclables, plastic credits, EPR, and carbon credits
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

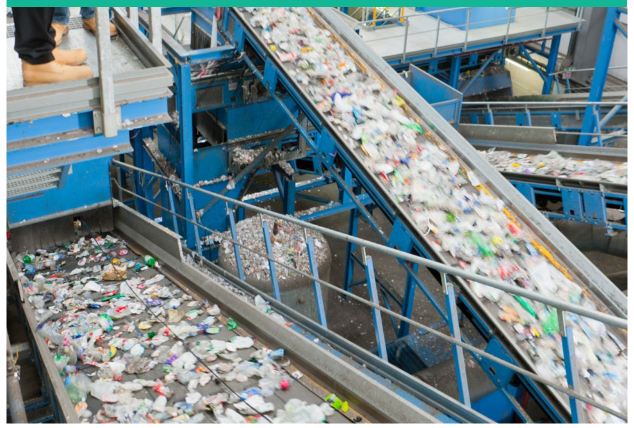
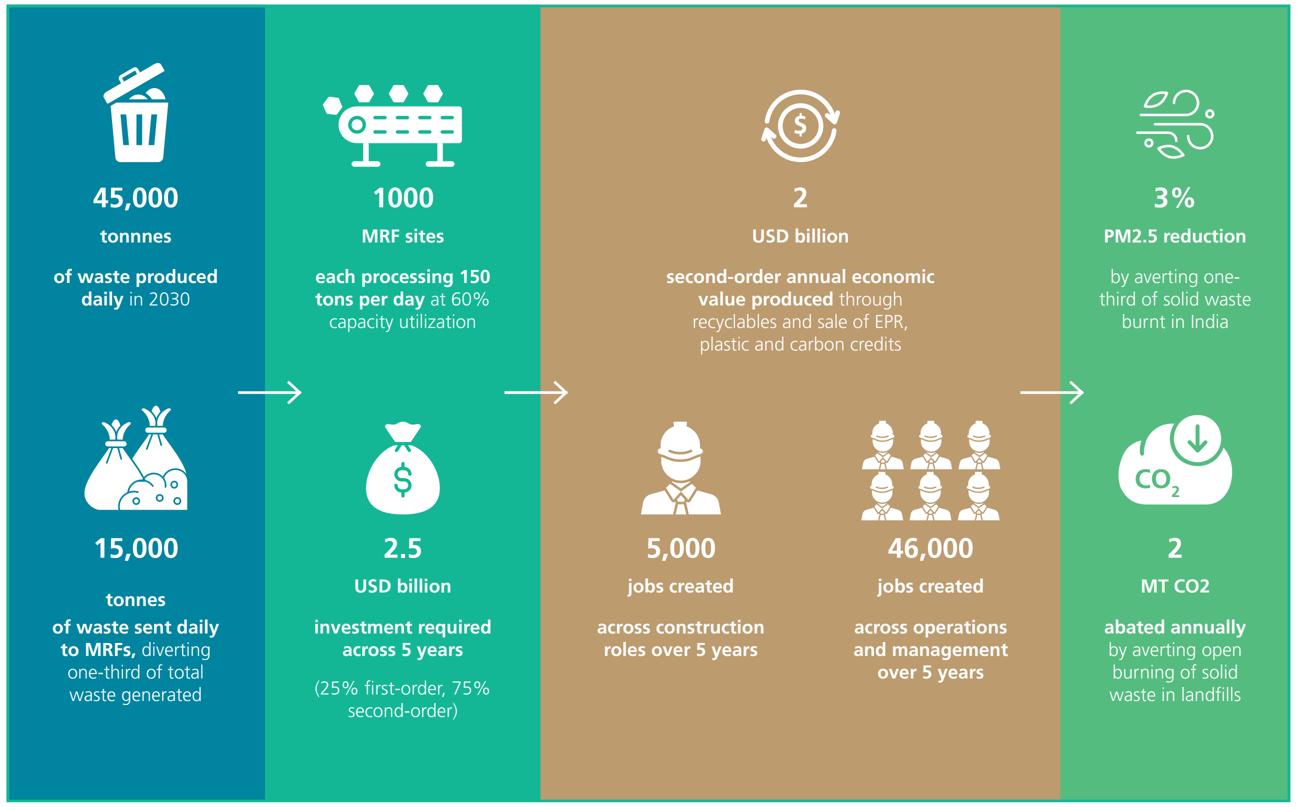


*Figure 33: Investing $2.5 billion in 1000 MRFs can unlock $2 billion annually while delivering significant employment and environmental benefits*








## Investment required

**Setting up ~1,000 MRFs by 2030 will require ~US$ 2.5 billion in capital investment over a 5-year period.** Each plant requires US$ 2.3 million in capex, with government subsidies from viability gap funding (VGF) covering up to ~25% of the project cost,[138] acting as first-order investment.

The remainder, 75% second-order investment, is supported by 70% debt financing, with banks such as HDFC and SBI providing financing for waste projects under their sustainability frameworks, resulting in a funding structure of ~US$ 1.1 million in debt and ~US$ 470,000 in equity per MRF, thereby indicating ~80% of capital investment for MRFs can be derived from green financing. For example, Nepra Resource Management has launched Material Recovery Facilities in Ahmedabad, Indore, Jamnagar, Pune, and Bhopal[139] and secured funding of US$ 31.50 million from green financiers like Aavishkar VC and Circulate Capital.[140] Expanding access to finance creates a stable revenue stream for investors, unlocking a significant opportunity for them.

## Job creation potential

**The deployment of all 1,000 MRFs will generate over 50,000 direct gross jobs across construction, operations, and management across 5 years.** 0.25 construction jobs and 0.31 O&M jobs are created per TPD of MRF processing capacity. With construction periods of ~8 months, this translates to ~5,000 construction jobs and ~46,000 O&M jobs permanently across all MRFs over 5 years.[141] In addition to this, there is significant potential to integrate informal waste pickers into formal roles across collection, sorting, and plant operations, enhancing livelihoods while improving efficiency of waste management systems. Since these jobs are completely new in the value chain, they are considered second-order outcomes.

## Annual economic value-add

**These MRFs can generate US$ 2 billion in gross annual revenue, primarily through the sale of recyclables.** Each plant can produce ~US$ 200,000 in annual value, unlocked through multiple revenue streams across recyclables, plastic credits, EPR, and carbon credits. With each plant processing over 20,000 tonnes of recyclables per year, it can generate ~US$ 1.8 billion from the sale of recyclables. An additional ~US$ 175,000 is generated through the sale of plastic credits and ~US$ 25,000 from sale of EPR to corporates, based on plastic and tyre waste recovered by an MRF. A marginal ~US$ 5,000 can further be generated from the sale of carbon credits.[142] These are second-order economic benefits because they are incremental in nature and expand the total economic value generated, rather than replacing existing revenue streams.

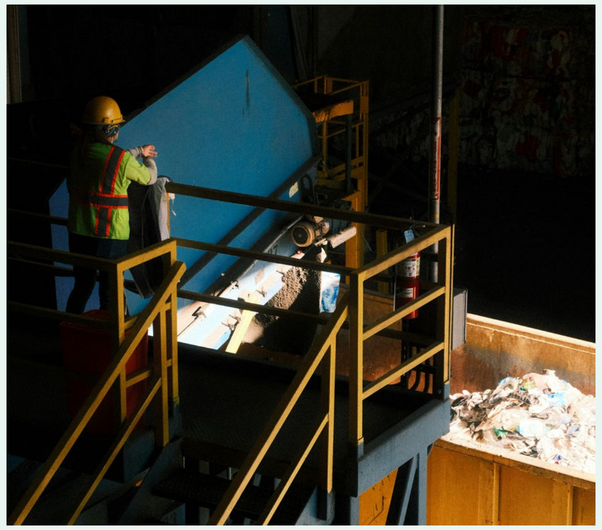
## Co-benefits potential

**MRFs can avoid 2 million tonnes of CO2e emissions annually by diverting waste burnt from landfills.** 24% of total waste in India is sent and burnt in landfills, diverting per tonne of which to MRFs can annually abate 0.14 tonnes of CO2e, leading to cumulative annual abatement of ~2 million tonnes per year, which can abate ~2% of total CO2e emissions from solid waste burning.[143]

## PM2.5 and DALYs reduction

**These MRFs can abate India's PM2.5 by ~3% by 2030 by diverting waste burnt, thereby averting ~1.8 million DALYs annually.** Solid waste burning in India contributes to ~9% of India's PM2.5, of which ~30% can be sent for processing at MRFs, reducing India's PM 2.5 by ~3%.[144] This can further accrue health benefits by averting ~1.8 million DALYs[145] attributable to air pollution in India. However, achieving these gains will require complementary efforts to ensure waste is transported to MRFs using emission-free or low-emission vehicles.

*Figure 34: Case Study: NEPRA's successful Material Recovery Facility in Ahmedabad[146]*



**NEPRA in Ahmedabad**

NEPRA, in a public–private partnership with Ahmedabad Municipal Corporation, invested ₹12 crore to establish a 4,000 m² state-of-the-art MRF with the capacity to sort 70 metric tonnes of dry waste daily, complemented by automated equipment and an ERP-based collection and payment system. This facility supports up to 40 collection vehicles, integrates micro-entrepreneurs, and has recycled over 12,500 tonnes of dry waste—averting an estimated 38,999 tonnes of $CO_2$ emissions

## 2. Agricultural residue burning

**Crop residue burning is a major contributor to air pollution pan-India, which is worsened for the Indo-Gangetic plain due to climatological factors.** Crop residue burning residue is the third largest contributor to India's air pollution (13%)[147] and second largest contributor to air pollution in Delhi-NCR (15%).[148] In Punjab and Uttar Pradesh, about 30-50% of crop residue generated annually is either partially or entirely burned, releasing pollutants that exacerbate the region's air quality crisis.[149,150]

*Figure 35.a.: Contribution of crop residue burning to air pollution in Delhi-NCR*

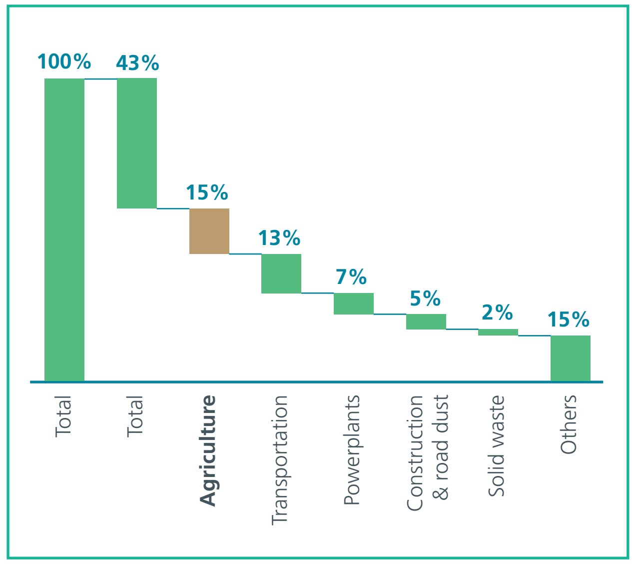
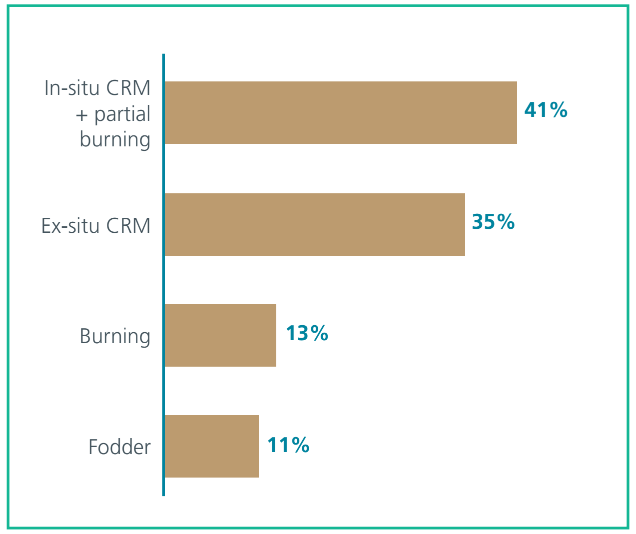



*Figure 35.b.: Crop residue management of the 20 million tonnes produced in Punjab annually*







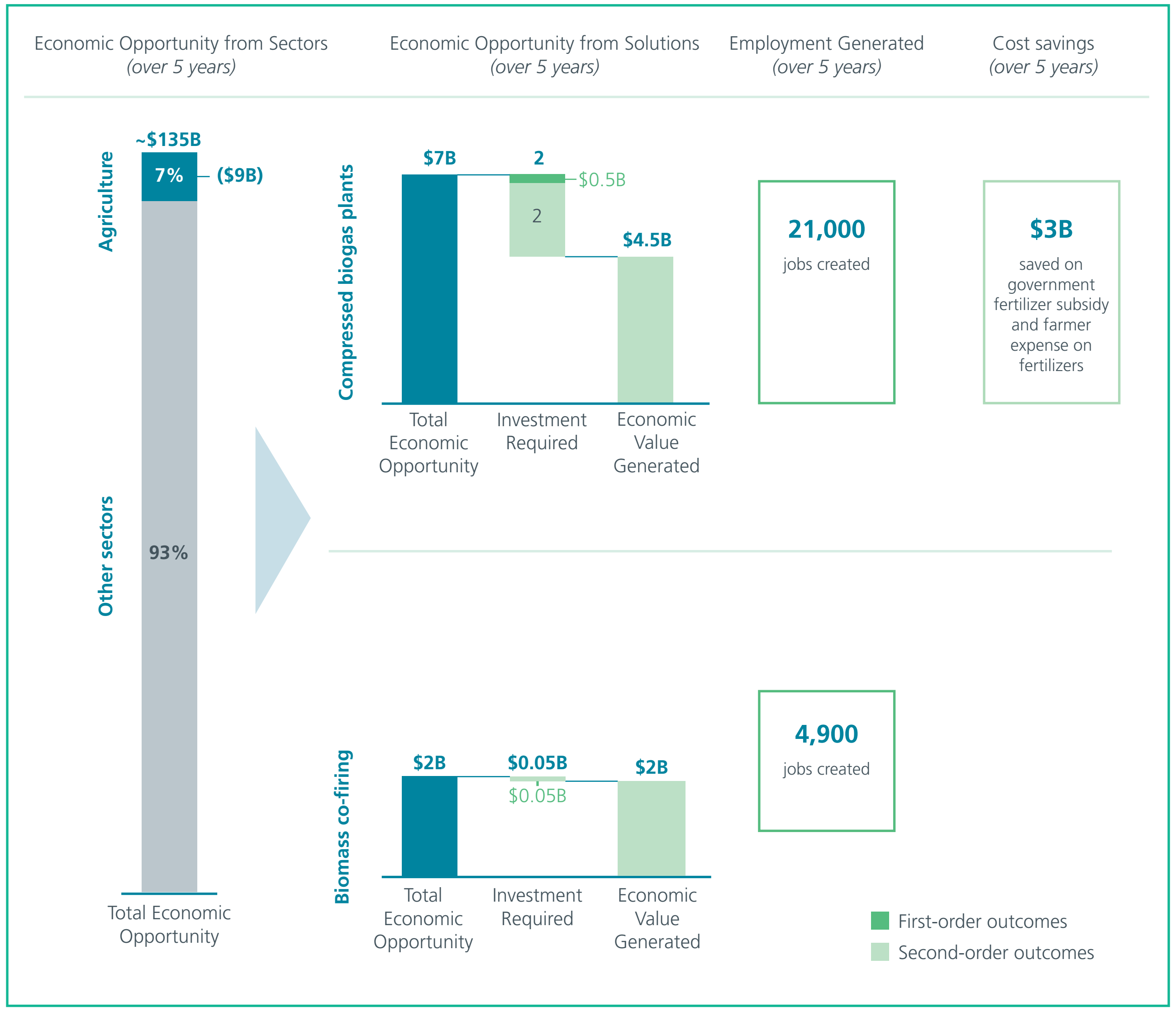

**While crop residue can be managed through in-situ and ex-situ mechanisms, farmers are increasingly adopting ex-situ management of crop residue, with compressed biogas (CBG) plants and co-firing of bio-pellets in thermal power plants emerging as the preferred solutions.** In-situ crop residue management involves incorporating residue back into the soil using machines like happy seeder or super seeders, while ex-situ involves collecting and transporting residue for alternative uses such as fuel or fodder. However, farmers face challenges in adopting in-situ solutions due to limited availability of seeders due to last-mile challenges, high operational costs (US$ 20–30 per acre), and concerns about reduced wheat yields and pest attacks. Additionally, in-situ measures involve partial burning, requiring financial incentives from government for Straw Management Systems which can prevent formation of dense stubble left behind by combine harvesters, which is otherwise burned before operating in-situ equipment like Happy Seeders. As such, farmers are moving towards ex-situ practices, with CBG and cofiring of bio-pellets preferred by most. One-third of farmers in Punjab use ex-situ practices. Among these adopters, 60% prefer supplying crop residue to CBG plants, while 30% use it as fodder.[151] An additional opportunity is emerging in the form of bio-pellet production, where crop residue is densified and sold to thermal power plants for co-firing. This channel offers a ready demand base from existing power infrastructure and creates another market for surplus agri-residue.

**CBG plants hold strong potential for sustainable crop residue management, though a few systemic challenges continue to affect large-scale deployment.** Banks typically finance only 25–70% of project value, limiting access to affordable capital for developers.[152] Many plants operate at just 30–40% capacity due to weak offtake for byproducts like bio slurry and organic manure, which are yet to find stable markets.[153] Seasonal residue availability, fragmented collection systems, and the absence of long-term feedstock contracts also make operations less predictable, slowing steady scale-up despite growing policy support.

**Biomass co-firing in thermal power plants offers a promising channel for utilising agricultural residue, but implementation challenges remain.** India needs ~95,000 tonnes of biomass pellets daily to meet its 5–7% co-firing target, while current capacity stands at only ~7,000 tonnes/day.[154] Pellet supply is further diverted toward higher-paying industrial buyers, and technical issues such as pellet moisture and corrosion risks require operational adjustments. Limited storage infrastructure and the absence of financial incentives for utilities continue to constrain wider adoption.

**Favourable government policies and initiatives are driving strong momentum in favour of both CBG development and bio-pellet-based solutions.** The SATAT scheme by the Ministry of Petroleum and Natural Gas promotes the establishment of CBG plants by independent entrepreneurs. The MNRE's Waste to Energy initiative offers Central Financial Assistance for setting up CBG projects, and the Fertiliser (Inorganic, Organic or Mixed) Order, Amendment, 2025 recognises 'Organic Carbon Enhancers' from CBG plants as fertilisers, encouraging wider adoption of organic alternatives. Additionally, MNRE's National Bioenergy Programme (2021–26) provides financial support and policy impetus for biogas, biomass, and waste-to-energy projects, including co-firing initiatives. The Ministry of Power has also mandated thermal power plants to co-fire biomass pellets up to 5–7%, creating an institutional pull for bio-pellet procurement.

***Figure 36: Solutions combatting PM2.5 production in the agriculture sector contribute 7% ($9B) to the total economic opportunity, distributed across CBG plants and co-firing bio-pellets***




**Diverting 10% of stubble burnt to CBG plants can unlock gross annual economic value addition of US$ 850 million across diverse revenue streams and create over 21,000 gross jobs in plant construction and operation over the next 5 years and generate US$ 3 billion in cost savings, while saving US$ 540 million in subsidies annually, abating CO2e emissions by 2 million tonnes annually and reducing India's PM2.5 by 1.3% by 2030.**

**To divert 10% of stubble burnt in 2030 to CBG plants, ~90 large plants are required, each processing ~28,000 tonnes per day of crop residue.** Government and industry projections estimate a CBG potential of ~4.5 million tonnes annually from crop residue by 2030.[155] This requires diverting ~40% of the projected ~95 million tonnes of stubble that would otherwise be burnt each year by 2030.[156] However, supply chain limitations suggest a maximum of 10% of stubble burnt diverted to CBG plants by 2030,[157] producing ~1 million tonnes of CBG per year. To process this 10% of stubble, an additional capacity of ~28,000 tonnes per day is needed, up from the ~1,000 TPD current capacity.[158] This translates to ~90 new large-scale plants, each with 300 TPD processing capacity. While the SATAT scheme targets ~5,000 CBG plants, they are likely to be of smaller scale to meet the full CBG potential from multiple feedstocks, while the estimate of ~90 plants focuses on large-capacity CBG plants for crop residue to meet 2030 demand.





**First-order outcomes:**

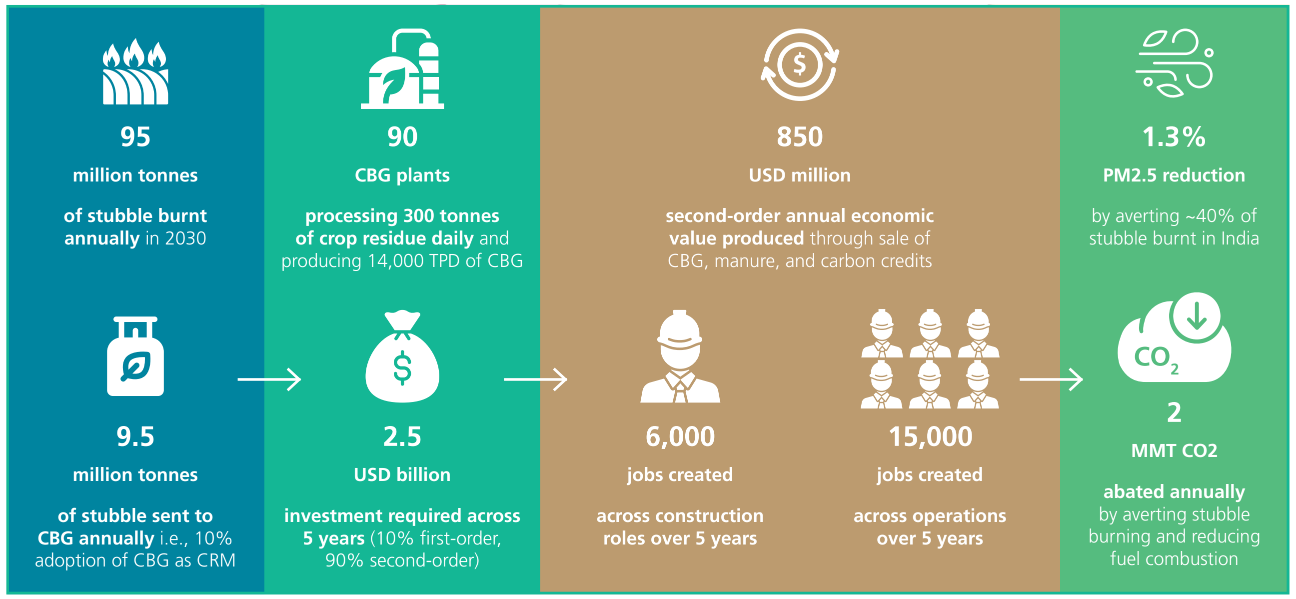
Diverting 10% of stubble currently burnt to Compressed Biogas (CBG) plants will generate a **first-order outcome of catalytic initial investment,** enabled through the SATAT Scheme and the MNRE Waste to Energy Scheme, and seed capital required to set up blended finance instruments. In this context, public investment is considered the only first-order outcome because CBG represents a completely new value chain: all revenues and jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the deployment of CBG plants will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to construct and operate these plants
- **Creation of nearly 21,000 new jobs,** across manufacturing and operations of these CBG plants
- **USD 4 billion in annual economic value generated** from sale of CBG, manure and carbon credits
- **US$ 540 million in cost savings per year** in government fertiliser subsidies, with potential for an **additional US$ 270 million per year savings** for farmers at full scale CBG adoption
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 37: Investing in 90 CBG plants requires $2.5 billion but can unlock $800 million annually in economic value, while delivering significant environment and employment gains***



## Investment required

**Scaling CBG capacity to 2030 requirement levels will need US$ 2.5 billion in capital investment over the next 5 years.** Each plant involves a capex of US$ 26 million,[159] with first-order catalytic capital via subsidies such as MNRE Waste to Energy Scheme covering ~10% of this investment requirement as well as capital needed to set up blended finance instruments such as risk sharing debt facility.[160]

This public catalytic share is expected to unlock the remaining ~90% from second-order commercial sources. A typical funding structure involves ~70% debt and ~20% equity, translating into about US$ 17 million in loans and US$ 7 million in equity per plant. Green financing will play a central role, with banks and NBFCs expanding their EV and clean energy portfolios to include CBG. For example, the Union Bank of India provides working capital and term loans ~70% of the project cost to borrowers eligible under the SATAT scheme to produce CBG in India,[161] unlocking an economic opportunity for financiers.

## Job creation potential

**Setting up these CBG plants could create over 21,000 gross jobs across plant construction and operations over the next 5 years, acting as a second-order outcome.** Each new plant employs ~400 workers on average,[162] with 60% in the construction phase and 40% in long-term operations.[163] With the construction phase lasting for 1.5 years,[164] the sector is projected to generate ~6,000 permanent jobs in construction and ~15,000 in daily operations over 5 years. These jobs are expected to be concentrated in rural areas, offering significant employment opportunities in regions with high stubble generation.

## Annual economic value-add

**The ~90 plants will be able to generate US$ 850 million in gross annual revenue, largely driven by revenue from sale of CBG and manure.** Each plant, operating at 70% capacity utilisation, produces 33 TPD CBG and 650 TPD of Fermented Organic Manure (FOM),[165] generating ~US$ 6.5 million and ~US$ 3.5 million annually in revenue respectively.[166] An additional ~$60,000 can be derived from the sale of carbon credits.[167] These are second-order economic benefits because they are incremental in nature and expand the total economic value generated, rather than replacing existing revenue streams. While CBG plants unlock multiple lucrative revenue streams, to realise the full potential, government support for market creation of CBG in the form of gas grid development, of FOM through incentives, and of carbon credits is required.

## Co-benefits potential

**These plants can further abate ~2 million tonnes of CO2e annually by averting stubble burnt and avoiding combustion of fuel.** Each plant at ~70% capacity utilisation avoids 20,000+ tonnes of $CO_2$-equivalent emissions annually,[168] adding up to ~2 million tonnes per year across all plants. This includes emissions avoided from stubble burning and from displacing fossil fuel combustion, abating ~1.5% of total CO2e emissions from stubble burning in India.[169]

## PM2.5 and DALYs reduction

**The plants can abate India's PM2.5 by ~1.3% by 2030 by diverting stubble burnt, thereby averting ~750,000 DALYs annually.** Stubble burning in India contributes to ~13% PM2.5, diverting 10% of which to ~90 CBG plants will abate ~1.3% of India's PM2.5. This can further accrue health benefits by averting ~750,000 DALYs[170] attributable to air pollution in India.

## Cost savings

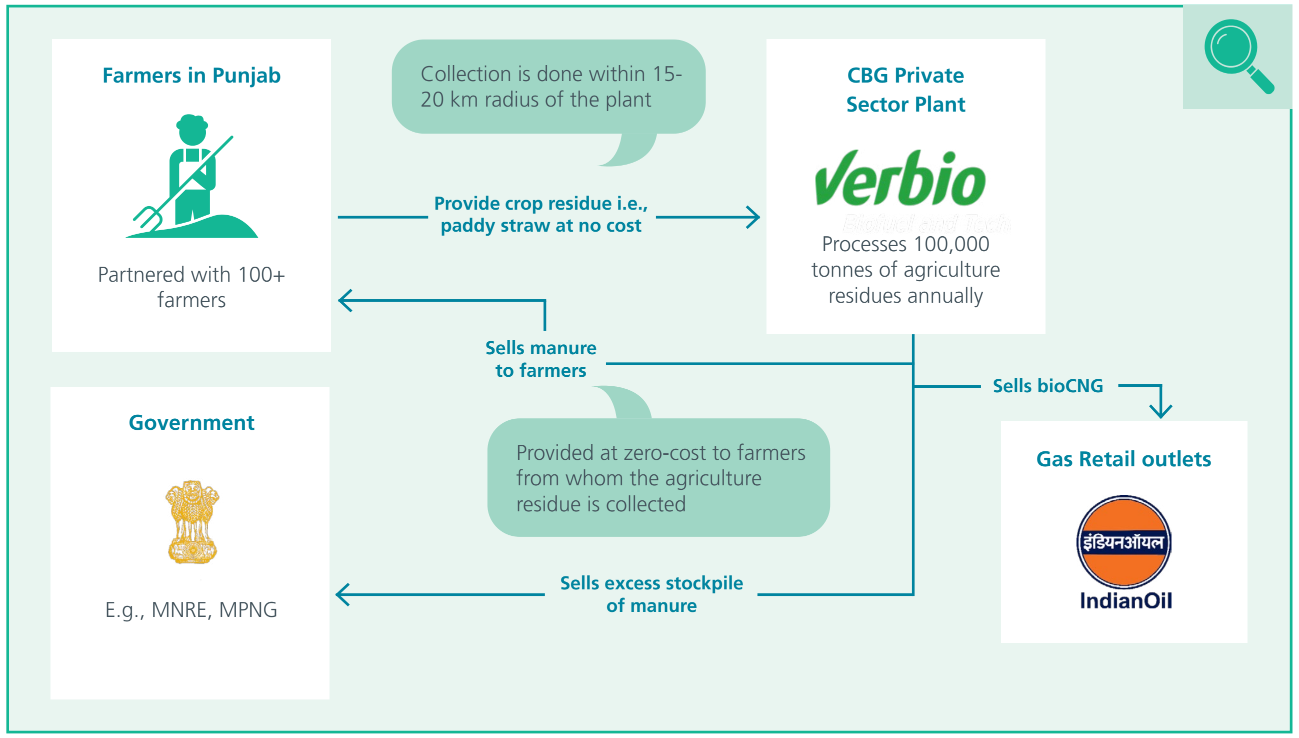
**CBG use from these plants will save ~US$ 540 M per year in government fertiliser subsidies, with potential for an additional US$ 270 million per year savings for farmers at full scale CBG adoption.** Each TPD processed by CBG plants can save the government US$ ~1.7 million on fertiliser subsidies,[171] cumulatively yielding savings of ~ US$ 540 M per year.[172] Additionally, full scale expansion of CBG across feedstocks can replace conventional DAP (diammonium phosphate) fertiliser with FOM, which is sold to farmers at 1/3rd of the subsidised DAP price,[173] yielding cost savings of ~US$ 270 million annually to farmers.





**CBG plants unlock win-win opportunities for all by connecting farmers with off-takers.** Successful models like Verbio AG exist, which transform agricultural residues into clean energy and bio-manure at an unprecedented scale. Verbio partners with farmers within 15-20 km radius of the plant, who provide crop residue at no cost. After processing the residue, Verbio provides manure to the partnered farmers at no cost, selling bioCNG to gas retail outlets like IndianOil, and selling excess stockpile of manure to the government. The plant, India's largest, processes 100,000 tonnes of agricultural residues annually and produces 30+ TPD of BioCNG and 650 TPD of bio-manure, highlighting the potential for scaling CBG solutions.

*Figure 38: Case Study: Verbio's scalable CBG model*




## (ii) Co-firing bio-pellets

**Diverting 10% of crop residue burnt to ~200 bio-pellet plants for co-firing in TPPs can unlock gross economic value addition of over US$ 400 million annually and create nearly 4,900 jobs over the next 5 years, while abating 3 million tonnes of $CO_2$ emissions per year and reducing India's PM2.5 burden by 1.3% by 2030.**

**There is a need for an additional bio-pellet manufacturing capacity of 5 million tonnes per year, across ~200 new bio-pellet manufacturing plants to meet projected demand from thermal power plants.** India is expected to burn ~95 million tonnes of stubble annually by 2030.[174] The government's Biomass Policy mandates 7% biomass co-firing in thermal power plants (TPP) from 2025 onwards,[175] indicating an annual requirement of ~50 million tonnes of bio-pellets.[176] This means that that half of all of the stubble burnt must be diverted towards bio-pellet manufacturing units for TPPs.

**However, supply chain challenges limit progress. Currently, less than 5% of stubble is diverted for bio-pellet use in TPPs – a figure expected to reach 10% by 2030,[177] enabling an annual production of ~10 million tonnes of bio-pellets for TPPs.** Present bio-pellet production capacity is 10 million tonnes per year,[178] split evenly between TPPs and industrial boilers.[179] To meet the additional 5 million tonne demand for TPPs, there is a need for ~200 new plants, each processing 60 tonnes per day across ~330 operating days.

**First-order outcomes:**

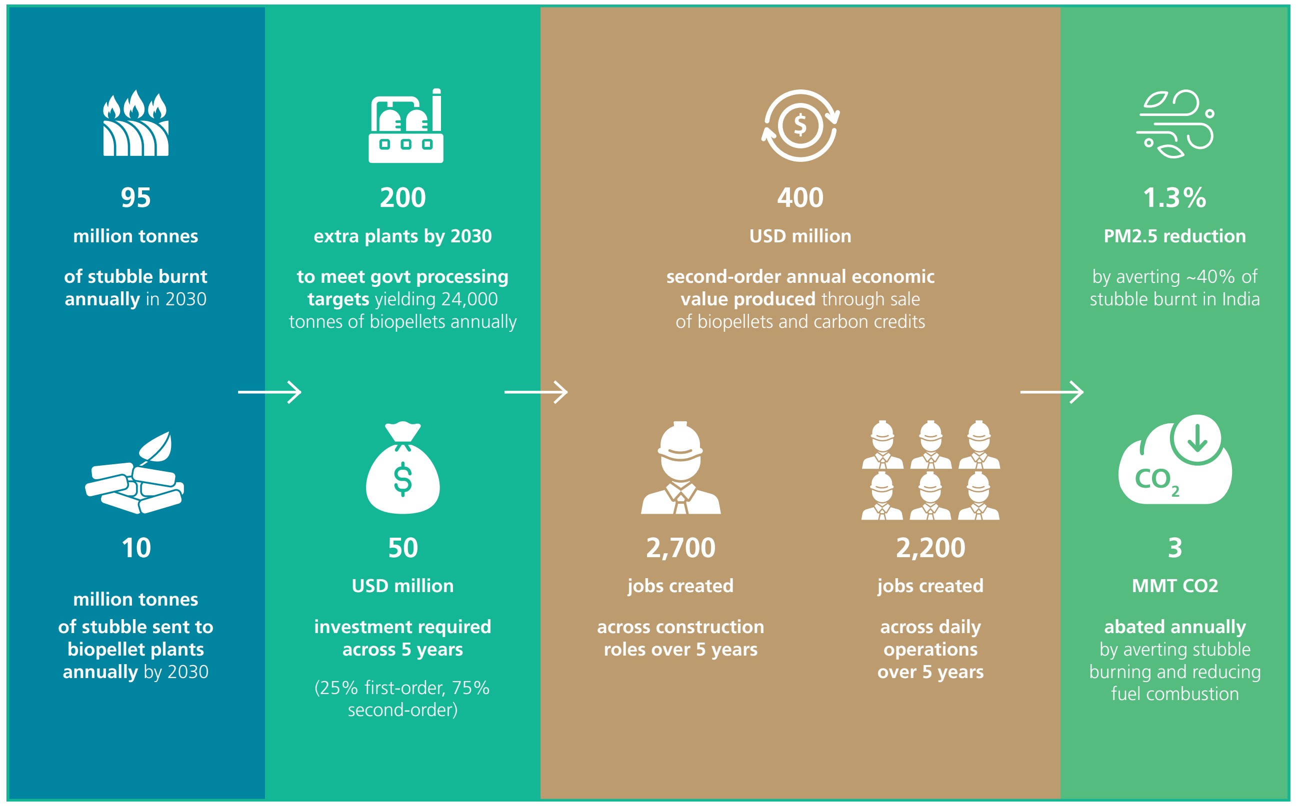
10% of crop residue burnt to ~200 bio-pellet plants for co-firing in TPPs can generate a **first-order outcome of catalytic initial investment,** enabled through 25% government subsidy seed capital required to set up blended finance instruments. In this context, public investment is considered the only first-order outcome because co-firing bio-pellets creates a completely new value chain: all revenues and jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

Building on the multiplier effect of these first-order outcomes, the co-firing of bio-pellets will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with private investment mobilised to construct and operate these facilities
- **Creation of nearly 5,000 gross new jobs,** across manufacturing and operations of these plants
- **USD 400 million in gross annual economic value generated** from sale of bio-pellets and carbon credits
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

***Figure 39: Investing $50 million in the build-out of 200 extra bio-pellet plants by 2030 unlocks an investment of $400 million and delivers significant environmental and employment outcomes***








## Investment required

**These bio-pellet plants will require US$ 50 million in capital investment by 2030, with high potential from green financing.** Each plant requires a capex of US$ 230,000,[180] operating at a capacity of 60 tonnes per day, for 333 days a year. ~25% of this capital can potentially come from first-order investment comprising government subsidy and capital needed to set up blended finance instruments such as risk sharing debt facility, with government support via subsidies by MNRE under the Biomass Program covering US$ 53,000 per plant[181].

The remainder 75% can potentially be financed via second-order investment, with a 70% debt financing by financial institutions and capital from commercial sources. The resulting funding structure includes US$ 0.1 million in debt and US$ 50,000 in equity per plant, indicating that the remaining capital investment can be derived from green financing across subsidies and financial institutions. This will thereby drive economic gains to them in the form of interest revenue. For example, the Central Pollution Control Board provides financial assistance of up to 40% of the capital cost for plant and machinery of a 1 TPH (tonne per hour) plant in the NCR region.[182]

## Job creation potential

**The deployment of the bio-pellet plants could create nearly 5,000 direct gross jobs across plant construction and operations over the next 5 years.** The construction of each plant generates 40 jobs,[183] with a construction period of 1.5 years, indicating 10+ permanent jobs across the next 5 years for constructing each plant. Additionally, 10 permanent jobs are created per plant for operations.[184] This results in the creation of ~5,000 gross jobs across the bio-pellet plants, which are second-order outcomes, and can play a crucial role in stimulating the local, rural economy and in driving industrial development.

## Annual economic value-add

**The plants will also generate over US$ 400 million annually in gross economic value, primarily driven by the sale of bio-pellets.** The average selling cost of bio-pellets to thermal power plants is placed at ~$75 per tonne.[185] With the output capacity across the additional plants at 5 million tonnes annually, this results in an annual economic value of ~US$ 400 million by bio-pellet manufacturers. An additional ~$US 10.5 million can be generated through the sale of carbon credits by thermal power plants. This revenue stream is a second-order outcome, since bio-pellets are a completely new value chain.

## Co-benefits potential

**Using ~5 million tonnes of bio-pellets in thermal power plants annually can abate ~3 million tonnes of CO2e annually across all plants.** Co-firing the additional ~5 million bio-pellets produced annually in thermal power plants can abate ~3 million tonnes of CO2e from TPPs annually. This number can potentially reach ~38 million tonnes of CO2e abated per year, as India eventually reaches 7% co-firing in all thermal power plants, leading to a ~3% reduction of all CO2e emissions emitted by thermal power plants.[186]

## PM2.5 and DALYs reduction

**Diverting stubble burnt to bio-pellet plants can abate India's PM2.5 by 1.3% by 2030, thereby averting ~780,000 DALYs annually.** Stubble burning in India contributes to ~13% PM2.5, diverting 10% of which for the creation of bio-pellets can abate ~1.3% of India's PM2.5. Reduced PM2.5 will drive health benefits and avert ~780,000 DALYs[187] attributable to air pollution in India.

*Figure 40: Case Study: NTPC's (National Thermal Power Corporation) co-firing biomass pellets achievement*

**NTPC's Scaled Demonstration of Biomass Co-Firing in Thermal Power Plants**

**NTPC has successfully demonstrated technical and operational viability of biomass co-firing at scale in Indian thermal power plants.** In 2024, it conducted India's first successful co-firing of **20 wt % torrefied biomass** in an existing coal-fired boiler at its Tanda Unit, marking a significant decarbonization milestone in the power. Earlier, the utility had consistently co-fired **7-10 wt % non-torrefied biomass** in Dadri Unit. These achievements validate the technical feasibility of blending high proportions of agricultural residue-based pellets to reduce both carbon emissions and stubble burning, offering a scalable template for cleaner baseload generation.

## 3. Residential combustion

**Residential combustion is one of the largest sources of air pollution in India, largely driven by the burning of solid fuel in homes for cooking.** Approximately 27% of India's total PM2.5 emissions are created by cooking and heating fuels,[188] with household air pollution (HAP) alone accounting for ~37% of ambient air pollution nationwide.[189] As the point of emission is indoors, it poses severe health risks, causing an estimated 800,000 premature deaths annually, with an additional 300,000 deaths linked to outdoor pollution from household sources. Women and children are disproportionately affected, facing the highest exposure from long hours spent cooking, and the added labour burden of collecting fuel for 4-5 hours daily.

**The bulk of this pollution comes from burning solid fuels for cooking, highlighting the need for improved cooking solutions.** ~75% of India's PM2.5 from residential combustion is attributable to the use of solid fuels for cooking, followed by lighting and heating.[190] Tackling this requires both improved cooking solutions and a transition to cleaner fuels. A variety of improved cooking solutions exist, including biomass-based improved cookstoves (suited for households near forests), bio-pellet stoves (more common in institutions

and restaurants), and electric cookstoves (suited for households in areas with reliable electricity). Biomass cookstoves can cut PM2.5 emissions by ~60%, while electric alternatives can achieve over 80% reductions.[191] The cleanest shift is to LPG (liquefied petroleum gas), but in regions where affordability and access remain barriers, improved cooking solutions offer a more practical path. It is also important to note that in some northern areas, particularly during winters in Delhi-NCR, solid fuels for heating can contribute as much pollution as cooking, underscoring the need for targeted solutions like electric heaters in certain geographies.





**Recognising the scale of pollution from solid fuel cooking, the government of India has made remarkable strides in expanding access to clean cooking fuels through policies that leverage targeted subsidies, last-mile distribution and direct benefit transfers.** The Pradhan Mantri Ujjwala Yojana (PMUY) has been central to this effort, expanding LPG access to over 90% of households nationally, backed by a US$ 0.9B allocation for FY23-24.[192] Delhi exemplifies policy success, ensuring that LPG distributors are located within 1-3 km of every household, offering an increased subsidy of US$ 4 per cylinder, and implementing direct benefit transfers that minimise leakages and administrative delays.[193] Complementing LPG access, initiatives like the National Efficient Cooking Program (NCEP) have introduced induction stoves as viable alternatives, offering a 25-30% cost advantage over traditional cooking methods.[194]

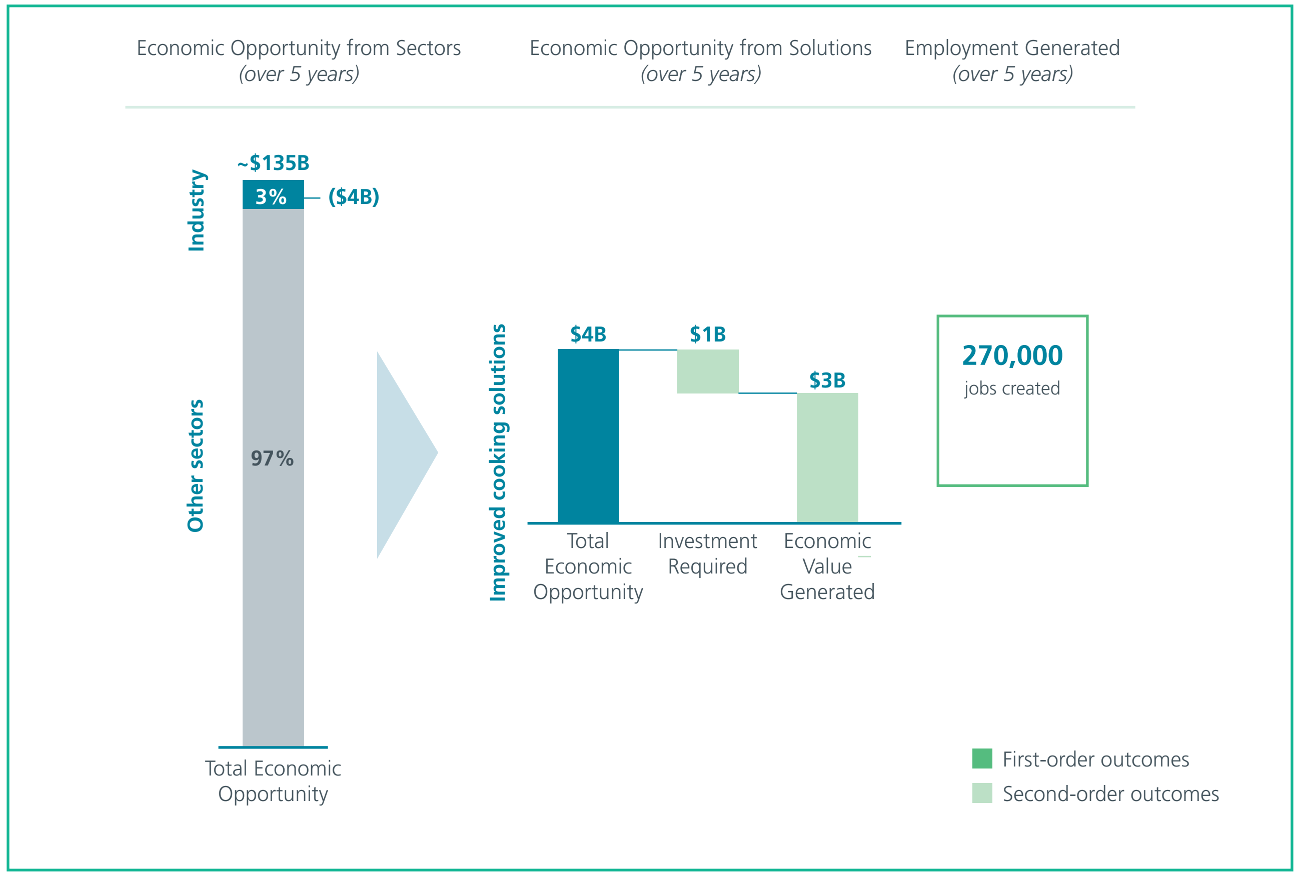
**Despite strong policy efforts, major barriers persist, with non-notified slums facing systemic exclusion from government efforts, while high fuel costs prevent sustained use of clean cooking fuels in low-income households.** Non-notified communities, often outside formal urban planning frameworks, face documentation barriers that prevent them from accessing financial assistance via government programs and schemes such as LPG subsidies under PMUY. Coupled with unstable incomes and no formal service delivery, 40-50% of these households remain dependent on polluting solid fuels for daily activities.[195] Even when clean cooking fuels are accessible, affordability presents a fundamental barrier, with most urban poor families relying on volatile and seasonal incomes from daily-wage work in the informal sector, making the US$ 12 cost per 14.2 kg LPG refill a significant financial burden.

**Based on these constraints, improved cooking solutions have emerged as the preferred solution, offering a more affordable, durable, and practical alternative over other clean cooking solutions.** Under the PMUY scheme, the government provides a US$ 4 monthly subsidy per LPG refill, bringing down the effective cost to US$ 8 per cylinder.[30] Even with infrastructure already in place for 100 million beneficiaries,[196] sustaining this subsidy costs approximately US$ 8.4 billion annually.[197] Extending full LPG access to a conservative estimate of 130 million households projected to use solid fuel by 2030 would require a first-year outlay of US$ 12 billion including upfront setup and two months of supply, with over US$ 56 billion over five years. In contrast, supplying the same 130 million households with improved cookstoves for five years would cost ~US$ 2.5 billion at current selling prices – a 95% reduction in required spending. Furthermore, unlike LPG, improved cookstoves do not require formal infrastructure, documentation, or continuous fuel purchases, making them suitable for communities facing exclusion from existing schemes. Their one-time distribution model and compatibility with a variety of informal settlement conditions ensures that even the most underserved households can access cleaner and more sustainable cooking solutions.

**A few adoption barriers may slow widespread transition to clean cooking.** In urban areas, fragmented program delivery leaves non-notified settlements outside formal schemes, creating distribution and access gaps. Cultural preferences, perceptions of safety, and limited awareness further reduce willingness to adopt newer technologies. In addition, upfront device costs of ~US$ 36–60 for improved cookstoves and uncertainties in carbon-credit–based business models constrain financial sustainability and long-term scale-up.

**However, these challenges also open a pathway to unlock economic opportunity and accelerate inclusive clean cooking transitions at scale.** Targeted subsidies, carbon-market mechanisms, and microfinance solutions can help bridge affordability gaps, while social marketing and last-mile distribution networks can drive behavioural adoption. Returns will extend beyond air quality improvements, advancing gender equity, reducing household drudgery, and improving health outcomes for millions of women and children.

*Figure 41: Solutions combatting PM2.5 production in the residential combustion sector contribute 3% ($4B) to the total economic opportunity, while driving employment and socio-economic benefits*




**Deploying ~50 million improved cooking solutions across India by 2030 can drive ~US$ 600 million in gross economic value annually and generate ~270,000 gross jobs across manufacturing and distribution by 2030, while simultaneously averting 210 million tonnes of GHG annually, unlocking 600 million days of quality time for women per year and reducing India's PM2.5 levels by ~2% by 2030.**

**To transition all households utilising solid fuel to improved cooking solutions by 2030, ~50 million improved cooking solutions need to be deployed across India over the next 5 years.** These solutions include natural draft, forced draft, electric, bio-pellet, biogas, and LPG cookstoves, representing a range of cleaner and more efficient technologies. At the current distribution of 40% solid fuel use across households,[198] an estimated 150+ million households will be using solid fuel in 2030[199]. Out of these, those households already using LPG as a primary fuel are expected to fully transition to LPG. Based on this, the analysis takes ~35% of solid fuel using households to require improved cooking solutions.[200,201]





**First-order outcomes:**

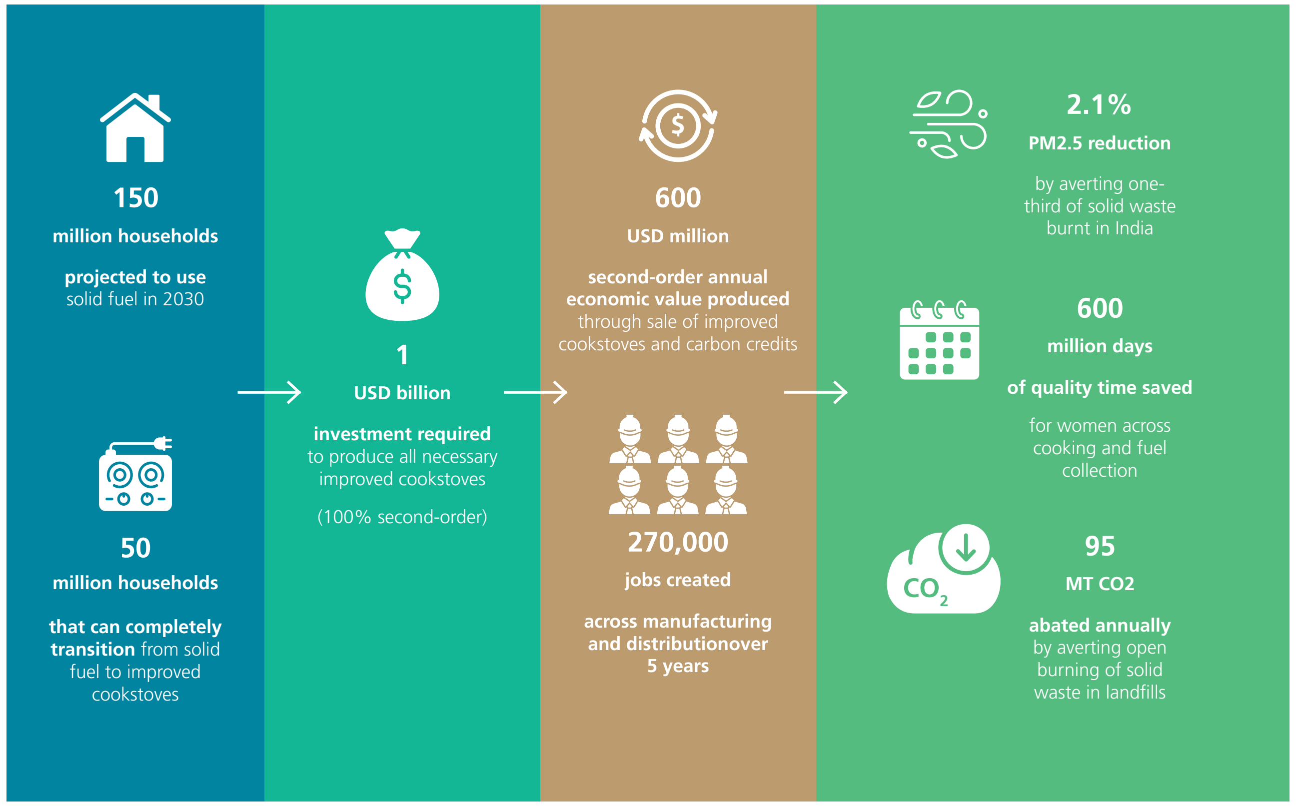
Transitioning households to improved cooking solutions does not generate any **first-order outcome.** Unlike other air quality management solutions, improved cooking solutions do not have first-order catalytic public investment, since the government doesn't provide any financial support for their adoption. They can be financed through up-front sale of carbon credits (explained in detail below). Further, since they are new solutions which will be deployed, jobs created, and annual economic value generated are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

The transition of all households in India utilising solid fuel to improved cooking solutions by 2030 will catalyse a range of second-order impacts, including:

- **Crowding-in of commercial capital,** with the up-front sale of carbon credits allowing private sectors to finance this transition
- **Creation of 270,000 direct gross jobs** across manufacturing and distribution of improved cookstoves
- **USD 600 million in direct annual revenues** from cooking solutions sales of US$ 300 million, and US$ 300 million from carbon credit earnings
- **Environmental and public health benefits,** including substantial GHG abatement and reduced DALYs from lower air pollution exposure

*Figure 42: Investing $1 billion in cooking solutions can unlock $600 million in economic value annually, abating GHG emissions and saving quality time for women*



## Investment required

**Scaling production of improved cooking solutions to serve 50 million households by 2030 will need ~US$ 1 billion in capital investment over the next 5 years.** Assuming existing cookstove and utensil manufacturing facilities can be repurposed (where technically feasible), negligible additional overheads are required to produce improved cooking solutions.[202] The projection estimates a production margin of 20%, with the average selling price of an improved cooking solutions placed at ~US$ 20.[203]

**The upfront sale of carbon credits can be used to finance the distribution of clean cookstoves by providing working capital before emission reductions are realised.** The proceeds from these forward-sold credits cover a major share of the upfront cost, while future carbon revenues are used to repay investors or lenders. This approach enables immediate scale-up of clean cooking access without waiting for credit verification cycles.

**Targeted financing innovations like carbon-linked subsidies and micro-loans offer pathways to finance this clean cooking transition, serving as second-order investment sources.** Partnerships between manufacturers and financial institutions for EMI or micro-finance options can provide access to finance, especially for rural women, while achieving green financing goals of financial institutions.[204] Monetising emission reductions from improved cooking solutions and other e-cooking devices through carbon markets can subsidise upfront costs by 40–80%.[205]

**Bundling these products with micro-loans through NBFCs or MFIs, or offering pay-as-you-use models, further ease adoption friction, while also driving revenue for these institutions through interest payments.** For example, in Madhya Pradesh and Odisha, Greenway Grameen scaled up the leasing of ~1,000,000 improved cookstoves through a US ~$6.5 million senior secured loan from the Asian Development Bank, enhanced by a US$ 3.25 million first-loss liquidity reserve facility from the Climate Innovation and Development Fund. The project leverages committed carbon credit revenue through SDG 13 Ventures Private Limited, which sells verified carbon units generated from the improved cookstoves to international buyers. ADB's debt financing will allow Greenway to bridge the gap between the time it takes to sell the carbon units and the general operation costs, while still subsidising the cost of the new cookstoves to rural households, thereby generating a new avenue for channelling carbon markets to finance climate change mitigation projects.[206]

## Job creation potential

**The transition to improved cooking solutions is projected to create 270,000 direct gross jobs across manufacturing and distribution over the next 5 years.** Experience from previous large-scale clean cooking deployments in Bangladesh, Indonesia, and countries across Africa reveal 0.005 jobs created per improved cookstove.[207] Applying the same learning to India presents a significant opportunity to generate employment, especially among rural and urban-poor women, who could be primarily involved in the last-mile delivery and distribution of these cooking solutions through SHGs and local networks. Since these are jobs in a completely new value chain, they classify as second-order outcomes.

## Annual economic value-add

**Implementing these clean cooking solutions can generate ~US$ 600 million in direct gross annual revenues.** This includes annual cooking solutions sales of US$ 300 million, and US$ 300 million from carbon credit earnings, based on an assumed credit price of US$ 3 per tonne of $CO_2e$, adjusted for an expected 3% loss due to migration in slum populations.[208] This strong economic potential highlights the commercial viability of clean cooking solutions for investors, manufacturers, and local enterprises. Since improved cooking solutions are a completely new value chain, the revenue produced through their sales and carbon credits is a second-order outcome.

## Co-benefits potential

**Scaling improved cooking solutions in India can avert 95 million tonnes of GHG emissions annually[209] and unlock over 600 million days of quality time for women every year.** The transition from solid fuel combustion to clean fuel hence provides strong support to national climate targets. In addition to emission reductions, each improved stove saves each woman an average of 300 hours of quality time per year across time in cooking and fuel-related activities.[210] This is time that could otherwise be spent on income generation, producing goods that otherwise would be bought, education, rest, and/or leisure. Unlocking this quality time for women not only improves well-being but allows them to invest time in income-generating activities, skill-building and more, empowering them and leading to more equitable development outcomes.

## Cost savings

**Direct annual cost savings from the transition to improved cooking solutions is negligible, as most households currently collect firewood and biomass at no additional cost.** The economic argument for improved cooking solutions must therefore be anchored in climate value, health benefits, and quality time savings[211], that can indirectly drive economic returns in reduced climate abatement efforts, saved health expenditures, and unlocking additional women-driven revenue streams.

## PM2.5 and DALYs reduction

**Transitioning ~50 million households to improved cooking solutions can reduce India's PM2.5 by 2% by 2030 and avert ~1.3 million DALYs annually.** Solid fuel for cooking is one of the highest contributors of India's PM2.5 at ~20%.[212] Improved cooking solutions, depending on the type of the cookstove, can reduce PM2.5 by 60-80%.[213] Taking into account fuel stacking behaviours and limited stickiness due to challenges in driving behaviour change, distributing improved cooking solutions to ~50 million households can reduce India's PM2.5 by ~2% by 2030. This will further drive health co-benefits, especially for women, thereby averting ~1.3 million annual DALYs[214] linked to air pollution.

***Figure 43: Case Study: Carbon credit monetisation can help finance distribution of cookstoves at a subsidised cost. (Source: ADB, 2023)***

**Case Study: ADB and Greenway partnered to distribute 10L improved cookstoves in Madhya Pradesh and UP by monetizing carbon credits**

Greenway ADB

**About the program**

- ADB has provided a **$6.5M loan to cookstove company Greenway,** with a $3.25M first-loss liquidity reserve from the Climate Innovation and Development Fund
- Households can buy improved cookstoves at **85% subsidised costs**
- Greenway will **sell carbon credits** generated to **repay the debt**

**Progress so far**

- 3.5 lakh cookstoves distributed in 12 districts of Madhya Pradesh (e.g., Seoni, Katni)
- 1.1 lakh cookstoves distributed across 7 districts of Odisha (e.g., Angul, Deogarh)

**Projected Impact**

- **10 lakh cookstoves** distributed in MP and UP, abating **22.9 million tons of CO2**

## 4. Road dust

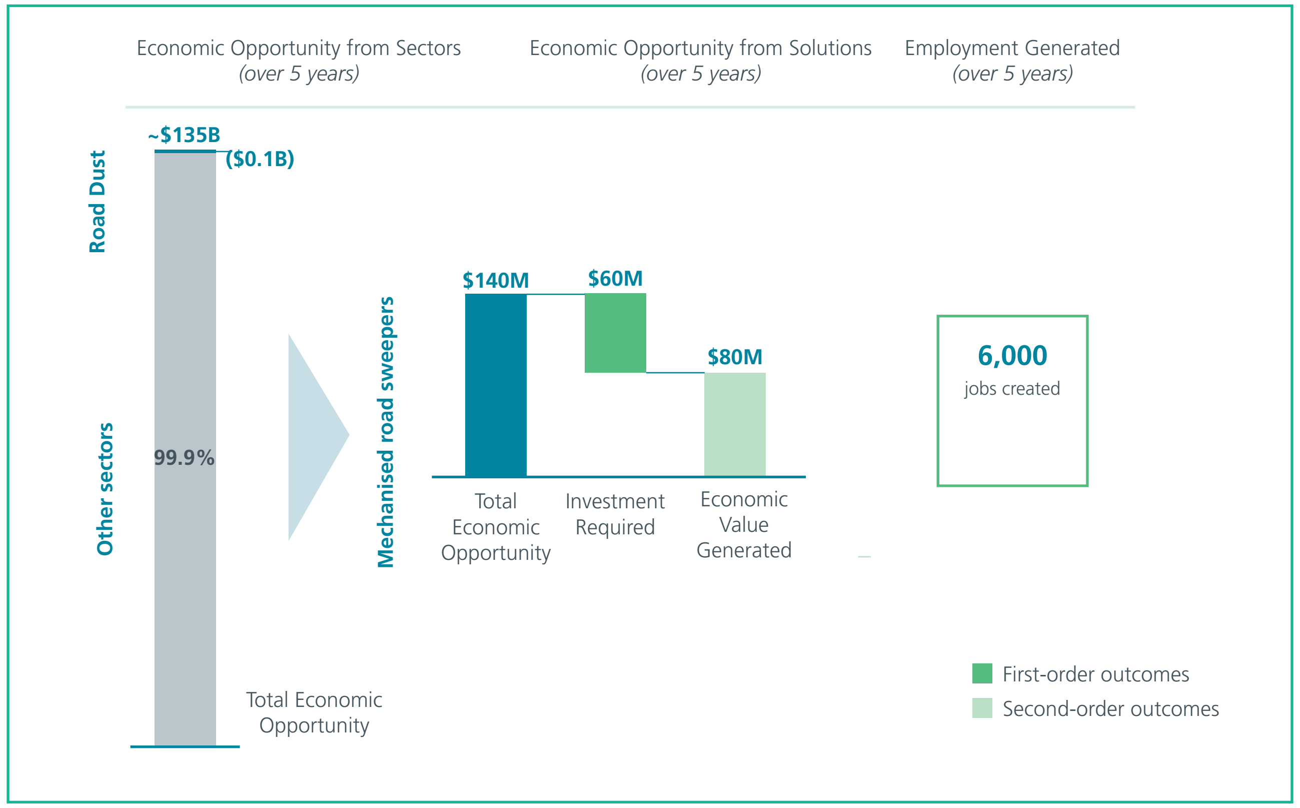
**Dust from roads is a major source of air pollution in India, driven by unpaved roads, accumulated silt, resuspension from traffic, often worsened by transboundary dust.** Construction and road dust together account for ~6% of India's PM2.5 emissions and ~27% of India's PM10 emissions,[215] rising to 30% in metropolitan areas like Delhi-NCR. Transboundary dust further contributes to the problem in cities like Delhi where dust is carried in from distant regions such as the Thar Desert and even the Middle East, especially during the summer when higher wind velocities increase long-range dust transport[216].

**Mechanised road sweepers offer the most effective tools to curb dust emissions at scale.** Unlike solutions like smog guns or afforestation that only suppress airborne dust, mechanised road sweepers (MRS) actively remove settled dust before it becomes airborne. The use of water sprinklers along with MRS can magnify the impact, with studies indicating over 90% reduction in deposited dust loads.[217]

**However, a few implementation and coordination challenges continue to limit the effectiveness of mechanised road sweepers.** High procurement costs constrain fleet expansion, with Delhi-NCR alone requiring ~400 additional units, which is an investment of around US$ 30 million.[218] Many cities also face underutilisation and weak deployment; in Bengaluru, only ~50% of procured machines are functional, while in Hyderabad, ~40% of arterial roads remain unswept.[219] Limited enforcement of road repair and construction dust norms further undermines impact, as do low utilisation rates of NCAP funds earmarked for dust control.

**Government momentum on these solutions is growing, supported by policy mandates and public investment, presenting a significant economic opportunity.** The National Clean Air Programme allocated US$ 8 million for MRS procurement in 27 cities,[220] while Delhi alone has deployed over 60 machines. This demand enables manufacturers, operators, and service providers (for sweeping, O&M, and logistics) to scale standardised, performance-linked offerings. Strengthened municipal SOPs on route planning, shift rostering, water-use protocols, and data-backed monitoring can lock in effectiveness and accountability.

*Figure 44: Road dust solutions contribute ~0.1% (~$0.1B) of the total ~$135B opportunity; mechanised road sweepers unlock ~$140M over 5 years and ~6,000 jobs.*








### Mechanised Road Sweepers

**Deploying mechanised road sweepers (MRS) across 154 Indian cities would generate a gross annual economic value addition of USD $16 million and create ~6,000 gross jobs across manufacturing and operations by 2030, while reducing PM2.5 by 1.4% by 2030 due to road dust reduction.**

India requires ~2,800 mechanised road sweepers (MRS) across NCAP and major airshed cities for effective road dust control by 2030. 94 critical airsheds in India, spanning 154 cities,[221] including all NCAP cities, cover 4.5% of India's area[222] i.e., 147,927 sq. km, with the need for MRS deployment most urgent in these cities. ~2,800 MRS, across varying road widths, are required to cover this area, with 6-8-wheeler MRS required for roads more than 60 feet wide, 4-wheeler MRS for 20-60 feet roads, and hand-drawn machines for roads less than 20 feet.

**First-order outcomes:**

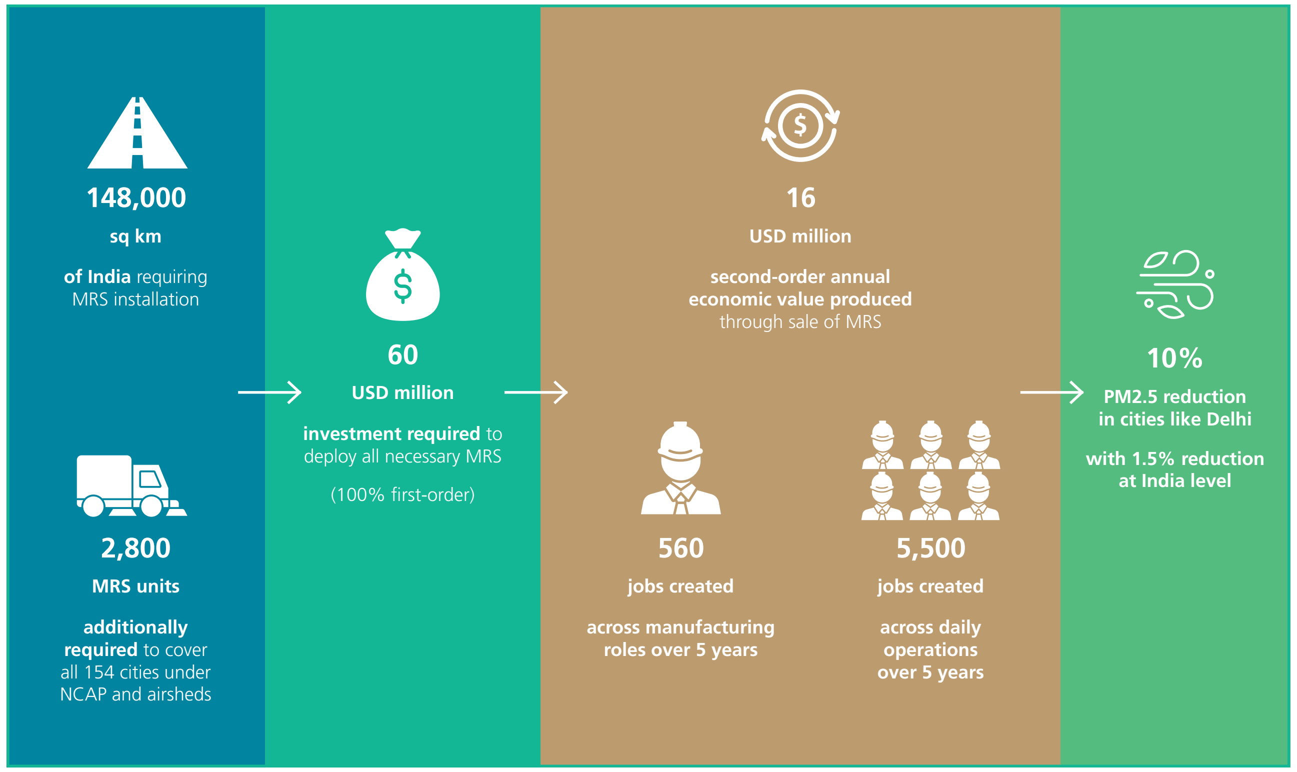
Deploying ~2800 MRS in India can generate a **first-order outcome of initial investment,** financed through government contracts. In this context, public investment is considered the only first-order outcome because MRS represents a completely new value chain: all revenues and jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

The deployment of MRS will catalyse a range of second-order impacts, including:

- **Creation of 6,000 direct gross jobs** across manufacturing and operations of MRS
- **USD 16 million** in annual economic value generated through sale of MRS to municipalities
- **Public health benefits,** i.e., reduced DALYs from lower air pollution exposure

*Figure 45: Investing $60 million in deploying MRS across India can drive significant employment, environmental, and health outcomes*




## Investment required

**Deploying these MRS will require US$ 60 million in investment over a five-year period.** The average production cost is US$ 80,000 for a six-eight-wheeler MRS, US$ 65,000 for a 4-wheeler MRS, and US$ 14,000 for a hand-drawn machine[223]. Across the ~2,800 MRS to be deployed in India, this results in a weighted average production cost of US$ 24,000 per MRS, requiring an investment of ~US$ 60 million by MRS manufacturers. This scale-up would be financed through first-order investment via government contracts involving municipalities, and will create a steady, asset-linked lending opportunity for financiers.

## Job creation potential

**The MRS roll-out can create over 6,000 gross jobs in manufacturing and operations by 2030.** MRS operations can create significant employment of ~5,500 jobs with each MRS expected to create 2 operations jobs, across a driver and co-driver cum operator.[224] Additionally, each MRS creates 0.2 manufacturing jobs.[225] Cumulatively, these ~6,000 jobs enable cleaner streets while supporting local employment. Since these are new jobs that would be created in the ecosystem, they classify as second-order outcomes.

## Annual economic value-add

**MRS operators can generate ~US$ 16 million in direct gross annual economic revenues by 2030.** With an average profit margin of 20%, the average purchasing cost of an MRS is ~US$ 28,000. With ~2,800 MRS sold across the next 5 years, MRS operators can generate US$ 16 million annually from the sale of MRS to municipalities. Since MRS would be a newly deployed solution, the revenues accrued from their sale would count as second-order outcomes.





**There are 2 ways in which MRS models can be operationalised: 1. Where the government purchases and the municipal corporations operate these MRS, and 2. Where outsourced models to MRS contractors are deployed instead of capital outlay to ease the financing burden.**

Instead of upfront capital investment by municipalities, MRS contracts can be outsourced to private vendors who procure and operate the machines, recovering costs through long-term operational contracts. Indore has successfully adopted this model by contracting MRS procurement and operations to the International Waste Management Company for US$ 8,200 per month per machine, reducing respirable suspended particulate matter by almost half from 2014 to 2017. Such a model could replace the upfront US$ 29 million required by the Municipal Corporation of Delhi with an annual outlay of US$ 5 million.

*Figure 46: Case Study: Indore Municipal Corporation (IMC) subcontracting MRS*

**Case Study: Indore improved air quality levels by subcontracting MRS operations**

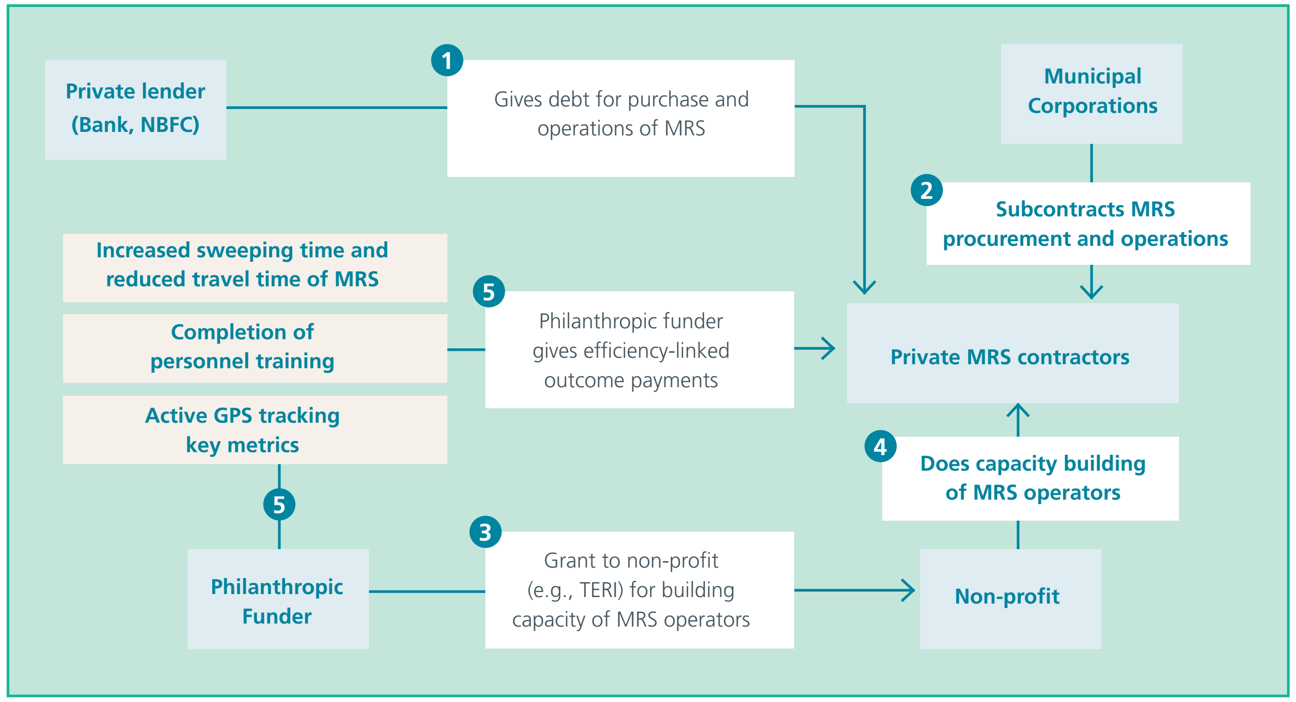
In 2016, **IMC issued a contract to International Waste Management (IWC),** a company from Kuwait, to outsource MRS procurement and operations.

The IMC got their service at a **competitive price of Rs 7 lakhs per month per machine,** with IWC then using 12 high-quality Elgin MRS for **sweeping 450-500 km per day.**

Due to MRS, the respirable suspended particulate matter (RSPM) **reduced from 142 ug/m³ in 2014 to 76 ug/m³ in 2017.**

**Additional economic value can be generated by incentivising MRS operators with efficiency-linked payments from results-based funders.** Results-based financing can be layered onto outsourced models to drive efficiency of MRS operations. by layering results-based financing to drive efficiency of MRS operations. For example, a philanthropic funder contracts a nonprofit to strengthen MRS operators and ties disbursements to verified results. The funder releases outcome payments when pre-agreed indicators are met—e.g., training completion rates, increases in sweeping coverage, and active GPS tracking—rather than paying upfront inputs. Alternatively, government contracts with MRS vendors can be performance-linked, with disbursement of funds on achievement on pre-determined targets.

*Figure 47: Outcome-linked payments can drive efficiency of MRS operations*




## PM2.5 and DALYs reduction

**Deploying these MRS can reduce India's PM2.5 by ~1.5% by 2030 by collecting road dust, subsequently averting over ~800,000 DALYs annually.** Road dust contributes to ~3% of India's PM2.5, largely driven by urban cities, captured under NCAP and India's key airsheds.

With ~45% PM2.5 reduction efficiency, deploying MRS across the 154 cities can reduce India's PM2.5 by ~1.5%. Improvement in air quality can drive health benefits and avert ~800,0000 DALYs[226] attributable to air pollution in India.

# Pathway C

**Includes solutions that are imperative but do not generate substantiate economic value:** These solutions are essential for ensuring industries meet environmental standards, but unlike other solutions, they do not lead to any additional value generation. Their primary contribution is in safeguarding health and ensuring regulatory compliance.

## 1. Power

**Thermal power plants are a major contributor to air pollution in India, driven by the release of SO2 emissions.** Thermal power plants contribute to ~3% of air pollution in India,[227] with the contribution as high as 8% in Delhi-NCR.[228] In 2022, India emitted 11.2 million tonnes of $SO_2$, making it the largest in the world and accounting for over 20% of the world's anthropogenic emissions. This is primarily due to India's heavy reliance on coal for electricity generation, with five of the top ten $SO_2$ emission hotspots from coal and power generation located in India.[229] $SO_2$ is a critical precursor to PM 2.5 formation, contributing significantly to air pollution. $SO_2$ reacts with meteorological factors like sunlight and humidity, converting into fine particulate matter.





**Globally, Flue Gas Desulphurisation (FGD) has emerged as a commercially viable and scalable technology to curb $SO_2$ emissions from thermal power plants**. Several countries have successfully deployed FGD, a technology that removes $SO_2$ from flue gases, thereby curbing SO2 emissions from power plants. China adopted FGD in the 2000s, achieving ~95% $SO_2$ reduction post-installation. Despite China's coal consumption being ~5 times higher than India's, its SO2 emissions are ~12% lower than India's, due to an FGD penetration rate of over 90%.[230] Even countries like the US, Indonesia, and Poland, have realised a ~92-95% $SO_2$ reduction post-FGD installation.[231]

**Recognising this, India has strict emission standards in place, requiring FGD installation across thermal power plants.**[232] The Ministry of Environment, Forest and Climate Change (MoEFCC) introduced strict emission norms for coal-fired plants in 2015. The norms vary by plant age, with the most stringent limit of 30 mg/Nm³ PM 2.5, 100 mg/Nm³ SO2, and 100 mg/Nm³ NOx for units installed on or after January 1, 2017.[233] For compliance with SO2 emission norms, thermal power plants of categories A and B across India have been mandated to install FGD. The deadlines for compliance have been staggered with plants in densely populated or highly polluted areas (Category A) to comply by December 2027 and those in critically polluted or non-attainment cities (Category B) by December 2028. All others (Category C) have been exempted from installing FGD as per a revised notification by MoEFCC in July 2025.[234]

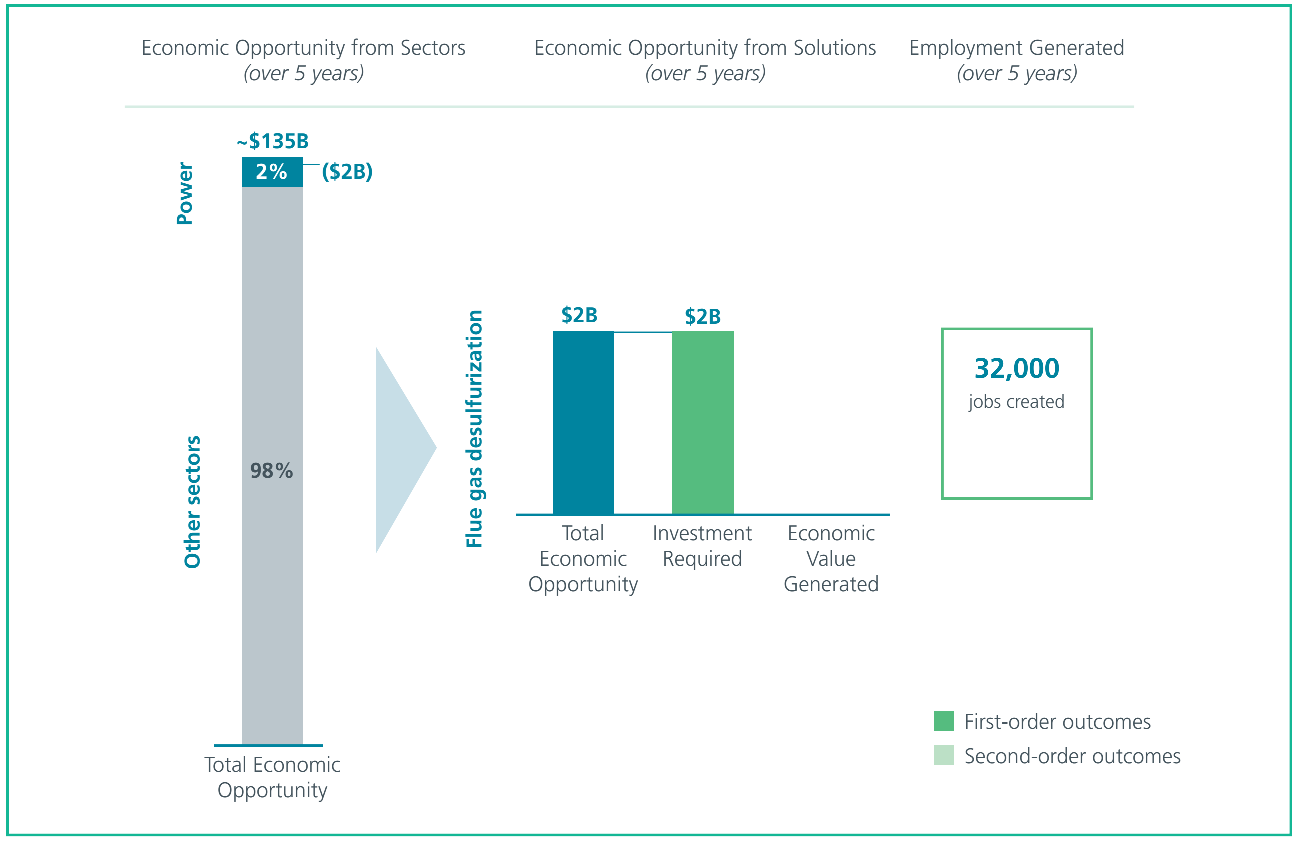
*Figure 48: Emission norms for thermal power plants in India*

| Date of installation | PM | SO2 | NOX |
|---|---|---|---|
| Before 31 Dec 2003 | 100 mg/Nm3 | 600 mg/Nm3 for <500 MW<br>200 mg/Nm3 for >=500 MW | 600 mg/Nm3 |
| After 1 Apr 2004 & upto 31 Dec 2016 | 50 mg/Nm3 | 600 mg/Nm3 for <500 MW<br>200 mg/Nm3 for >=500 MW | 300 mg/Nm3 |
| **On or after 1 Jan 2017** | **30 mg/Nm3** | **100 mg/Nm3** | **100 mg/Nm3** |

**However, a few operational and implementation challenges may slow the large-scale roll-out of FGD systems across thermal power plants.** India's domestic vendor capacity can support only ~16–20 GW of installations annually, against more than 180 GW still pending, creating a significant execution gap.[235] Simultaneous tenders for ~200 GW of capacity are straining engineering and procurement bandwidth, while long installation timelines of 36–44 months delay tangible emission reductions.[236] Repeated deadline extensions have also reduced momentum, and the higher energy and water intensity of FGD systems could partly offset environmental gains through increased auxiliary power use and $CO_2$ emissions.

**These challenges also present a significant economic opportunity to strengthen India's clean power value chain.** Expanding domestic FGD manufacturing, localising component supply, and mobilising concessional finance can unlock new investment and job creation across engineering, construction, and maintenance services. Over time, this can transform compliance-driven retrofits into a growth industry, enhancing energy security, improving air quality, and positioning India as a global hub for clean power technologies.

*Figure 49: Installing FGDs to combat PM2.5 emissions in the power sector can create 2% ($2B) of total economic opportunity*




## Flue Gas Desulphurisation

**Installing FGDs across thermal power plants (TPPs) presents an investment opportunity of ~US$ 2 billion across the next 5 years, and can create over 32,000 direct gross jobs by 2030, while reducing India's PM2.5 emissions by 0.4% over the 5-year-period.**

**There is a need to install FGDs in >70 TPP units across Category A and B plants in India by 2030 where neither installation nor bids have been awarded.** Out of 44,600 MW (megawatts) of capacity across Category A and Category B plants that require FGD installation, only ~8,200 MW have installed FGDs, and ~16,000 MW have been awarded bids. This leaves a clear implementation gap of ~20,000 MW, spanning ~70 TPP units.[237]

### First-order outcomes:

Installing FGDs across thermal power plants (TPPs) can generate a **first-order outcome of initial investment,** financed by TPP operators. Currently, while the government has mandated the installation of FGDs in TPPs, it does not provide any financial incentive or support to do so.

### Second-order multiplier outcomes:

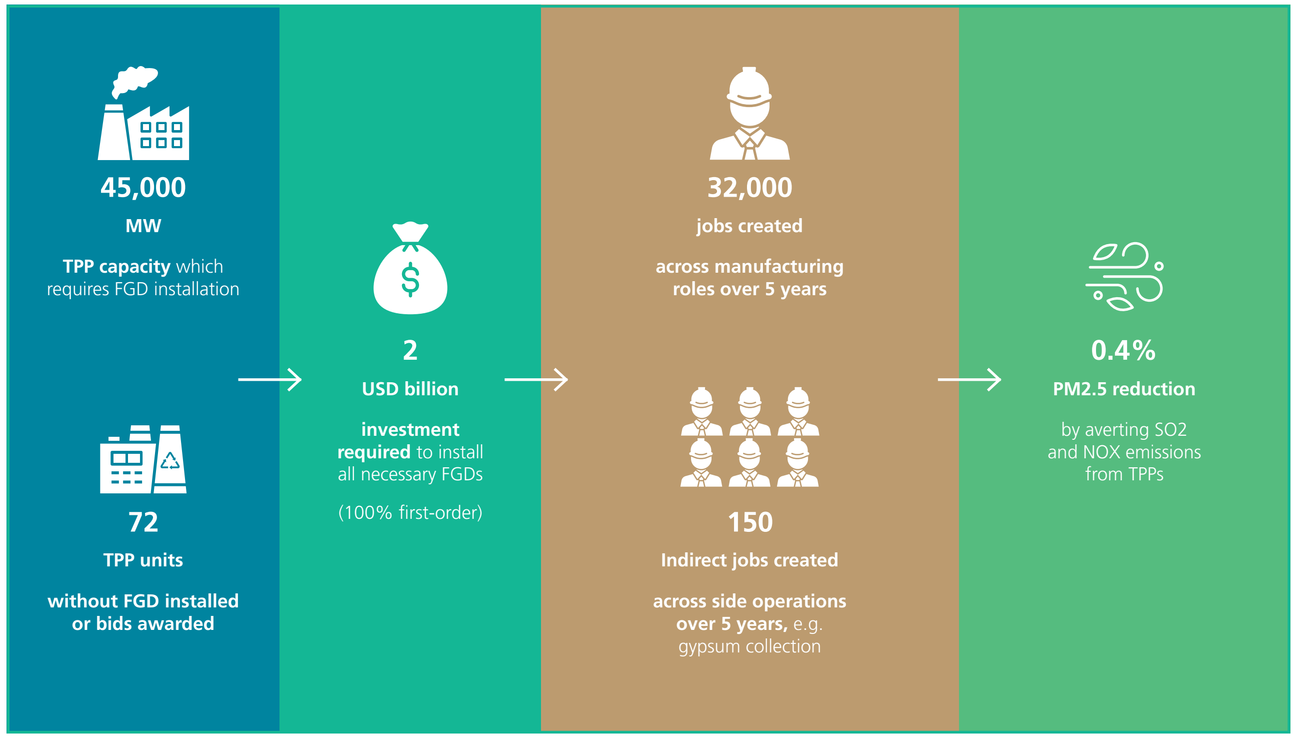
The installation of FGDs will catalyse a range of second-order impacts, including:

- **Creation of 32,000 direct gross jobs** across manufacturing and installation of FGDs
- **Public health benefits,** i.e., reduced DALYs from lower air pollution exposure





*Figure 50: Investing $2 billion in installing FGDs to meet government mandates can drive significant employment, environmental and health outcomes*

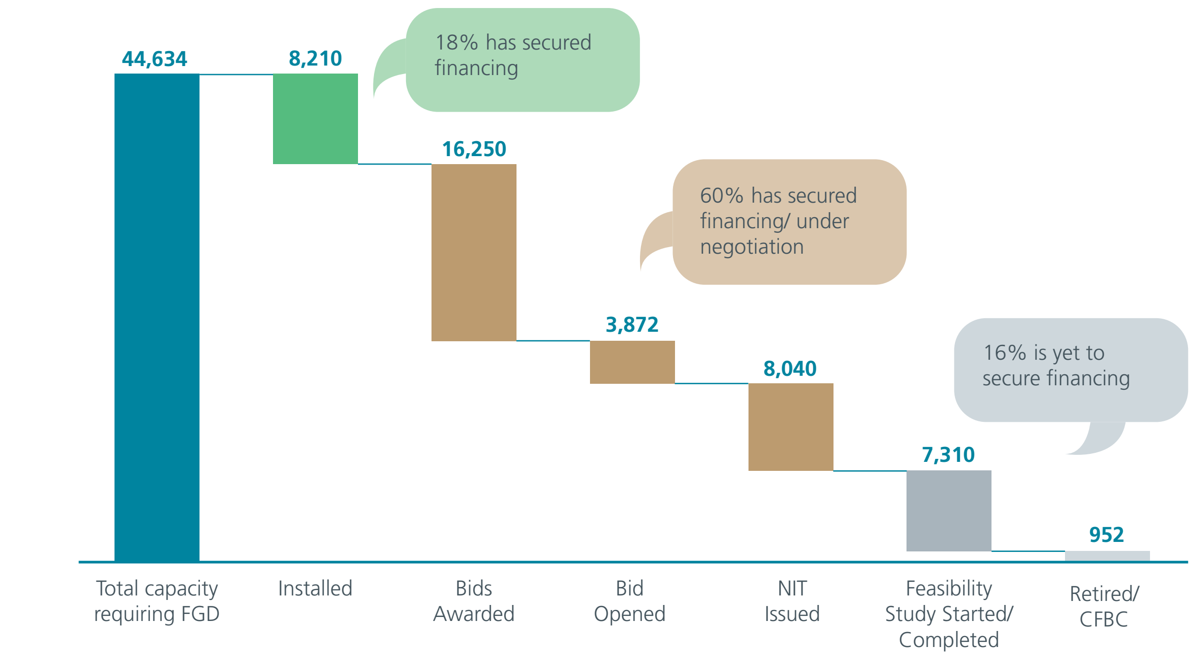



## Investment required

Installing FGDs in the remaining TPP capacity requires a capital investment of US$ 2 billion by 2030. The average cost of FGD installation is estimated at ~US$ 94,000 per MW, driven higher by inflation in recent years.[238] Since the government does not provide any financial incentive for FGD installation, this is a first-order investment borne entirely by the TPP operators. While this is a significant investment by TPP operators, the cost can be recovered through regulated electricity tariff adjustments. Power producers can factor the FGD capital and operational costs into their tariff petitions under CERC or state regulators, allowing pass-through of these expenses to consumers within the regulated tariff framework.[239] This pass-through mechanism ensures that FGD installation does not result in a profit or loss for operators while delivering meaningful air quality improvements.

**While FGD installation requires a significant capital outlay, access to finance is not the key barrier.** FGD installation is expensive, with costs increasing more than double in the last decade. However, access to finance is not the core challenge, as ~20% of TPP capacity mandated with FGDs have already secured financing and installed FGDs, and ~60% in bid awarded, bid opened, and tender specification made stages, indicating financing has likely been secured or under negotiation. Thermal power plant players like CLP and NTPC have demonstrated the financial viability of FGD through syndicated and consortium loans. For instance, CLP's Jhajjar power plant raised $460M from a banking consortium of 15 banks, while NTPC secured $750M in syndicated loans from Japanese banks for its pan-India FGD rollout.

*Figure 51: Status of financing for FGD across thermal power plants in India by capacity (MW)*




Source: Inputs from NTPC and CEA

## Job creation potential

**Deploying FGDs across the required TPPs can generate over 32,000 direct gross jobs in manufacturing and installation over a 5-year-period.** Infrastructure investment can create ~2 direct jobs per US$ 120,000 spent.[240] In addition, each operational FGD unit is expected to generate two permanent jobs in O&M roles across gypsum handling and system monitoring. These are second-order outcomes, since the installation and operation of FGDs is a newly deployed solution, and does not replace an existing solution.

## PM2.5 and DALYs reduction

**These TPPs can reduce India's PM2.5 by ~0.4% by 2030 and thereby avert ~230,000 DALYs annually.** Thermal power plants directly contribute to ~3% of India's PM2.5. Installing FGDs, which have ~60% PM2.5 reduction efficiency, in Category A and Category B power plants (~20% of total TPP capacity without FGDs) can reduce India's PM2.5 by ~0.4%. This can further yield health benefits and avert ~230,0000 annual DALYs[241] attributable to air pollution in India.

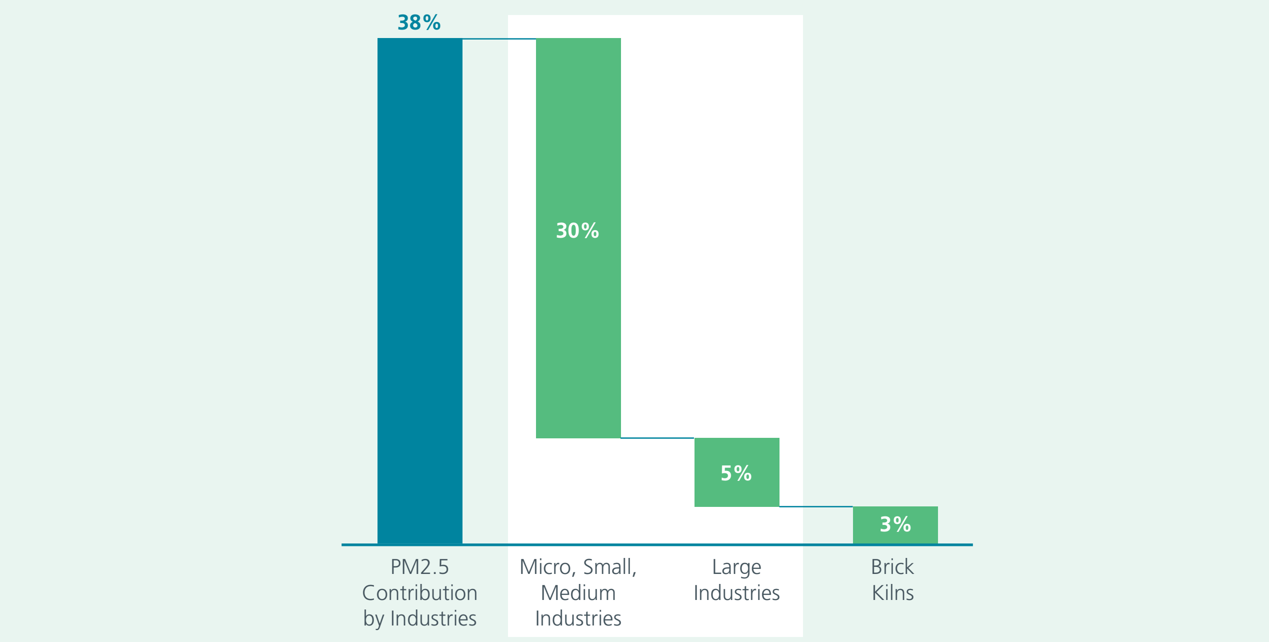




# 2. Industry: Large industries and MSMEs

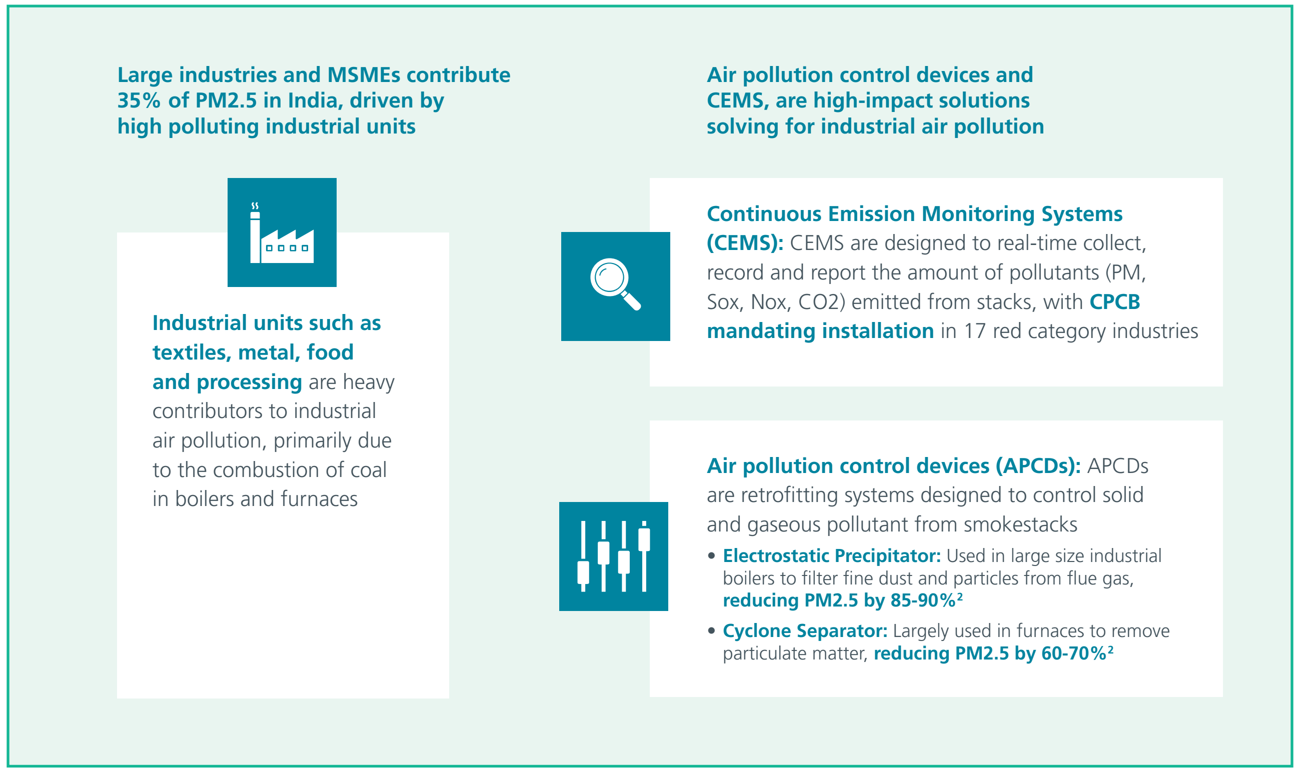
**Industries are the largest contributors of air pollution in India.** Industries contribute to 38% of PM2.5 in India,[242] with the number as high as ~48% in regions like Delhi-NCR.[243] Micro, small, and medium industries contribute around 30%, with emissions from outdated combustion equipment, low-quality fuels, and poor pollution controls across sectors like foundries, stone crushers, and chemical processing. Large industries such as cement and steel add another 5% through energy-intensive operations like clinker production and blast furnaces, which release concentrated PM2.5, $SO_2$, and $NO_x$.

*Figure 52: Contribution of different types of industries to India's PM2.5*




**A suite of pollution control technologies and cleaner production options is already shaping India's industrial emissions landscape.** Industries can deploy air pollution control devices such as flue gas desulphurisers for $SO_2$, electrostatic precipitators and cyclone separators for particulate matter capture, and selective catalytic reduction systems for $NO_x$ reduction. Additionally, energy efficiency upgrades, including waste heat recovery systems, process optimisation, and fuel switching to cleaner alternatives like natural gas, are potential measures for high-emitting industries. Green hydrogen is also gaining momentum, particularly in hard-to-abate sectors like steel and cement, offering reductions in both carbon dioxide and air pollutants when replacing coal or pet coke. Alongside pollution control measures, real-time monitoring tools like Continuous Emissions Monitoring Systems (CEMS) can be deployed to support regulatory enforcement efforts.

*Figure 53: Solutions for industrial air pollution*




**Large industries must ensure compliance with pollution control mandates, including installation of real-time emissions monitoring through CEMS and operations of APCDs.** As per Central Pollution Control Board (CPCB) and MoEFCC regulations, units in the 17 high-polluting industry categories are required to install Continuous Emissions Monitoring Systems (CEMS)[244] and report emissions data regularly. Additionally, while many large industries already have APCDs in place to meet emission norms, their maintenance and operations remain a challenge.

**Smaller industries need to adopt pollution control devices, given their outsized role in industrial emissions.** With micro, small, and medium industries contributing to ~80% of industrial air pollution, there is a need to install APCDs such as cyclone separators and bag filters, especially in high polluting sectors such as textiles, food processing, and chemicals. These units, due to their fragmented structure, often lack pollution control systems, leading to high concentrations of particulate emissions.

**Adopting a "CEMS and APCD as-a-service" model can address key barriers to compliance and enable scalable implementation across industries.** Many industrial units, especially smaller players, face challenges related to high upfront capital costs, technical expertise, and ongoing maintenance for APCDs and CEMS. A service-based model allows industries to subscribe to bundled packages for CEMS and APCDs, avoiding capex and gaining dedicated compliance support. Empanelled service providers can supply, install, and operate these systems, while offering end-to-end services including maintenance and reporting. The government can play a catalytic role by defining emission norms, auditing service providers, and operating a centralised compliance platform. This model shifts the burden of implementation away from fragmented industries and toward specialised service providers, enabling faster and more reliable deployment of air pollution solutions at scale.

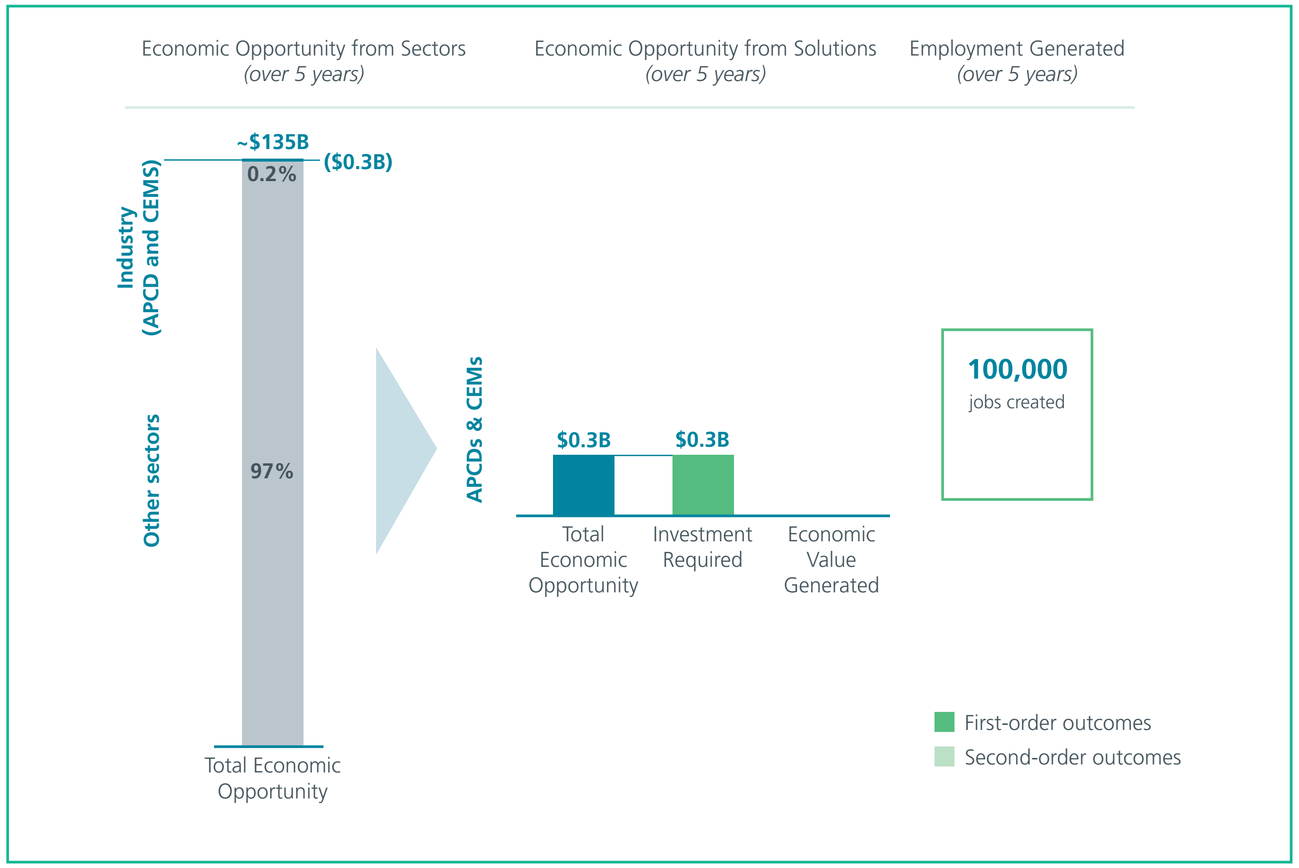
**However, a few systemic challenges could continue to slow widespread adoption of APCDs and CEMS.** High upfront costs and limited financing options constrain smaller industries, particularly those unable to pass on compliance costs in competitive markets. The absence of sector-specific emission benchmarks makes regulations less tailored, often placing a heavier burden on SMEs. Operational challenges such as irregular maintenance and 20–30% downtime reduce system effectiveness, while fragmented technology standards across CEMS vendors hinder data integration and real-time oversight by regulators.[245]





**Nonetheless, these barriers also create an opportunity to reimagine industrial pollution control as a scalable service ecosystem.** Standardising technology benchmarks, expanding concessional finance, and enabling third-party compliance providers can overcome cost and capacity gaps, and returns will accrue through improved regulatory certainty, operational efficiency, and reputational gains as industries align with global environmental standards, thus unlocking the economic opportunities of the sector.

*Figure 54: Solutions combatting PM2.5 production in the large and MSME industry sector contribute 0.2% ($0.3B) to the total economic opportunity, distributed across APCDs and CEMS*




## Air Pollution Control Devices (APCDs) and CEMS in industries

**Deploying APCDs in small industrial boilers and CEMS in high-polluting industrial units can generate an annual investment opportunity of US$ 300 million and create ~100,000 gross jobs by 2030, while reducing India's PM 2.5 by ~2.5% over the next 5 years.**

**Effective industrial air pollution control hinges on wide-scale deployment of APCDs across 50,000 small boilers and CEMS across 700 high-emission units by 2030.** While most large industries have installed APCDs, India has ~50,000 small industrial boilers requiring APCDs such as cyclone separators or bag filters.[246] APCDs are required in other small-to-medium industries, which make up the bulk of industrial air pollution. However, on-ground deployment remains a challenge due to the high fragmentation of industrial units, with APCDs in small industrial boilers offering an effective solution in the short-term as they tend to be in clusters. In parallel, only ~3,500 of the 4,200+ high-polluting industrial units mandated to install CEMS have complied, leaving 700+ units where real-time monitoring is a gap.[247]

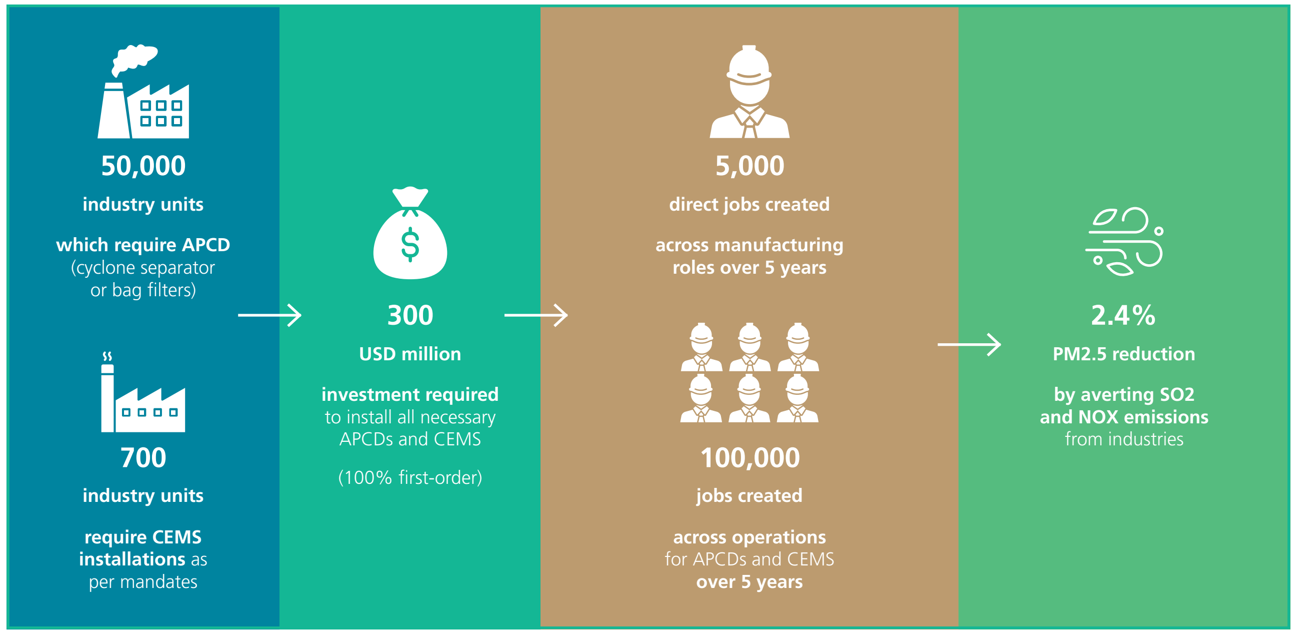
**First-order outcomes:**

The wide-scale deployment of APCDs across 50,000 small boilers and CEMS across 700 high-emission units by 2030 can generate a **first-order outcome of catalytic investment,** enabled through private capital by owners of these industries. In this context, this initial investment is considered the only first-order outcome because APCDs and CEMS are new solutions which will be deployed; jobs created are incremental and therefore classified as **second-order outcomes.**

**Second-order multiplier outcomes:**

The deployment of APCD and CEMS will create **nearly 100,000 gross new jobs,** across manufacturing and operations. It will also lead to health benefits (reduced DALYs) due to decreased exposure of the population to air pollution.

***Figure 55: Investing $300 million in APCD and CEMS installation in required industry units can unlock significant employment, PM2.5 abatement, and health benefits***




## Investment required

**Scaling coverage of APCDs and CEMS in prioritised industrial units requires US$ 300 million across the next 5 years.** Installing APCDs across the 50,000 smaller units will cost US$ 300 million, with average cost of a cyclone separator and bag filter being US$ 6,000.[248] An additional US$ 3.3 million is needed to install CEMS in the 700+ large units yet to comply with the CPCB mandate, with each CEMS installation costing US$ 4,700.[249] This entire investment would come from initial capital financed by industry-owners and operators, and would quantify as first-order investment (currently, no government support exists to deploy APCD and CEMS). By enabling financial access to industries for installation of such devices, they can unlock a significant economic opportunity through interest revenue streams.

## Job creation potential

**These solutions can create over 100,000 gross jobs across manufacturing, installation, and operations by 2030.** Infrastructure investments are expected to generate ~2 jobs per US$ 118,000 spent.[250] In addition, each APCD and CEMS system are expected to create ~ 2 permanent operations jobs.[251] Combined, the APCD and CEMS deployment could generate ~100,000 direct gross jobs, all of which would count as second-order outcomes, offering a scalable employment boost in cleaner manufacturing and pollution control services.





## PM2.5 and DALYs reduction

**The installation of APCDs in 50,000 industrial boilers can reduce India's PM2.5 by ~2.5% by 2030, leading to a reduction of ~1.5 million DALYs annually.** Micro, small, and medium industries are the largest contributors of India's PM2.5 at 30%, with 3% coming from ~50,000 small industrial boilers. Installing APCDs, which have ~70% PM2.5 reduction efficiency, across all these boilers can reduce India's PM2.5 by ~2.5% by 2030. This improved air quality will yield improved health benefits by averting ~1.5 million DALYs[252] annually attributable to air pollution.

***Figure 56: EPIC India's Use of CEMS to Enable Market-based Pollution Control***

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**EPIC's Use of CEMS to Enable Market-Based Pollution Control**

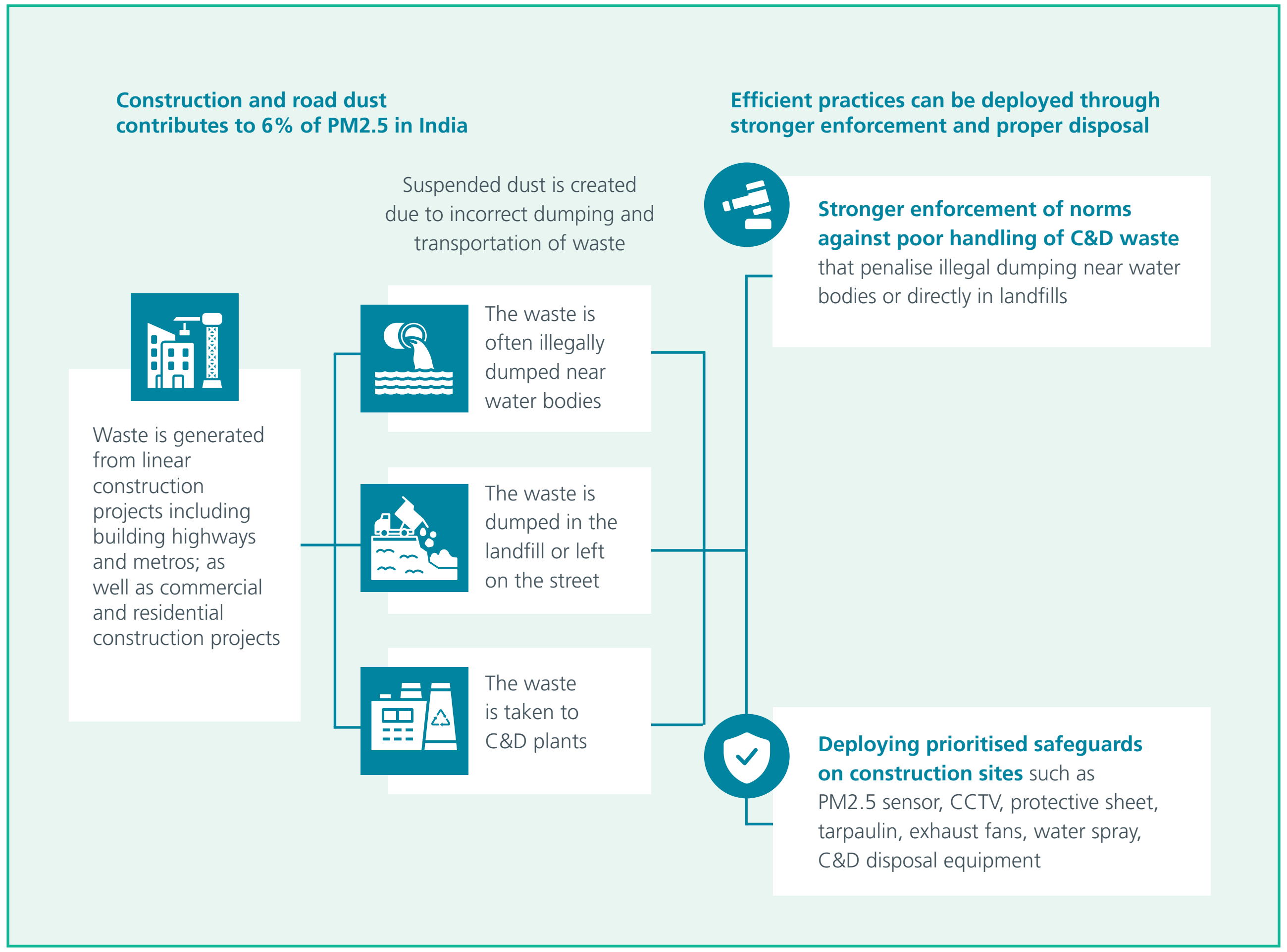
EPIC India and J-PAL South Asia leveraged **Continuous Emission Monitoring Systems (CEMS)** to operationalise India's first **Emission Trading Scheme (ETS)** in Surat. CEMS enabled **real-time, transparent tracking of industrial emissions,** creating a data foundation for market-based regulation. Installed across **150 textile units,** the system achieved **95% data availability** and allowed regulators to verify compliance continuously. This digital backbone proved **that continuous monitoring can make emissions trading credible, enforceable, and scalable,** paving the way for wider adoption across states.

## 3. Construction

**Dust from construction is a major source of air pollution in India, largely attributable to poor handling of construction and demolition (C&D) waste.** Construction and road dust together account for ~6% of India's PM2.5 emissions and ~27% of India's PM10 emissions,[253] rising to 30% in metropolitan areas like Delhi-NCR. C&D waste adds another 8%,[254] as debris left in open roadside piles releases PM2.5 into the air. Lack of construction safeguards, such as screens, tarpaulins, and water sprays, further aggravate dust emissions from construction sites.

**A suite of construction safeguards can substantially curb these emissions at scale.** C&D waste management, tarpaulin covers, PM2.5 sensors, CCTV cameras, and sprinklers reduce on-site dust emissions and are essential for preventing fugitive dust from entering public spaces. However, the effectiveness of these solutions is contingent on robust government support, including strict enforcement of dust control norms, timely pothole repairs to prevent dust accumulation, and the establishment of secondary collection points for C&D waste.

***Figure 57: C&D disposal and safeguards, and stronger enforcement can abate air pollution from construction dust***



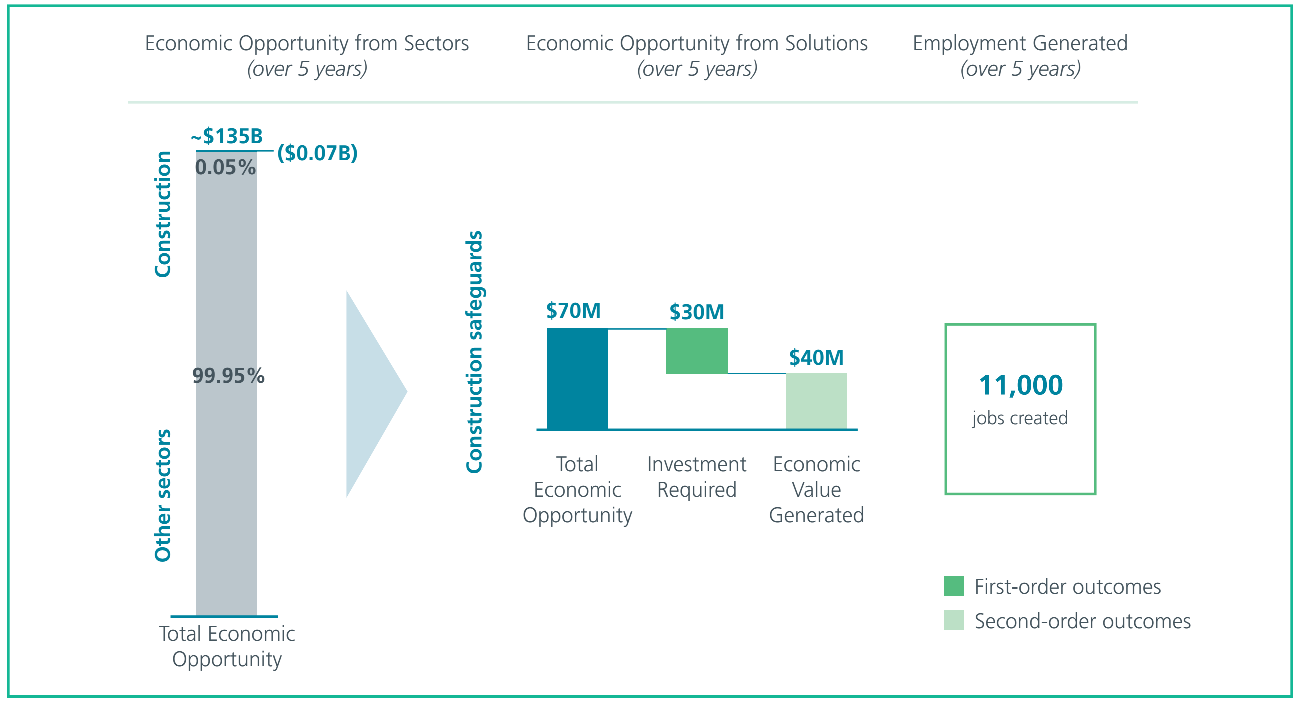





**However, construction air quality safeguards face barriers related to cost, compliance, and on-ground coordination.** Smaller contractors often struggle with the cost of installing and maintaining safeguards such as anti-smog guns and air filtration systems, while overlapping regulatory requirements across agencies create administrative complexity. Technical gaps such as improper installation of barriers or inadequate inspection reduce overall effectiveness. Weak coordination among contractors, regulators, and local bodies further limits consistent compliance and enforcement across sites.

**Government momentum on construction safeguards is growing, supported by policy mandates and public investment, presenting a significant economic opportunity.** In Delhi, pollution control committees have mandated 27 guidelines for dust control measures at construction sites, requiring safeguards such as proper C&D disposal, PM2.5 sensors, CCTV cameras, protective sheets, tarpaulins, exhaust fans, water sprays.[255] The regulatory momentum creates opportunity across the value chain, for manufacturers of equipment as well as contractors offering C&D services. The Gujarat Pollution Control Board (GPCB) too mandates SOPs for dust control at construction sites, requiring site barricading, water sprinkling, covered material transport, paved internal roads, and ambient air quality monitoring,[256] while the Maharashtra Pollution Control Board (MPCB) requires 35-ft metal barricades for sites above one acre, anti-smog guns for sites over 20,000 sqm, enclosure with green cloth or tarpaulin, water fogging during handling, and CCTV and air-quality sensors at work sites.[257]

***Figure 58: Construction safeguards combatting PM2.5 production in the construction sector contribute 0.05% ($0.07B) to the total economic opportunity***




## Construction Safeguards

**Scaling construction safeguards across 154 cities can unlock a gross annual economic value of ~US$ 7.5 million and create nearly 11,000 gross jobs across manufacturing and site operations over 5 years, while reducing PM2.5 by 2.5% in urban areas from construction dust by 2030.** India requires construction safeguards in ~5,500 construction sites in 154 cities across NCAP cities and major airshed cities by 2030. 154 cities, including all NCAP cities, across 94 critical airsheds in India have ~5,000 construction sites, greater than 500 sq. metre.[258] Based on pollution control committee guidelines for construction sites in major cities like Delhi, each site requires a set of construction safeguards, including a PM2.5 sensor, 4 CCTV cameras, 1 protective sheet i.e., green net scaffolding, an enclosed space creation comprising tarpaulins, exhaust fans, and water sprays and proper C&D disposal.

**First-order outcomes:**

Scaling construction safeguards across 154 cities in India can generate a **first-order outcome of initial investment,** financed privately by construction-site owners.

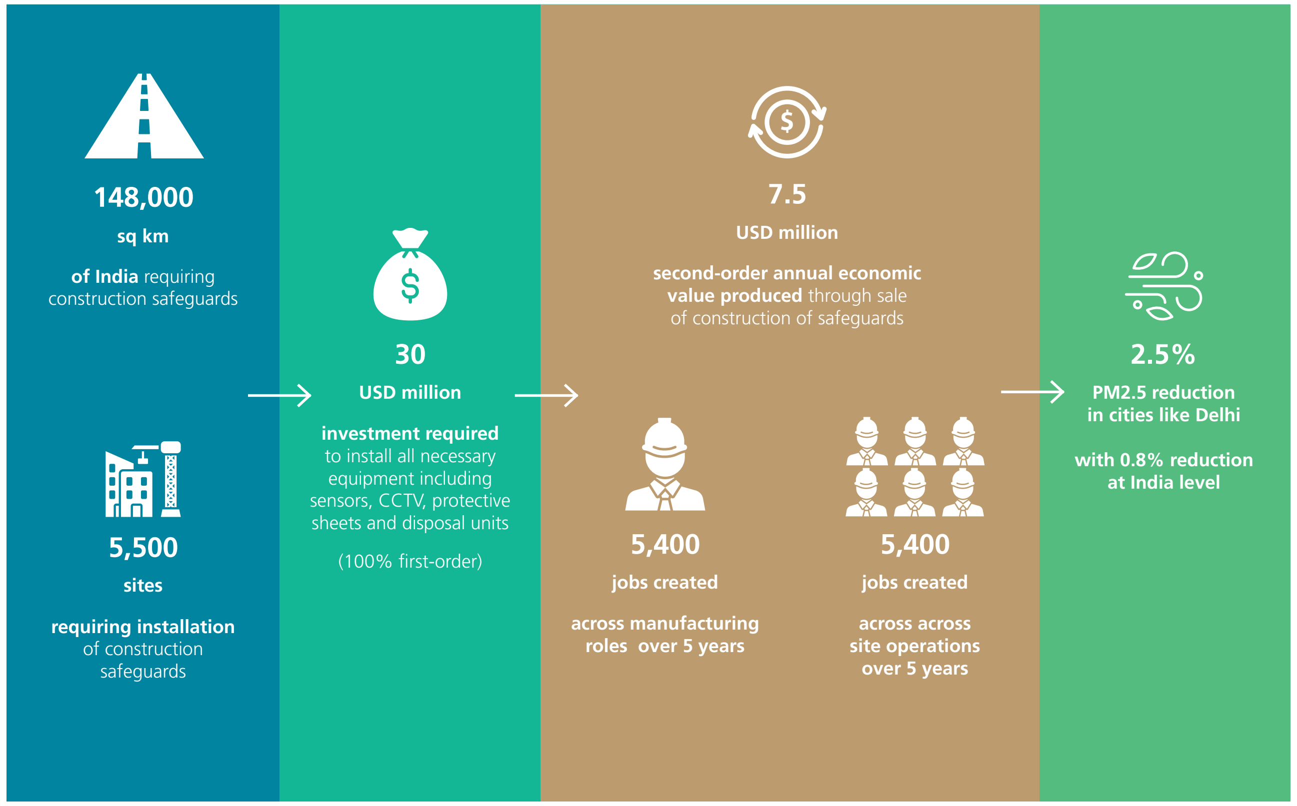
Construct safeguards do not create new value chains or incremental revenue to business models apart from the revenue from the sale of these instruments, hence this revenue is categorised as a first-order outcome.

**Second-order multiplier outcomes:**

The deployment of construction safeguards will catalyse a range of second-order impacts, including:

- **Creation of 11,000 direct gross jobs** across manufacturing and operations of construction safeguards
- **Public health benefits,** i.e., reduced DALYs from lower air pollution exposure

***Figure 59: Investing $30 million in installing construction safeguards across 154 sites in India can unlock 11,000 jobs and avert 0.8% PM2.5 emitted***




## Investment required

**Nationwide enforcement of these construction safeguards requires an investment of ~US$ 30 million over 5 years.** The average cost of production of construction safeguards for one construction site is ~US$ 6,000, with the cost of production of a PM2.5 sensor US$ 1,000, US$ 650 for one CCTV camera, US$ 235 per protective sheet, US$ 470 per enclosed space creation, and US$ 1500 for C&D disposal.[259] Deploying these safeguards across ~5,500 construction sites requires an investment of ~US$ 30 million by construction safeguard manufacturers. Financing this rollout offers lenders a short-cycle, repeat-order market tied to regulatory compliance, ensuring consistent demand and repayment potential. Since there is no financial support from the government for the deployment of these safeguards, the capital for this comes entirely from private sources i.e., construction-site owners and operators. Therefore, this is considered a first-order investment.





## Job creation potential

**The roll-out of safeguards can create nearly ~11,000 gross jobs across manufacturing and site operations across a 5-year-period.** Each construction site is expected to support 0.125 construction jobs per safeguard, averaged across all the components. An additional 1 job for safeguard operation is further created.[260] This offers a pathway to formal employment within the construction ecosystem, while improving urban health outcomes. Since these construction safeguards are new deployments, they lead to the second-order outcome of gross job creation.

## Annual economic value-add

**Construction safeguards can generate ~USD $7.5 million in direct gross annual economic value.** Each construction site can drive ~USD $7,000 in revenue for construction safeguard manufacturers. Deploying these safeguards in ~5,500 construction sites over the next 5 years can generate ~US$ 7.5 million in annual economic value. Indirect value can further be unlocked through reduced regulatory non-compliance delays, improved public perception, and smoother project delivery. However, these revenue streams stem from a response to compliance and monitoring demand and thus represent first-order economic outcomes.

## PM2.5 and DALYs reduction

**Ensuring deployment of the construction safeguards can reduce India's PM2.5 by ~0.8% by 2030 through minimisation of emissions from construction activities and thereby avert ~450,000 DALYs annually.** Construction activities contribute to ~3% of India's PM2.5, largely driven by urban cities, captured under NCAP and India's key airsheds. Deploying construction safeguards across the 154 cities can reduce India's PM2.5 by ~0.8%. Improvement in air quality can drive health benefits and avert ~450,0000 DALYs[261] attributable to air pollution in India.

***Figure 60: Hyderabad's decentralised C&D waste recycling network[262]***

**Hyderabad's Decentralised C&D Waste Recycling Model**

Hyderabad has demonstrated the feasibility of **decentralised C&D waste recycling** at scale. The **Greater Hyderabad Municipal Corporation (GHMC)** operates **four plants** at Jeedimetla, Fathullaguda, Shamshabad, and Thumakunta with a **total capacity of 2,250 TPD,** forming southern India's largest C&D recycling network. This system cuts transport distances, fuel use, and tipping fees while reducing dust and emissions. As of **September 2024,** over **2.9 million tonnes** of waste had been collected, with **26%** recycled into usable materials. By integrating informal workers and introducing **QR-based vehicle tracking,** GHMC has created a scalable, **transparent model** for cleaner, circular urban growth.

## 4. Monitoring

**Air quality monitoring plays a foundational role in understanding and managing India's air pollution crisis, with the country having laid down solid institutional infrastructure.** The Central Pollution Control Board (CPCB) has issued comprehensive guidelines for setting up Continuous Ambient Air Quality Monitoring Systems (CAAQMS) in India, covering the selection of monitoring locations, approved sensor technologies, calibration methods, data reporting standards, and compliance requirements. Over 450 Continuous Ambient Air Quality Monitoring System (CAAQMS) and 800+ manual stations operate under CPCB's National Air Quality Monitoring Program (NAMP) and State Pollution Control Boards (SPCBs), covering more than 300 cities, towns and villages.[263] This institutional network captures key pollutants including PM 2.5. PM 10, $NO_2$, $SO_2$, CO, and $O_3$, and feeds into the National Air Quality Index (AQI) system to inform the public on daily pollution levels.

**However, India's air quality monitoring network remains limited, fragmented, and poorly integrated, constraining both data reliability and timely policy response.** As of 2023, only 6 to 8% of the monitoring infrastructure required under IS 5182[264] is in place, and many stations face frequent downtime due to underfunded operations, limited maintenance, and a shortage of skilled technical staff. Equipment procurement varies across states, leading to inconsistent data quality, and less than half of manual stations monitor PM2.5. Only 7% meet the minimum requirement of 104 monitoring days. The lack of a unified platform to integrate data from regulatory monitors, low-cost sensors, satellites, and mobile systems further limits the generation of timely and granular insights. Without standardised calibration protocols or interoperable metadata such as meteorology or emissions inventories, it is difficult to enable dynamic modelling or source attribution. At the institutional level, data often does not reach urban local bodies in a usable format, even though they are responsible for local interventions. Coordination remains limited, with 74% of non-attainment cities lacking structured SPCB–ULB collaboration and only 30% having emergency protocols linked to AQI levels.

**Emerging technologies like low-cost sensors, AI-driven data fusion, satellite monitoring, and super site monitors offer a pathway to transform India's fragmented air quality monitoring ecosystem into an integrated,**

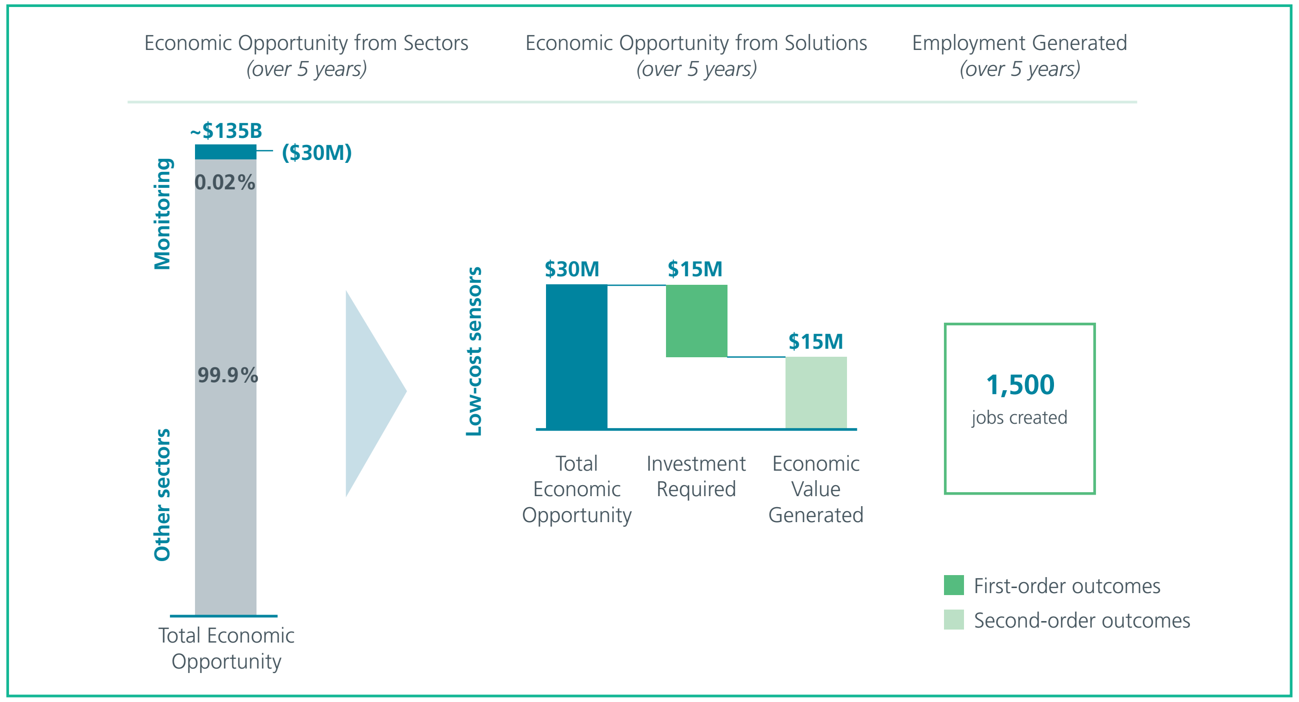
**next-generation intelligence network.** These tools can fill spatial and temporal data gaps, delivering hyperlocal, real-time insights at a fraction of the cost of traditional systems, particularly in regions underserved by CAAQMS coverage. India can scale AI-calibrated sensor networks, unify disparate data streams through a national open-access platform, and institutionalise AQI-linked action protocols at the ULB level. In parallel, super site monitors, equipped to track a wide range of pollutants and meteorological parameters, can enable quick and real-time source apportionment. Programs like PM Gati Shakti and NCAP provide policy scaffolding, while financing models such as Results-Based Financing (RBF) and CSR-backed community monitoring can catalyse innovation and unlock cleaner air at scale.

**Low-cost sensors (LCS) offer the most promising pathway to rapidly and affordably expand India's air quality monitoring capacity.** While the government has mandated the installation of nearly 4,000 CAAQMS stations across cities, progress has been slow due to high capital and operational costs. LCS, by contrast, are significantly cheaper, have in some cases demonstrated up to 90% accuracy with proper calibration, and are already gaining traction through state-led pilots.[265] Their affordability makes them ideal for dense and distributed deployment, especially in areas where CAAQMS coverage is limited. Production and assembly of LCS pose minimal barriers, with several units already manufactured domestically or easily imported. When paired with AI-based calibration and integrated into national data platforms, LCS can deliver real-time, hyperlocal insights to inform local interventions. As NCAP cities seek scalable and cost-effective solutions, LCS present a practical complement to CAAQMS and a viable tool to bridge India's monitoring gap.

**However, a few technical and institutional factors may limit the large-scale integration of low-cost sensors into India's monitoring framework.** Sensor accuracy and reliability continue to vary under different environmental conditions, with performance often affected by humidity, temperature, and cross-reactions with other pollutants. Frequent calibration against reference-grade monitors is needed to maintain data quality, but logistical and cost barriers make this difficult at scale. In addition, the absence of standardised calibration protocols and interoperability guidelines leads to inconsistent data across networks, making it harder to integrate LCS outputs into regulatory systems despite their growing potential for hyperlocal monitoring.

**However, these gaps also create an opportunity to build a more agile, data-driven air quality intelligence ecosystem.** Standardising calibration protocols, developing interoperable data platforms, and enabling public–private innovation in sensor technology can bridge monitoring gaps and strengthen regulatory responsiveness. Returns will come through better-targeted interventions, improved policy coordination, and a robust evidence base to guide India's clean air transition.

***Figure 61: Solutions combating PM2.5 production through monitoring nationwide emissions contribute 0.02% ($25M) to the total economic opportunity***




## Low-cost sensors

**Deploying ~11,000 additional LCS across 154 Indian cities by 2030 can generate a gross annual economic value addition of US$ 3 million and create over 1,500 gross jobs in manufacturing and operations over a 5-year-period.**

**There is a need to target the installation of ~11,000 low-cost sensors (LCS) across NCAP and airshed cities in India by 2030.**[266] While the government has already mandated the establishment of Continuous Ambient Air Quality Monitoring Stations (CAAQMS), high capital and operational costs have slowed progress, leaving many cities under-monitored. LCS, which offer ~90% accuracy at a fraction of the cost, present a scalable complement to CAAQMS and are well-suited to fill spatial and financial gaps in the existing monitoring network. Each city requires 70 LCS, including background sensors, for efficient ambient air quality monitoring.[267] 154 cities require deployment of LCS, including 130 NCAP cities and additional cities under 94 airsheds.[268] While pilot deployments exist, large-scale coverage remains negligible, requiring installation of 11,000 sensors to meet India's target. Assuming a 2.5-year average lifespan of one low-cost sensor, over 5 years, India will need ~22,000 such sensors. fans, and water sprays and proper C&D disposal.

**First-order outcomes:**

Scaling low-cost sensors across 154 cities in India can generate a **first-order outcome of initial investment,** financed through public catalytic capital.

Low-cost sensors do not create new value chains or incremental revenue to business models apart from the revenue from their sale, hence this revenue is categorised as a **first-order outcome.**

**Second-order multiplier outcomes:**

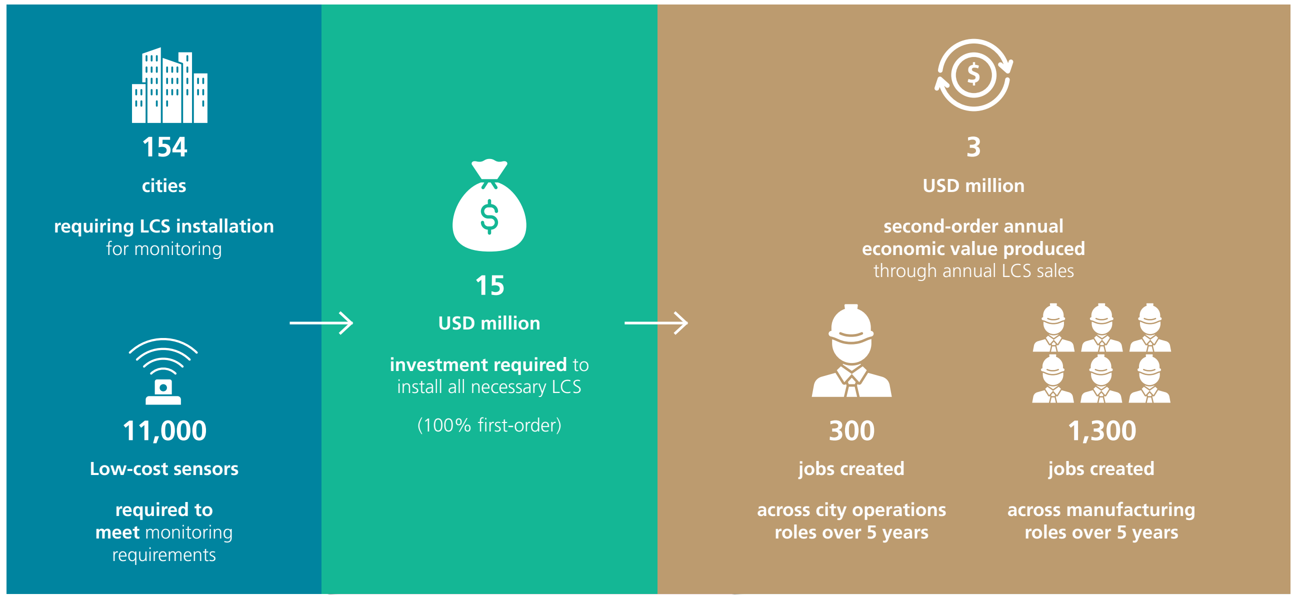
The deployment of LCS will catalyse a range of second-order impacts, including:

- **Creation of 11,000 direct gross jobs** across manufacturing and operations of construction safeguards
- **Public health benefits,** i.e., reduced DALYs from lower air pollution exposure





*Figure 62: Installing low-cost sensors across 154 Indian cities to meet government monitoring targets requires $14 million, while driving annual economic value of US$ 3 million and delivering significant employment*




### Investment required

**The manufacturing and nationwide deployment of 22,000 additional LCS by 2030 will require a capital investment of US$ 30 million across the next 5 years.** The projection estimates a production margin of 10% benchmarked to leading manufacturers, with the average purchasing cost of an LCS placed at ~US$ 1,300.[269] For equipment operation and maintenance, typically ~10% of this initial capital expenditure is incurred. Assuming a 2.5-year average lifespan of one low-cost sensor, over 5 years, India will need ~22,000 such sensors, making the total investment requirement US$ 30 million. This capital could potentially come from first-order investment, as it would be financed through public catalytic capital.

### Job creation potential

**The roll-out of LCS across the next 5 years is projected to create ~1,500 direct gross jobs across manufacturing and operations.** Estimates project that every 400 sensors can support 50 manufacturing jobs,[270] translating to 0.125 jobs per LCS, with 2 full-time operations jobs per city to manage calibration, maintenance, and data collection.[271] Moreover, these are relatively high-skill jobs, which can build local capacity in the growing air quality management ecosystem. This presents a modest but strategic employment opportunity, while ensuring total coverage of air quality monitoring infrastructure.

### Annual economic value-add

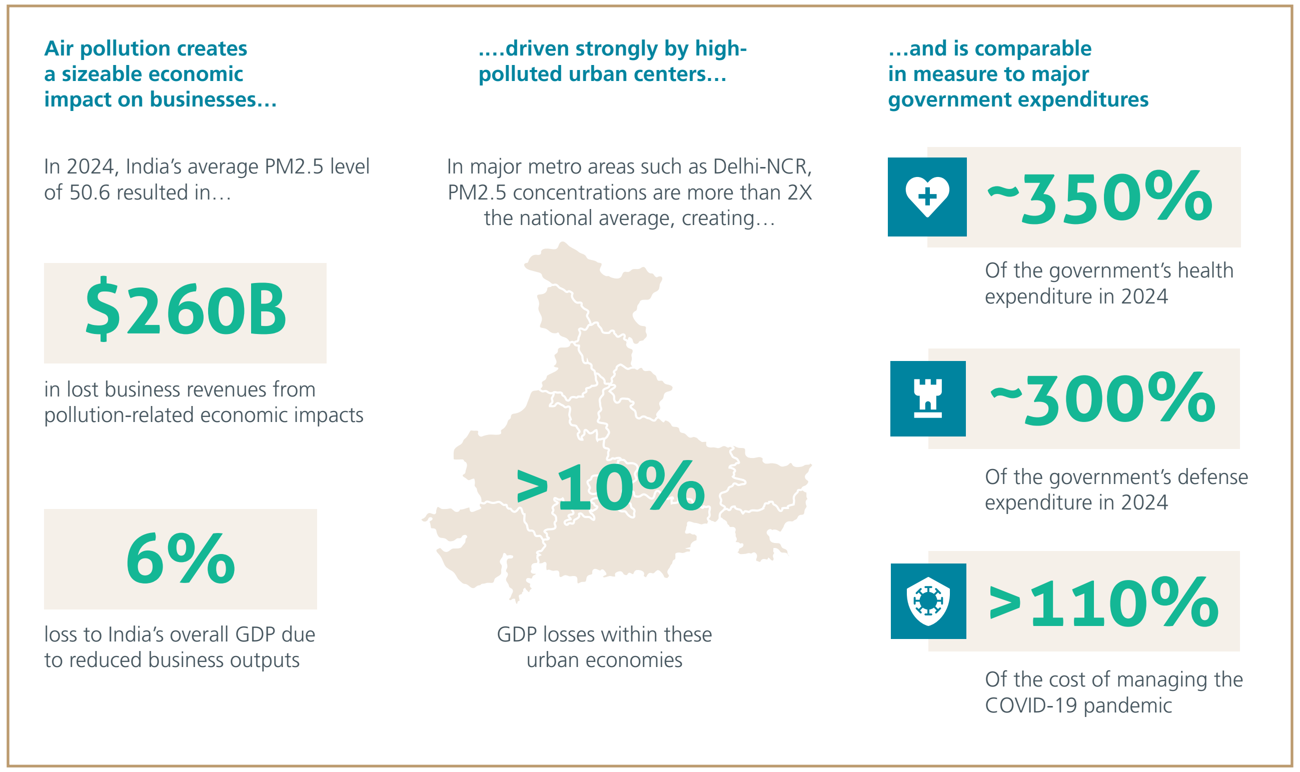
**The scale up of LCS across 154 Indian cities is projected to generate USD $7 million in direct gross annual revenues by 2030.** With a unit price of $1,400 per LCS, this creates a steady market opportunity for domestic manufacturers and suppliers, underscoring the commercial viability of LCS deployment and its potential to stimulate growth in India's air quality monitoring ecosystem. Low-cost sensors do not create new value chains or incremental revenue to business models apart from the revenue from their sale, hence this revenue is categorised as a first-order outcome.

**The system can be further strengthened by embedding citizen engagement as a core layer—expanding data accessibility and fostering public ownership of air quality action.** Globally, apps like Plume, AirVisual, and OpenAQ have democratised access to air quality data; in India, platforms like Sameer (by CPCB) and SmartAQ.net (a collaboration led by University of Chicago's EPIC India and IIT Kanpur) have enabled real-time citizen access. However, citizen science in India remains limited to pilot zones. With appropriate training, residents' associations, schools, and RWAs can effectively operate low-cost monitors, increasing spatial granularity and building public ownership over pollution control.

# V. Economic Cost Of Air Pollution

**This analysis builds on and updates the 2021 study by the Clean Air Fund, Dalberg Advisors, and the Confederation of Indian Industry (CII), which estimated that air pollution cost the Indian economy approximately USD 95 billion—equivalent to 3% of India's annual GDP.** In this refreshed analysis, these impact channels have been revisited using updated data and economic parameters to reflect the current scale of India's air pollution challenge. The estimated annual economic cost has risen sharply to USD 260 billion, underscoring the growing urgency of addressing air pollution as both a public health and economic priority.

*Figure 63: The economic cost of air pollution is driven strongly by urban centres and is much larger than government expenditures of health, defence and COVID-19 management*

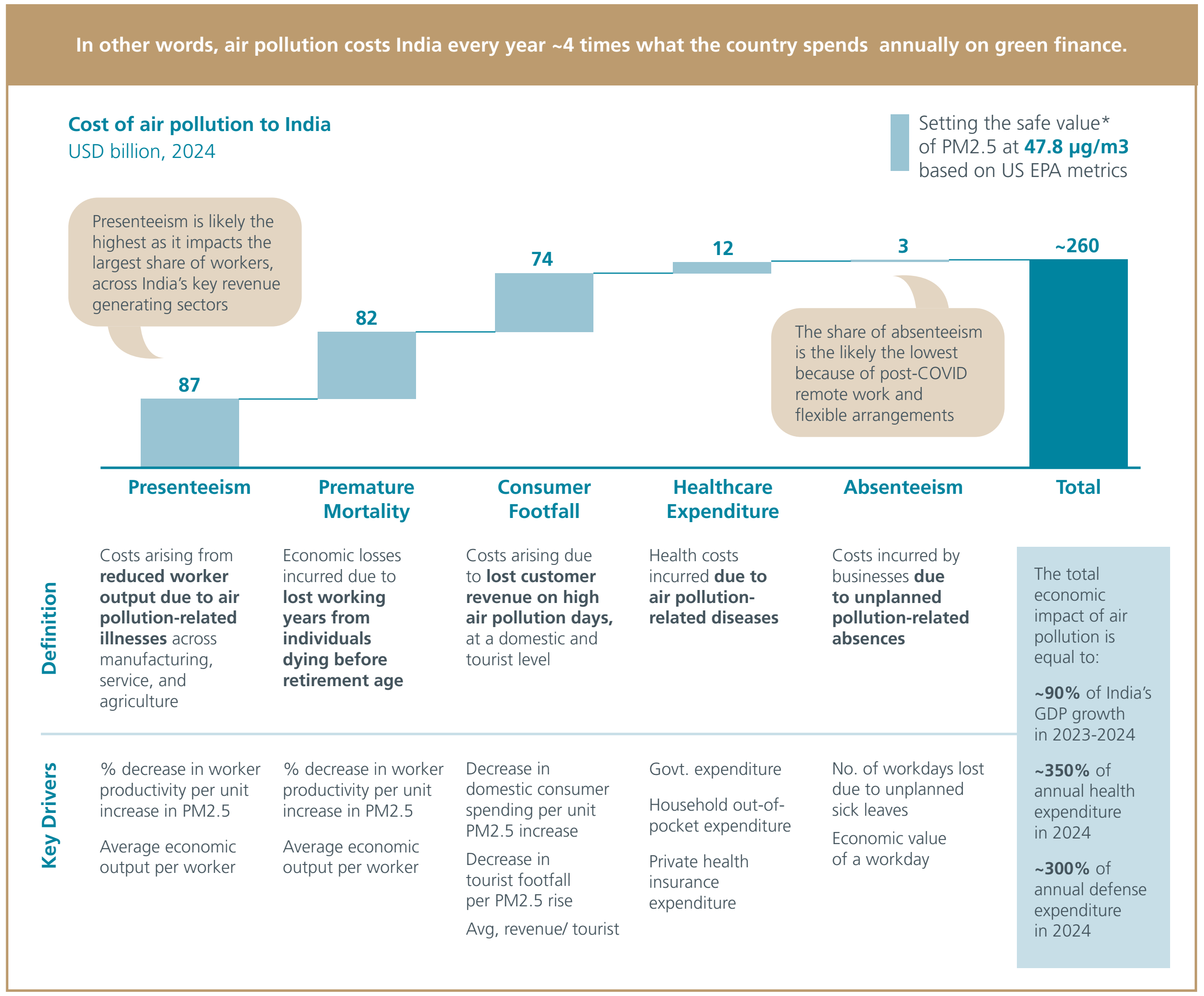







**This cost of USD 260 billion is primarily driven by five metrics of air pollution's impact on health.** These include (i) presenteeism, i.e., the reduced on-the-job worker productivity from pollution-related effects, (ii) premature mortality, i.e., the cost of forgone labour due to air pollution-linked premature mortality, (iii) consumer footfall, i.e., revenue loss from decreased consumer spending in outdoor-facing sectors due to avoidance on high-pollution, (iv) absenteeism, i.e., expenses incurred from lost labour days due to unplanned sick leaves, and (v) health expenditure i.e., expenses by government, households, and private insurers on air pollution-related diseases. Collectively, these factors not only create immediate economic setbacks but also undermine India's long-term economic growth and business resilience.

*Figure 64: Contribution of the 5 key metrics of health impact to the total cost of air pollution on India's businesses*



## A. Cost of presenteeism

**Air pollution–linked presenteeism refers to when employees attend work but underperform due to symptoms such as fatigue, illness, and difficulty concentrating, costing Indian businesses an estimated $87.2 billion in 2024.** In India, this manifests predominantly across three sectors due to their distinct vulnerabilities: (i) manufacturing, where physically demanding tasks heighten susceptibility to fatigue; (ii) high-skill service sectors, which demands sustained cognitive performance and focus, and (iii) agriculture, where extensive outdoor exposure and pollution-generating practices like crop-burning disproportionately affect workers. Globally, similar patterns are evident; factory workers in China displayed a USD 1.2 billion increase in productivity across factories on decreasing PM2.5 by 1%.[272] Further, the efficiency of strawberry harvesters in California decreased by 4.1% as PM2.5 rose by 10 µg/m3.[273] As per the analysis for this report, presenteeism represents the largest economic burden from air pollution in India, as it comparatively affects the broadest section of the workforce, impacting nearly every sector and skill level on a daily basis and causing sustained, economy-wide productivity losses. It is also highly sensitive to pollution fluctuations, with sudden peaks in PM2.5 levels leading to large productivity drops on a day-to-day basis.

***Figure 65: Sector-wise contribution to cost of presenteeism***

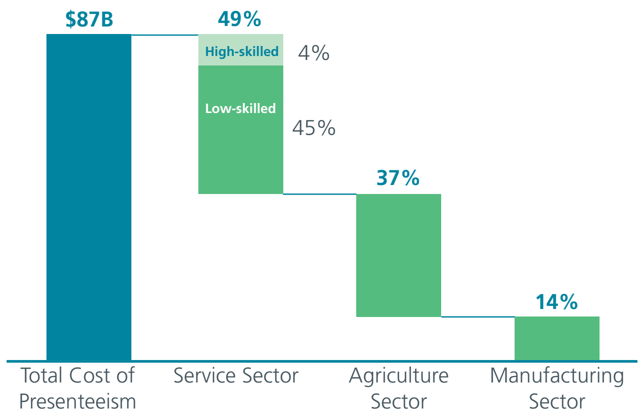



***Figure 66: Case Study: Whitefield's worker productivity loss due to increased air pollution[274]***

**Worker productivity in Bangalore's Whitefield drops by 12% due to air pollution**

**Bangalore's IT hub faces productivity losses on high-pollution days due to its cognitively demanding nature.** Whitefield, the city's most polluted area, recorded daily PM2.5 levels in 2025 consistently above the NAAQS safe limit of 60 µg/m3. A 10-unit rise in PM2.5 was linked to a 3.9% drop in worker traffic, with the most polluted winter months seeing a 12% traffic fall. In an industry where performance hinges on cognitive capacity, pollution-related illnesses translate directly into sharper output declines.





## B. Cost of premature mortality

**Premature mortality from pollution-related illnesses not only represents a profound human tragedy but also results in the loss of working-age individuals, reducing labour participation and economic productivity.** This contributes to an estimated $82 billion economic loss in 2024 for India. This includes both adult workforce deaths due to chronic illnesses spanning COPD, ischemic heart disease, and lung cancer, as well as pre-natal and neo-natal deaths. Notably, pre-natal and neonatal deaths alone account for over 30% of the cost and create a long-term economic drag through the loss of entire working lifespans and diminished parental productivity. Globally, similar trends are observed; in 2013, the APM-driven mortality rate is 18 deaths per 100,000 children under age 5, dropping in older children, and increasing to 397 per 100,000 in people over age 70.[275] In India, these mortalities are concentrated in the Northern Plains, especially in lower GDP per-capita states such as Uttar Pradesh, Bihar, Rajasthan, and Chhattisgarh.[276] Further, with India's median age expected to reach 32 by 2030, the vulnerability of working-age populations to premature mortality is set to increase. Unlike other indicators, the impact of mortality is irreversible, and demands sustained, long-term improvements to air quality to mitigate future losses.

***Figure 67: Contribution of different age groups to cost of premature mortality in India***

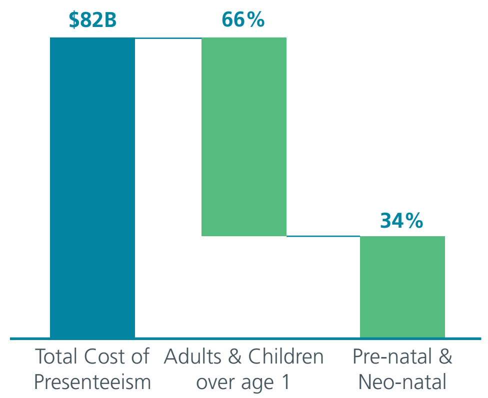



***Figure 68: Case Study: Drop in Meghalaya's life expectancy due to air pollution[277]***

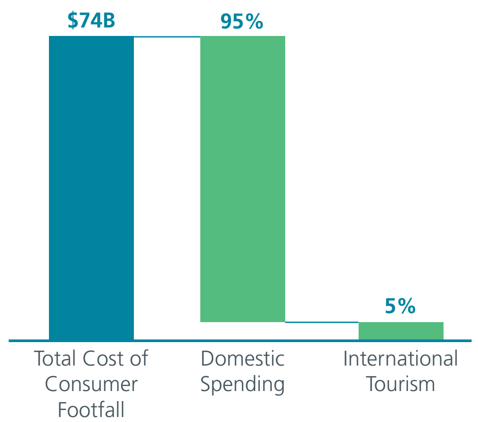
**Life expectancy in Byrnihat, Meghalaya has dropped by 5.2 years due to air pollution**

**Byrnihat's critically high PM2.5 levels are driving a surge of premature deaths and accelerating onset of fatal illnesses.** In 2024, Byrnihat became the most polluted city in the world, with PM2.5 levels reaching **128.2 µg/m3.** Hospitals in the area report a **40%** increase in respiratory illnesses in the last five years. Many of these deaths occur during peak productive years, cutting short decades of economic contribution. **India's 13 most polluted cities, including Byrnihat, drive 40% of India's pollution-related deaths –** and if left unaddressed, will continue to impose an irreversible drag on India's potential economic growth.

## C. Cost of consumer footfall

**Reduced consumer footfall, driven by people avoiding shopping, dining, travel, and other outdoor activities during periods of poor air quality, cost the Indian economy $74B in 2024 through lost spending and tourism revenue.** This impact is divided into two primary sectors: (i) domestic spending, where rising public awareness of pollution health risks dissuades people from stepping outdoors for discretionary shopping and dining; and (ii) tourism, where pollution-related reputations reduce international footfall and shorten their average stays[278]. Globally, effects on consumption due to air pollution have been widely documented – in South Korea, a unit increase in PM2.5 resulted in weekly spending losses of 3,654 won per customer[279], while China displayed a 0.74% decrease in tourist spending due to increased PM2.5 from 2013 to 2017.[280] In India, the most significant impacts occur between November and January, when pollution levels rise sharply (116% above annual averages), with commercial and tourist areas in Delhi subsequently experiencing a 33% drop in daily footfall.[281] There is an estimated 33% drop in footfall in New Delhi's commercial hotspots during the most polluted winter months, with the tourism sector suffering an annual loss of ~US$ 135 million due to Delhi's air pollution.[282] The sharpest declines occur in discretionary spending sectors – Mumbai's Linking Road market, for instance, displayed a 5% reduction in consumer traffic during the polluted winter months. An associated shift toward health expenditures also redirects household expenditures away from discretionary spending, further affecting these sectors. The impact, however, is highly sensitive to changes in air quality, with customer sentiments changing on a near-daily basis, making it possible to rapidly recover economic activity through timely improvements in pollution levels.

***Figure 69: Contribution of domestic spending and international tourism to total cost of decrease in consumer***








## D. Cost of healthcare expenditure

**Air pollution–related diseases imposed a healthcare cost of USD 12.3 billion in 2024.** This cost is distributed across three key stakeholder groups: (i) government, (ii) households, and (iii) private health insurers. Government health expenditure constitutes spending under all schemes funded and managed by the Union, State, and local governments. This includes allocations from multiple ministries and departments toward the healthcare of the general population and government employees. Household health expenditure comprises both direct out-of-pocket payments made at the point of receiving care, and indirect prepayments such as health insurance contributions or premiums, reflecting the extent to which households must rely on their own income and savings to meet healthcare needs. Private health insurance expenditure covers payouts under voluntary health plans offered by insurers and employers. Globally, healthcare expenditure from air pollution is a major and growing cost driver, with OECD estimates projecting outdoor air pollution–related healthcare expenditures to grow from $21B in 2015 to $176B by 2060.[283] In countries like China, a 10 unit decrease in PM2.5 would reduce annual healthcare spending by over $9.2B, equivalent to about 1.5% of the country's total annual healthcare expenditure.[284] In India, the combination of high disease prevalence, heavy household cost burden, and low public health spending make healthcare expenditure due to air pollution a significant pathway of economic loss.

***Figure 70: Contribution of different stakeholders to total cost of air pollution-linked healthcare expenditure in***

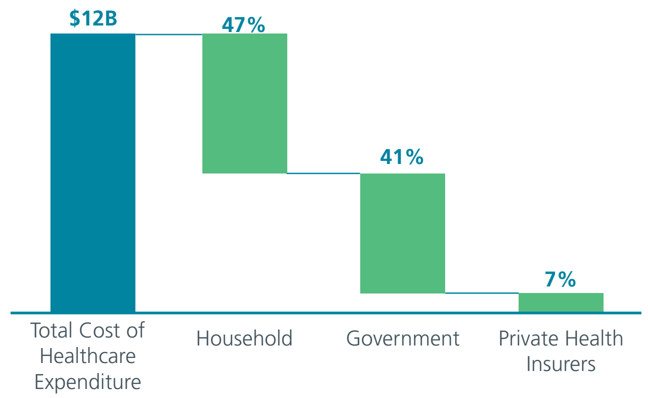



***Figure 71: Case Study: Rise in hospital admissions in Delhi due to severe air pollution[285,286]***

**Hospital admissions in Delhi surge during severe air pollution, driving up healthcare costs**

During Delhi's peak winter smog, PM2.5 levels average over 300 µg/m³, driving a **40–50% surge in outpatient visits and hospital admissions** for respiratory illnesses, such as bronchitis and breathlessness. For every 10-unit rise in PM2.5, Delhi records around **7 additional respiratory-related hospital admissions per week.** These spikes place heavy strain on public and private facilities, making pollution-linked healthcare expenditure a significant economic burden.

## E. Cost of absenteeism

**Absenteeism, i.e. the loss of productive workdays when employees are unable to attend work due to pollution-linked illness or related disruptions, cost Indian businesses $3.24B in 2024[287].** This was driven by two key channels, (i) direct health complications to workers, physically prohibiting them from working, and (ii) employees needing to stay home to care for dependents suffering from pollution-linked illnesses. Business costs are directly impacted by absenteeism, owing to day-to-day workflow disruptions and operational inefficiencies as workers call sick. Globally, studies have identified similar trends in absenteeism; for instance, traffic controllers in São Paulo incurred annual absenteeism costs of $75,400 for every 10 µg/m3 PM2.5 increase (about 20% of the company's operational expenses).[288] In India, absenteeism is majorly concentrated within outdoor workers due to high exposure, including municipal workers and agricultural workers,[289] with Northern and Eastern India disproportionately burdened.[290] Moreover, as India's GDP grows, the economic value of each workday rises, intensifying the financial impact on businesses with each additional day lost to absenteeism.

*Figure 72: Work-from-home policy in Gurugram to overcome pollution-linked absenteeism[291]*

**Gurugram has enforced a mandatory WFH policy to combat absenteeism**

**Severe air pollution and outdoor smog in Gurugram is driving worker illness and forcing large-scale absences.** In 2024, Gurugram's AQI rose to an average of **468,** and peaked at **494,** both in the 'severe' category. To limit worker exposure to toxic smog and prevent illness-based absenteeism, the Gurugram District Administration has enforced a 50% work from home mandate.



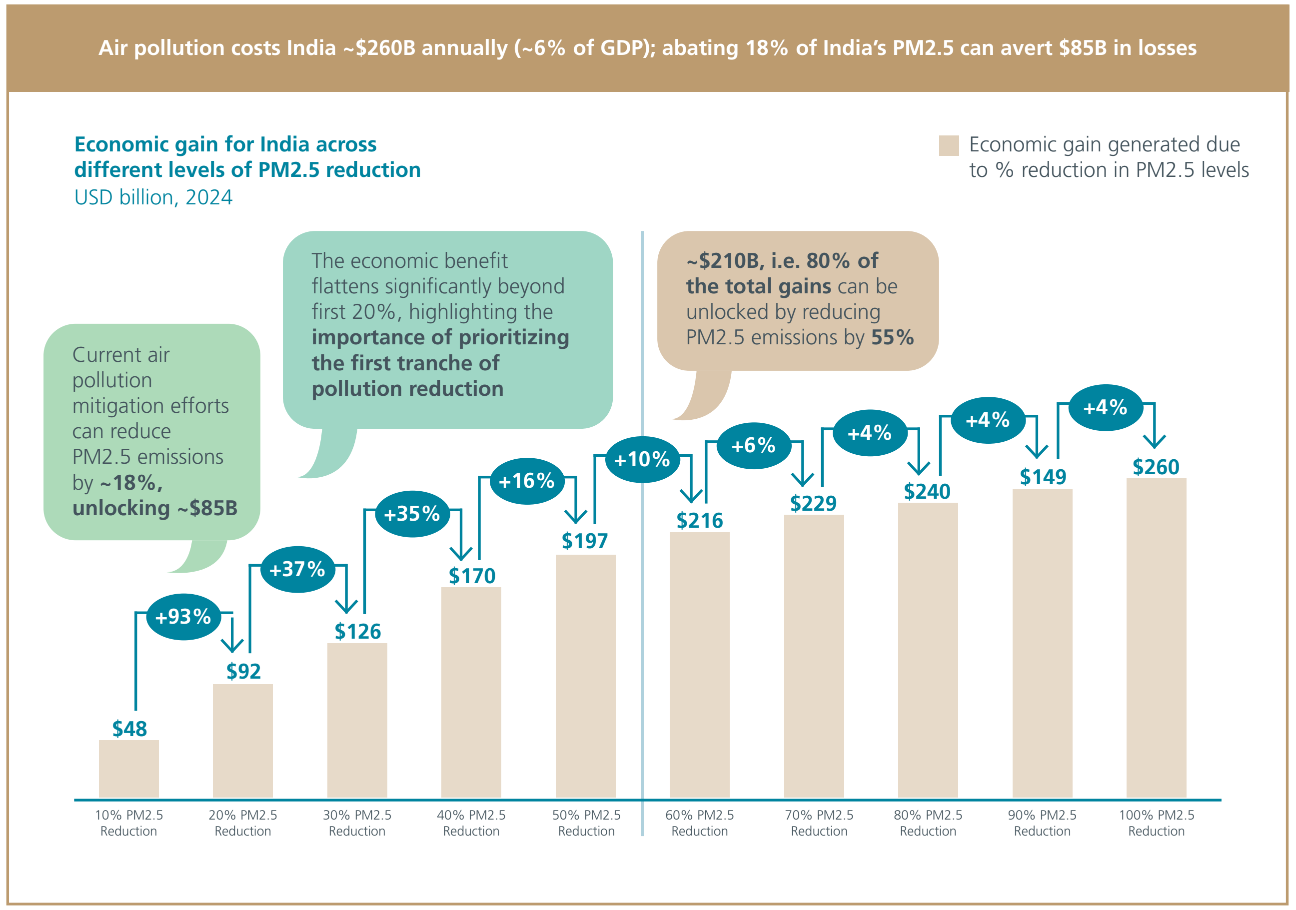



**Air pollution also drives significant non-market welfare losses by increasing the need for unpaid caregiving and other non-income activities, pulling working-age individuals away from the labour force and reducing overall productivity.** These welfare losses stem from reduced participation in activities such as caregiving and community support, particularly for children and the elderly who are most vulnerable to pollution-related illnesses. As their care needs rise, the burden typically shifts to the working-age population, leading to time off work or reduced hours. Over time, this results in compounding economic strain—through lost workdays, lower revenues, and workforce burnout—that indirectly but materially impacts business performance.

**Beyond people, the impact of air pollution is also visible on physical assets including buildings, machinery, agricultural produce, solar infrastructure and transport vehicles, reducing their productivity and lifespans.** Sulphur dioxide and nitrogen oxides cause corrosion and degradation in industrial buildings and machinery, while airborne pollutants damage agricultural output by 5-12%.[292] Solar panels also suffer efficiency losses as smog blocks sunlight,[293] and vehicles face reduced lifespans due to damaged engines and tailpipes.[294] These losses lead to decreased business output and higher maintenance and replacement costs, affecting the economy at large.

**Reducing PM2.5 levels in India by ~55% could mitigate 80% (~$210B) of the costs created by air pollution.** Marginal returns are large from the outset, with small reductions in PM2.5 driving substantial economic gains. The proposed group of solutions in this study can reduce PM2.5 emissions by ~20% in the next five years, subsequently unlocking over $85B in averted costs to businesses. These savings would not only mitigate existing business losses but also will bolster India's capacity to fund its own green transition, directly accelerating progress toward India's national climate and development goals.

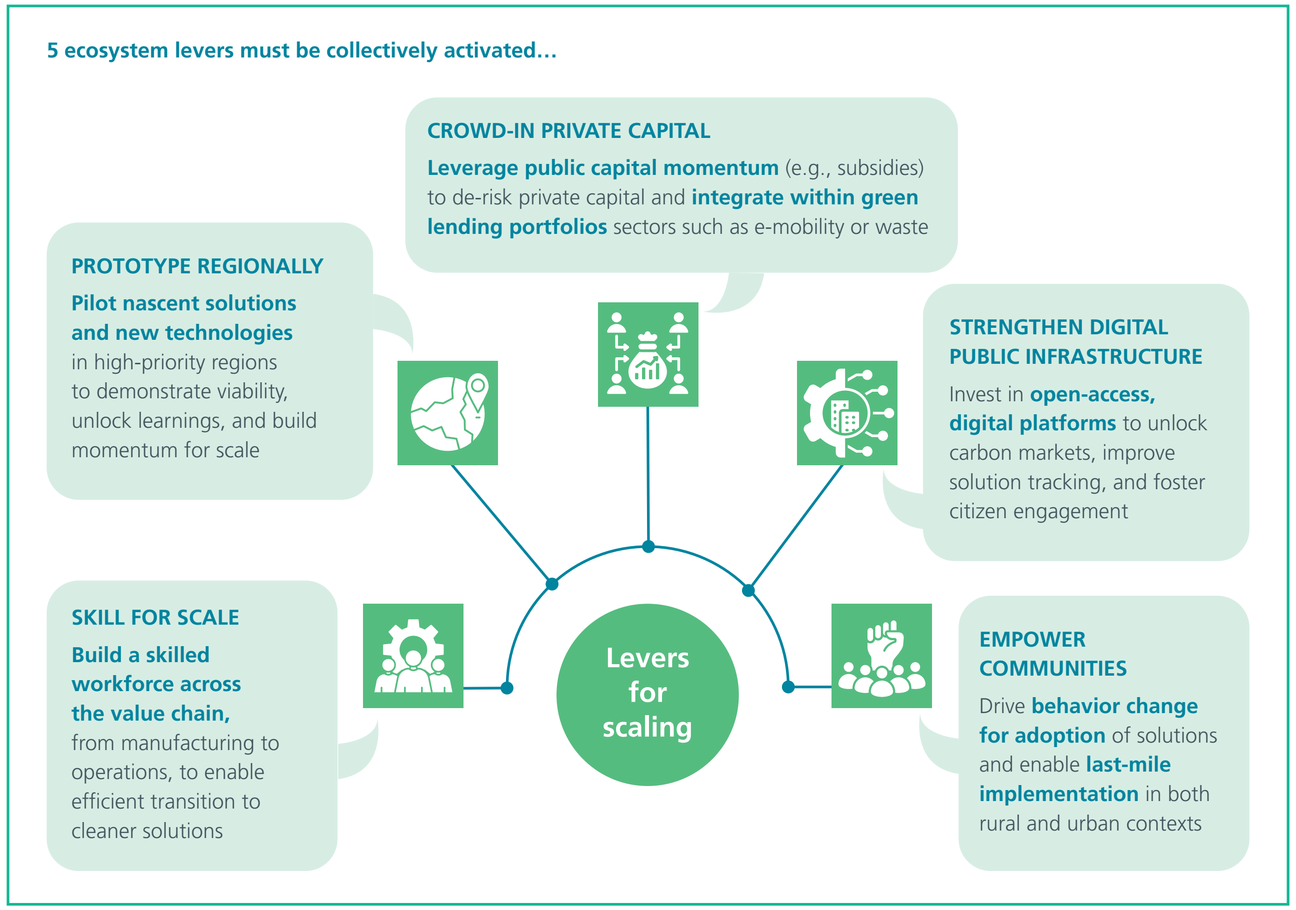
*Figure 73: Economic gains unlocked for every 10% reduction in PM2.5 levels in India*



# VI. Conclusion and Way Forward

**Scaling India's clean air solutions will require ecosystem-wide enablers that support sustained implementation across sectors.** Five levers must collectively work to drive scale: de-risking private capital, prototyping regionally, building a skilled workforce, empowering communities for last-mile adoption, and strengthening digital public systems.

*Figure 74: 5 ecosystem levers required to unlock scale for air pollution solutions in India*




1. **Cleantech skilling is essential to operationalise and maintain clean technologies at scale.** Building a future-ready workforce across the clean air value chain—from manufacturing and installation to operations and maintenance—is imperative for a successful transition. For e.g., drivers operating e-buses need to be trained to efficiently maintain battery life and adapt driving patterns to maximise the vehicle's range and reduce downtime. Skill development must be integrated into national and regional skilling frameworks, with tailored programs that reflect the requirements of emerging sectors such as e-mobility, clean fuels, and decentralised waste management.

2. **Regional pilots can demonstrate viability and accelerate policy and market readiness.** Prototyping solutions and technologies in high-priority geographies allows for rapid learning, de-risking, and iteration. For example, to understand behavioural preferences and the adoption rate of improved cookstoves, prototypes need to be piloted in select regions of India. IKEA is also developing a prototype for zero-emission electric trucks as part of its EV100+ commitment to electrify all heavy-duty vehicles in its supply chain by 2040. These pilots generate operational insights, validate business models, and build local momentum for scale. Successful regional demonstrations also inform national policy design and strengthen the enabling environment for investment and replication.

3. **Leveraging limited public funding in the forms of government subsidies and philanthropic capital is vital to de-risk private investment and encourage green financing.** Public capital momentum driven through government subsidies must be strategically leveraged to offer credit guarantees, concessional debt, and blended finance instruments that improve risk-return profiles and enable private sector participation. Realigning green financing towards solutions that curb both air pollution and carbon emissions will further accelerate capital flows into air quality–relevant sectors and scale impact. For example, the Green Climate Fund's partnership with Tata Cleantech Capital provided a $100 million credit line to finance energy efficiency projects in India, combining concessional funds with commercial lending to de-risk investments and catalyse market growth.

4. **Digital public infrastructure can accelerate clean air progress, enabling real-time data, community participation, and innovative finance.** Strengthening open-access digital platforms can integrate live air quality data into commonly used apps like Google Maps, as demonstrated by Google's Air View, giving residents access to hyperlocal information and enabling data-driven decision-making. These platforms can also drive public engagement by making air quality data visible and interactive, helping people feel connected to the problem and solution. In parallel, building digital infrastructure for carbon marketplaces can unlock new financing streams by enabling trading, and monetisation of emissions reductions.

5. **Behaviour change is critical to unlock last-mile adoption of clean air solutions.** Empowering communities is essential to ensure uptake and sustained implementation of air pollution solutions. This involves targeted behaviour change campaigns and resident engagement strategies that drive last-mile delivery and adoption in both urban and rural settings. Community involvement builds trust, creates accountability, and ensures that interventions meet local priorities and are implemented effectively on the ground. Indore, for example, demonstrates how empowering communities leads to transformation, with public awareness campaigns leading to 100% of household waste source segregation, leading the city to achieve the cleanest city tag for 8th year in a row in 2025.

**Mobilising these ecosystem-enablers for scalability requires coordinated action from government, financiers, private sector, and civil society.** Policymakers can de-risk private investment through mandates, financial incentives, and enabling systems; financiers can expand green portfolios and concessional lending; private sector can invest in R&D, manufacturing, and workforce skilling; and civil society can drive behaviour change and last-mile adoption (see Figure 75).

*Figure 75: Role of stakeholders for mobilising ecosystem enablers*

**Activating ecosystem enablers…**

1. Skill for scale
2. Prototype regionally
3. Crowd-in private capital
4. Strengthen digital public systems
5. Empower communities

**…requires coordinated action across stakeholders**

**Policy Makers** (e.g., MNRE/MoEFCC) — 1 2 3 4
- **Set mandates and financial mechanisms** to support demand creation and de-risk private capital
- **Invest in enabling infrastructure and systems** (e.g., gas grids, digital marketplaces for carbon credits, product certification/ standardisation processes, skill development programs)

**Private Financiers** (e.g., Banks/NBFCs) — 2 3
- **Expand green financing portfolios** to include priority clean air solutions (e.g., e-truck, CBG, biopellet)
- **Provide concessional loans** (e.g., higher LTV, longer tenures) by leveraging public momentum and partnerships with public financiers

**Public Financiers** (e.g., Philanthropy/MDBs) — 2 3
- **Deploy blended finance, credit guarantees, and risk-sharing facilities** to crowd in private capital
- **Provide grant-funding or results-based financing** tied to measurable air quality, carbon, health or socio-economic outcomes

**Private Sector** (e.g., Manufacturers) — 1 2 3
- **Invest in R&D, manufacturing capacity, and quality assurance** for clean air solutions
- **Establish local, government, and corporate partnerships** to boost investor confidence
- **Upskill the workforce** across manufacturing, installation, and daily operations of new solutions

**CSOs** (e.g., NGOs) — 1 2 5
- **Lead awareness and behaviour change campaigns** for solution adoption
- **Support skill development of workers,** including integration of informal sector actors
- **Monitor implementation and outcome** through independent audits and community feedback



**Each solution under the three economic pathways requires distinct actions from these key ecosystem actors.** Together, these actions can transform India's clean air transition from fragmented initiatives into a cohesive, economy-wide movement.

## Role of stakeholders in scaling Pathway A solutions:

- **E-buses:** The electrification of India's bus fleet requires policymakers to extend subsidies and demand aggregation programs, private financiers to offer affordable long-tenure loans, public financiers to provide blended capital support, OEMs to expand production and partnerships, and CSOs (civil society organisations) to upskill workers for e-mobility operations.
- **E-trucks:** To enable mass adoption of e-trucks in India, policymakers must integrate targeted incentives and carbon credits, private and public financiers should expand risk-sharing and green capital pools, private sector players must invest in both vehicle manufacturing and fleet partnerships, and CSOs should upskill the existing ICE truck workforce.
- **Zig-zag kilns:** To enable the large-scale transition to zig-zag kilns, policymakers must enforce compliance through pollution control boards, financiers need to expand access to concessional capital, and private sector actors can ensure high-quality retrofitting and worker training.

*Figure 76: Roles of different stakeholders to implement Pathway A solutions at scale*

| | Policy Makers (e.g., MNRE/MoEFCC) | Private Financiers (e.g., Banks/NBFCs) | Public Financiers (e.g., Philanthropy/ MDBs) | Private Sector (e.g., Manufacturers) | CSOs (e.g., NGOs) |
|---|---|---|---|---|---|
| E-buses | Extend PM E-Drive, PM E-bus SEWA **schemes to private operators**<br>Develop **carbon credit marketplace**<br>**Maintain long-term procurement mandates** to give scaling confidence | Offer **higher LTVs** (80%), **lower interest rates** (12%), and **longer tenure** (7 years)<br>**Expand green financing portfolio** to include e-bus loans | Expand blended finance partnerships with SIDBI and PFIs to **offer risk-sharing facilities to e-buses** | **Drive battery cost cuts** via domestic manufacturing<br>Explore **partnership models** between fleet operators and OEMs | **Upskill** ICE bus employees for e-bus manufacturing and operations |
| E-trucks | Integrate EV policies with **explicit e-truck incentives**<br>Develop **carbon credit marketplace,** with incentive integration in schemes (e.g., subsidies linked to credits) | Offer **higher LTVs** (80%), **lower interest rates** (12%), and **longer tenure** (7 years)<br>**Expand green financing portfolio** to include e-truck loans | Expand blended finance partnerships with SIDBI and PFIs to **offer risk-sharing facilities to e-trucks** | Expand **battery manufacturing** and **R&D**<br>Explore **partnerships models** between fleet operators and OEMs | **Upskill** ICE truck employees for e-truck manufacturing and operations |
| Zigzag kilns | **Enforce compliance** with through pollution control boards<br>Provide **fiscal incentives** for retrofitting | Offer **concessional loans** (e.g., low interest, reduced collateral requirements) | Set up **funds to provide capital or interest subsidy** for brick industry retrofit/upgrades | **Ensure proper design, and construction,** as suboptimal deployment reduces gains | **Improve worker welfare** through skilling and access to safety equipment, water, and heat shelter |

1. Fermented Organic Manure; 2. Urban local bodies

### Role of stakeholders in scaling Pathway B solutions:

- **CBG for waste:** To scale CBG plants for waste processing, policymakers must expand distribution infrastructure and create stable market mechanisms, private financiers must extend affordable capital, public financiers must provide de-risking instruments, private players must secure robust input and offtake linkages, and CSOs must strengthen source segregation.
- **MRF:** To scale centralised MRFs, policymakers must expand subsidies and tracking systems, financiers should extend concessional and risk-sharing instruments, private players need to build strong operational models, and CSOs must drive efficient segregation through community engagement.
- **Co-firing bio-pellets:** To enable large-scale co-firing of biomass pellets in thermal power plants, policymakers must formalise cost-recovery guidelines and quality standards, while financiers and manufacturers can expand production capacity and green financing access.
- **CBG for crop residue:** To scale CBG plants for crop residue, the central government must improve procurement prices and funding access, and banks and private players must increase lending and invest in market-making infrastructure respectively.
- **Improved cooking solutions:** Scaling improved cooking solutions across India requires discovery-driven changes in government policy, improved private capital lending, and greater private sector participation in cookstove distribution.
- **MRS:** To enable efficient deployment of MRS, policymakers must establish centralised tracking platforms and incentivise outcome-based contracts, financiers must offer concessional capital, private operators must deliver high-quality MRS services to ULBs, and CSOs must build capacity of ground-level staff to operate the equipment effectively.





*Figure 77: Roles of different stakeholders to scale Pathway B solutions*

| | **Policy Makers** (e.g., MNRE/MoEFCC) | **Private Financiers** (e.g., Banks/NBFCs) | **Public Financiers** (e.g., Philanthropy/ MDBs) | **Private Sector** (e.g., Manufacturers) | **CSOs** (e.g., NGOs) |
|---|---|---|---|---|---|
| **CBG Waste** | Invest in **national gas grid** to ensure sale of CBG at viable prices<br>Dedicated **policies for FOM[1] commercialization**<br>Develop carbon credit marketplace | Offer **higher LTVs** (80%), **lower interest rates** (12%)<br>**Expand green financing portfolios** to include CBG plant loans | Enter blended finance partnerships with SIDBI and PFIs to **offer risk-sharing facilities to CBG plants** | Build **feedstock sourcing networks** with ULBs2 and **long-term contracts** with offtakers | **Work with informal waste pickers** to drive efficient source segregation |
| **MRFs** | Expand subsidies for MRFs (e.g., expanding % of project cost eligible under **Viability Gap Funding)**<br>Develop **plastic** and **carbon credit marketplace** | Offer **higher LTVs** (70%), **lower interest rates** (12%)<br>**Expand green financing portfolios** to include MRF loans | Enter blended finance partnerships with SIDBI and PFIs to **offer risk-sharing facilities to MRFs** | **Engage with ULBs** for securing segregated waste and land permissions<br>**Fulfil EPR obligations** with corporate partnerships | **Work with informal waste pickers** to drive efficient source segregation |
| **Co-firing biopellets** | Create **pricing and quality certification standards** for biopellets (e.g., calorific value benchmarks; vendor accreditation)<br>Develop **carbon credit marketplace** | Offer **higher LTVs** (80%), **lower interest rates** (12%)<br>**Expand green financing portfolios** to include CBG and biopellet plants loans | Enter blended finance partnerships with NABARD and PFIs to **offer risk-sharing facilities to CBG and biopellet plants** | Scale up biopellet **production capacity with quality standards**<br>Establish robust **collection systems for feedstock** | Raise **farmer awareness** and **build capacity** for ex-situ crop residue management |
| **CBG for Agriculture** | Invest in **national gas grid** to ensure sale of CBG at viable prices<br>Dedicated **policies for FOM[1] commercialization**<br>Develop **carbon credit marketplace** | Offer **higher LTVs** (80%), **lower interest rates** (12%)<br>**Expand green financing portfolios** to include CBG and biopellet plants loans | Enter blended finance partnerships with NABARD and PFIs to **offer risk-sharing facilities to CBG and biopellet plants** | Build **feedstock sourcing networks** with farmers and **long-term contracts** with offtakers | Raise **farmer awareness** and **build capacity** for ex-situ crop residue management |
| **Improved cooking solutions** | **Relaunch improved cooking programs** like National Biomass Cookstove Programme and Unnat Chulha Abhiyan<br>Develop **carbon credit marketplace** | **Expand green financing portfolios** to include improved cooking solution loans | Engage in **blended finance programs** such as impact bonds linking carbon, health, and gender outcomes | **Partner with carbon credit verifiers** to strengthen MRV2 systems | **Drive distribution and behavior change** to increase cookstove adoption and stickiness |
| **MRS** | Launch a **platform for ULBs[2] to track** and ensure efficient MRS operations<br>Encourage **outsourcing of MRS** by ULBs, with outcome-linked incentives in contracts | Offer **concessional loans** (e.g., low interest) for MRS procurement | Provide **results-based financing,** tied to dust and PM2.5 reduction outcomes | **Provide MRS procurement and operation** services of to ULBs | **Build capacity of MRS operators** for efficient usage |

### Role of stakeholders in scaling Pathway C solutions:

- **APCD and CEMS:** To enable widespread deployment of APCDs and CEMS in industrial clusters, policymakers must tighten mandates and monitoring, private and public financiers should improve affordability and access to retrofit capital, the private sector must ensure high-quality operations and maintenance, and CSOs should strengthen data accountability.
- **FGD:** To scale FGD retrofits in thermal power plants (TPPs), policymakers must tighten compliance timelines and resolve manufacturing bottlenecks, financiers must provide innovative financing structures to spread risk, manufacturers need to expand domestic EPC capacity, and CSOs should advocate strong oversight and public monitoring.
- **Construction safeguards:** To institutionalise construction safeguards that reduce dust emissions, policymakers must enforce robust compliance systems, financiers should ease capital constraints, the private sector must improve deployment quality, and CSOs should monitor on-ground adherence.
- **Low-cost sensors:** To enable scale-up of low-cost sensors (LCS) for air quality monitoring, policymakers must institutionalise their role in regulatory systems, financiers should extend concessional or grant funding, private players need to expand deployment partnerships with ULBs, and CSOs must increase public awareness of pollution through hyperlocal data.

*Figure 78: Roles of different stakeholders to scale Pathway C solutions*

| | **Policy Makers** (e.g., MNRE/MoEFCC) | **Private Financiers** (e.g., Banks/NBFCs) | **Public Financiers** (e.g., Philanthropy/ MDBs) | **Private Sector** (e.g., Manufacturers) | **CSOs** (e.g., NGOs) |
|---|---|---|---|---|---|
| **APCD and CEMS** | Mandate APCDs in **small and medium** industrial units<br>Ensure **real-time data linkage** to pollution control boards from CEMS | Offer **concessional loans** (e.g., low interest), especially for small industries, for APCD procurement | Provide **funding support** (grants or interest subsidies) for installation in industrial clusters | Ensure **sustained operations and reliable data transmission** from CEMS to regulatory bodies | Conduct **third-party audits** of emission data<br>**Upskill small industries** for APCD operations |
| **FGD** | **Enforce compliance** through tighter deadlines and penalties for TPPs<br>**Incentivise domestic manufacturing** to resolve supply-side constraints | Provide **syndicate or consortium financing** to spread risk and support large-scale retrofits | Provide **blended finance or subsidies,** potentially linked to SO2 outcomes | Expand **domestic EPC[1] capacity** | **Advocate for strong enforcement** of emission norms<br>**Monitor public reporting** of emissions post-retrofit |
| **Construction safeguards** | Implement **stringent compliance checks** and impose **penalties** for violations, moving beyond closure notices | Offer **concessional loans** (e.g., low interest) for safeguard procurement | Provide **funding support** (grants or interest subsidies) for deployment in key urban areas | Procure and deploy safeguards, while ensuring **adherence to all C&D guidelines** | Conduct compliance monitoring at construction sites |
| **Low-cost sensors** | Integrate LCS in **NCAP**<br>Ensure **robust data sharing** with ULBs<br>**Initiate certification** for standard setting, supplemented by **mandated calibration** for quality control | Offer **concessional loans** (e.g., low interest) for LCS procurement | Provide **grant funding for LCS pilot** deployments in urban cities | **Partner with SPCs/PCCs** for deployment and maintenance contracts | Raise awareness on hyperlocal pollution using LCS data |





**By aligning all the ecosystem actors across sectors to act decisively, India can unlock its $220 billion clean air economic opportunity.** Policymakers, financiers, the private sector, and civil society each have distinct but interconnected roles that, when executed in concert, can overcome financing, technology, capacity, and adoption barriers. Coordinated action can crowd in private capital, demonstrate market-ready solutions, build a skilled workforce, strengthen digital infrastructure, and embed behaviour change in communities. By activating these enablers together, India can shift air pollution from a being perceived as a persistent economic burden to a driver of growth, health, and resilience.

# VII. Annex

# A. Glossary

| Term | Definition |
|---|---|
| **Airshed** | A geographical area that shares the same air mass and pollution characteristics, meaning emissions within it affect the same overall air quality |
| **Air Pollution Control Devices** | Equipment installed in industries to capture and remove pollutants such as particulate matter and gases from emissions |
| **Blended finance** | A financing structure that combines concessional (public or philanthropic) and commercial capital to reduce risk and attract private investment into clean air solutions |
| **Continuous Ambient Air Quality Monitoring Systems** | Real-time monitoring systems used to measure key pollutants such as particulate matter and sulphur dioxide in the atmosphere |
| **Continuous Emissions Monitoring Systems** | Real-time industrial monitoring systems that measure pollutant concentrations in stack emissions to ensure compliance with standards |
| **Co-benefits potential** | Additional health, environmental, or social benefits derived from implementing air quality solutions, such as reduced greenhouse gas emissions or DALYs averted |
| **Concessional loans** | Loans provided at below-market interest rates to make clean technologies and pollution-control projects more affordable |
| **Crowded-in commercial capital** | Private or market-based financing mobilised after catalytic or public capital reduces risk, enabling large-scale adoption of clean technologies |
| **Cyclone separator** | An air pollution control device that uses centrifugal force to separate particulate matter from industrial exhaust gases |
| **Disability-adjusted life year** | A health metric representing the total number of years lost due to illness, disability, or premature death caused by air pollution |
| **Economic value generated** | The gross revenue generated as result of deployment of the air quality management solution |
| **Existing revenue streams** | Ongoing income sources that persist under a new system or technology, such as passenger fares or product sales |
| **Flue Gas Desulphurisation** | A technology installed in thermal power plants to remove sulphur dioxide from flue gases, thereby reducing air pollution |
| **Gross job creation potential** | The total number of new jobs generated across manufacturing, construction, operations, and maintenance from clean air solutions. This does not account for job loss. |
| **Gross job transition** | The number of existing jobs adapted or shifted to new cleaner systems (for example, diesel to electric bus operations), typically requiring reskilling. This does not account for job loss. |
| **Happy seeder** | An agricultural machine that enables in-situ crop residue management by sowing seeds directly into the field without burning the stubble |
| **Initial catalytic capital** | Early-stage public or concessional funding used to de-risk investments and demonstrate commercial viability of clean air solutions |





| Term | Definition |
|---|---|
| **Investment required** | The total capital expenditure needed to implement clean air solutions, including equipment, infrastructure, and installation costs |
| **Low-cost sensors** | Affordable air quality sensors that provide real-time, hyperlocal pollution data to complement traditional monitoring systems |
| **Material Recovery Facilities** | Centralised facilities that sort, process, and recover recyclable materials from municipal solid waste, reducing open waste burning and related emissions |
| **National Ambient Air Quality Standards (NAAQS)** | Legally established pollutant concentration limits defining acceptable air quality levels in India |
| **National Air Quality Monitoring Programme** | A nationwide monitoring network coordinated by pollution control authorities to assess and report ambient air quality |
| **National Clean Air Programme** | India's flagship air quality management program aiming to reduce particulate matter levels by 40% by 2026 through multisectoral interventions |
| **New revenue streams** | Additional income generated from newly created value chains or markets, such as sales of recyclables, carbon credits, or biogas |
| **Off-taker** | An entity that agrees to purchase the output (such as goods, energy, or services) from a producer, typically under a long-term contract |
| **Pathways** | Channels through which air pollution solutions can generate economic opportunity (such as by greening existing industries, building new clean value chains, or enabling compliance-driven improvements). Individual solutions can be mapped under each pathway |
| **Presenteeism** | The reduction in worker productivity when employees continue to work despite being affected by air pollution-related illness or discomfort |
| **Results-based financing** | A funding mechanism that disburses capital only upon achieving predefined measurable outcomes, such as deployment targets or emissions reductions |
| **Safe value** | The benchmark pollutant threshold (for example, safe daily particulate matter level) used to assess exposure-driven health and economic impacts |
| **Solutions** | The interventions to address key air polluting sectors (e.g., compressed biogas plants for agriculture stubble burning) |
| **Sustainable alternative towards affordable transportation** | A government initiative promoting compressed biogas plants to create cleaner transport fuels |
| **Total Cost of Ownership** | The full lifecycle cost of acquiring, operating, and maintaining an asset or technology, used to assess comparative economic feasibility |
| **Vertical Shaft Brick Kiln** | An energy-efficient and low-emission brick production technology designed to replace traditional high-polluting kilns |
| **Zig-zag kiln** | A cleaner brick kiln technology that improves airflow to ensure uniform combustion, reducing particulate emissions by up to 75% |

## B. Computation of CO2e Tonnes Abated by Solution

| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3[295] |
|---|---|---|---|---|
| in million tonnes | Description | Data | | in US$ million |
| **E-buses** | | | | |
| 3 | Total annual GHG reduced by 1 e-bus | 14 tonnes | ITI Aayog & RMI, India's Electric Mobility Transformation, 2019<br><br>Emissions from CNG buses are ~5% lower than diesel buses | ~8 M<br><br>(2.6 M tonnes * USD 3) |
| | Additional e-buses in India 2025-2030 | ~188,000 | Calculated in section VII, pathway A, part A: Transport | |
| | Total annual GHG reduced by all additional e-buses | 2.6 (~3) M tonnes | | |
| **E-trucks** | | | | |
| 0.2 | Total annual GHG reduced by 1 e-truck | 18 tonnes | Scania, Study shows that electric outperforms diesel in climate impact within first year of operation<br><br>As per the current grid of 30% renewables | ~0.53 M<br><br>(0.18 M tonnes * USD 3) |
| | Additional e-trucks in India 2025-2030 | 10,000 | PSA, ZET Adoption in India and its Impact on Emission and Energy, 2025 | |
| | Total annual GHG reduced by all additional e-trucks | 0.18 (~0.2) M tonnes | | |



| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3[295] |
|---|---|---|---|---|
| in million tonnes | Description | Data | | in US$ million |
| **Zig-zag kilns** | | | | |
| 0.4 | $CO_2$ emissions per FCBTK per year | 560 tonnes | Shakti Foundation, Towards Cleaner Brick Kilns in India, 2013 | 1.2 M<br><br>(0.4 M tonnes * USD 3) |
| | Difference in emissions between FCBTK & ZZKs | 30% | Shakti Foundation, Towards Cleaner Brick Kilns in India, 2013<br><br>30% lower emissions than FCBTKs | |
| | Brick kilns that need to be retrofitted as zigzag kilns | 12,600 (~13,000) | Calculated in section VII, pathway B, part C: Industry | |
| | Proportion of kilns that will be retrofitted in 2025-2030 | 20% | Shakti Foundation, Towards Cleaner Brick Kilns in India, 2013<br><br>35,000 FCBTKs in India<br><br>Greentech, Guidance document - Brick Kilns India, 2022<br><br>FCBTKs account for 50% of the brick kilns<br><br>Adda247, Brick Kilns in India: MoEFCC Releases New Guidelines, 2022<br><br>Total of 70,000 brick kilns in India; zigzag kilns, VSBKs and Hoffmans account for 20% | |
| | CO2e emissions abated by installing zigzag kilns = 560 * 30% * 12,600 * 20% | 0.42 (~0.4) M tonnes | | |
| **CBG for solid waste** | | | | |
| 10 | Annual net avoided emissions from decomposition of municipal waste | 0.042 M tonnes | Expert interviews, as per current figures | 30 M<br><br>(10 M tonnes * USD 3) |

| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3 |
|---|---|---|---|---|
| **in million tonnes** | **Description** | **Data** | | **in US$ million** |
| 10 | Annual net emissions avoided from displacement of combustion of CNG at 100% | 0.012 M tonnes | Expert interviews, based on Indore plant | 30 M<br>(10 M tonnes * USD 3) |
| | Average capacity utilisation | 70% | Expert interviews, as per current sector trends | |
| | Total annual GHG reduced per plant = 0.042 + 0.012*70% | 0.051 M tonnes | | |
| | CBG plants by 2030 | ~200 | Calculated in section VII, pathway B, part A. Solid Waste Management | |
| | Total annual GHG abated = 0.051 * 200 | 10.2 (~10) M tonnes | | |
| **MRFs** | | | | |
| 2 | Total daily waste generated in India in 2030 | 0.45 M tonnes | MoHUA & IFC, Business Models Economic Assistance for MSW Projects, 2025 | ~5 M<br>(1.6 M tonnes * USD 3) |
| | % of waste sent to landfills | 24% | CPCB, MSW Annual Report, 2022 | |
| | Amount of waste sent to landfills daily by 2030 = 0.45 * 24% | ~0.11 M tonnes | 0.45 M tonnes 0.45 M tonnes | |
| | % waste that can be diverted to MRFs | 0.33 | MoHUA, Circular Economy in Waste Management, 2021 | |





| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3 |
|---|---|---|---|---|
| **in million tonnes** | **Description** | **Data** | | **in US$ million** |
| 2 | Amount of waste diverted from landfills to MRF daily by 2030 = 0.11 * 33% | ~0.036 M tonnes | | ~5 M<br>(1.6 M tonnes * USD 3) |
| | Total operational days | 333 | MoHUA, Circular Economy in Waste Management, 2021 | |
| | Additional MRF by 2030 | 995 | Calculated in section VII, pathway A, part A | |
| | Amount of waste diverted by 1 MRF per year = 0.036 * 333 / 995 | 0.012 M tonnes | | |
| | CO2e created by burning 1 tonne of waste | 0.14 tonnes | CPCB, LCA Study of Plastics Packaging Products, 2018 | |
| | Total annual CO2e averted by 1 MRF = 0.012 M * 0.14 | 1680 tonnes | | |
| | Additional MRF by 2030 | ~1000 | Calculated in section VII, pathway B, part A. Solid Waste Management | |
| | Total annual CO2e averted by all MRFs = 1680 * 1000 | 1.6 (~2) M tonnes | | |
| **CBG for agriculture residue** | | | | |
| 2 | Potential annual GHG reduced per plant | 0.031 M tonnes/year | Expert interviews, benchmarked to Verbio | 5.4 M<br>(1.8 M tonnes * USD 3) |
| | Average capacity utilisation of CBG plants | 70% | Renewable Watch, Harnessing CBG: Punjab's efforts to mitigate waste and generate renewable energy, 2024 | |

| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3 |
|---|---|---|---|---|
| in million tonnes | Description | Data | | in US$ million |
| 2 | Actual GHG reduced per plant = 0.031 * 70 | 0.0217 M tonnes/year | | 5.4 M<br><br>(1.8 M tonnes * USD 3) |
| | No. of additional plants required by 2030 | ~90 | Calculated in section VII, pathway B, part B. Agriculture | |
| | Total annual GHG abated = 0.0217 * 90 | 1.8 (~2M) tonnes/year | | |
| **Co-firing bio-pellets** | | | | |
| 3 | CO2e emissions abated by all plants | 37 M tonnes | CSE, Status of Biomass Co-Firing in Coal Based Thermal Power Plants In Delhi NCR, 2023 | ~10.5 M<br><br>(3.45 M tonnes * USD 3) |
| | Annual bio-pellets mandated | 53 M tonnes | PIB, Union Minister for Power and New & Renewable Energy, 2023 | |
| | CO2e emissions abated per bio-pellet = 37/53 | 0.69 (~0.7) | | |
| | Additional annual bio-pellets to TPP by 2030 | 5 M tonnes | Calculated in section VII, pathway B, part B, Agriculture | |
| | CO2e emissions abated annually by 2030 plants = 0.69 * 5 | 3.45 (~3) M tonnes | | |





| CO2e million tonnes abated per year | Rationale | | Source | Carbon Credits<br>Cost price of 1 carbon credit is ~USD 3 |
|---|---|---|---|---|
| in million tonnes | Description | Data | | in US$ million |
| **Improved cooking solutions** | | | | |
| 95 | No. of cooking solutions deployed | 53,025,000 | GAIA, Global Alliance for Clean Cookstoves, 2013<br><br>Dalberg study targeted transitioning 56 million households; As per PMUY, ~100M households given LPG given connections, hence remaining ~50M need improved cooking solutions | 300 M<br><br>(100 M tonnes * USD 3 |
| | Adoption rate of cooking solutions | 45% | Duke University, Adoption and Short-term Impacts of Improved Cookstoves in Rural India, 2017 | |
| | CO2e averted per year per cooking solution | 4 tonnes | EcoAct, Improved cookstoves help in transition to low-carbon economy, 2021 | |
| | Annual GHG averted by all cooking solutions = 45% * 53,025,000 * 4 | ~95 (~100) M tonnes | | |

## C. Computation of DALYs Averted by Solution

Note: to calculate DALYs averted per p.p.:

- Total 54M DALYs in 2019[296]
- ~90% PM2.5 reduction required from 2019 levels to safe level of 5 to avert all these DALYs[297]
- Hence, 54M/90 = 0.6 M DALYs averted per p.p.
- i.e., DALYs averted by solution = % point of PM 2.5 reduction * 0.6M

| DALYs reduced by the solution | Rationale | | Source |
|---|---|---|---|
| in no. of days | Description | Data | |
| **E-buses** | | | |
| 30,000 | Contribution of India's buses to PM2.5 | 0.7% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | Additional e-buses in India 2025-2030 | 187,904 (~188,000) | Calculated in section VII, pathway A, part A |
| | Number of buses currently in India | 2,400,000 | ICCT, Facilitating electric bus adoption by private bus operators across India - International Council on Clean Transportation, 2024 |
| | % of PM2.5 reduction by solution = 0.7% * 187,904 / 2,400,000 | ~0.1% | |
| | DALYs averted by solution | ~30,000 | |
| **E-trucks** | | | |
| 2,500 | Contribution of India's trucks to PM2.5 | 0.8% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | # of e-trucks in 2030 | 10,000 | PSA, ZET Adoption in India and its Impact on Emission and Energy, 2025<br><br>ICCT projections for 2030 based on PSA |
| | Total number of trucks in India currently | 2,000,000 | NITI Aayog, Transforming Trucking in India, 2022 |
| | % of PM2.5 reduction by solution = 0.8% * 10,000 / 2,000,000 | 0.004 | |
| | DALYs averted by solution | ~2,500 | |
| **Zig-zag kilns** | | | |
| 360000 | Contribution of traditional brick kilns to India's PM2.5 | 3% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of PM2.5 reduction by solution | 1% | GreenTech, Guidance Document on Environmental Technologies for Brick Kilns in India, 2023 |
| | DALYs averted by solution | 360,000 | |
| **CBG for solid waste** | | | |
| 2,500,000 | Contribution of solid waste open burning to India PM2.5 | 9% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of organic waste in solid waste | 50.00% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | Contribution of organic waste open burning to India's PM2.5 = 9% * 50% | 4.5% | CSE, Greening India's Energy Mix with Compressed Biogas (CBG), 2023 |
| | Additional CBG from MSW capacity required by 2030 | 99,605 | CSE, Greening India's Energy Mix with Compressed Biogas (CBG), 2023 |
| | Total amount of waste that should be diverted to CBG plants | 103,973 | CPCB, MSW Annual Report 2021-22, 2022<br><br>Assuming all unprocessed waste is susceptible to burning and 50% is organic |

| DALYs reduced by the solution | Rationale | | Source |
|---|---|---|---|
| in no. of days | Description | Data | |
| 2,500,000 | % of PM2.5 reduction by solution = 4.5% * 99,605/103,973 | ~4% | |
| | DALYs averted by solution | 2,500,000 | |
| **MRFs** | | | |
| 1,800,000 | Contribution of solid waste open burning to India's PM2.5 | 9% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of waste that can be directed to MRFs | 33% (~30%) | MoHUA, Circular Economy in Waste Management<br><br>Assuming proportion of recoverable waste in MSW is same as that in MSW burnt |
| | % of PM2.5 reduction by solution = 9% * 33% | 3% | |
| | DALYs averted by solution | ~1,800,000 | |
| **CBG for agriculture residue** | | | |
| 750,000 | % of stubble directed to CBG plants by 2030 | 9.67% | PIB, Compressed Bio Gas (CBG) is the Need of the Hour, 2022<br><br>Benchmarked to Verbio |
| | Contribution of crop residue burning to India's PM2.5 | ~13% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of PM2.5 reduction by solution = 9.67% * 13% | ~1.3% | |
| | DALYs averted by solution | ~750,000 | |





| DALYs reduced by the solution | Rationale | | Source |
|---|---|---|---|
| in no. of days | Description | Data | |
| **Co-firing bio-pellets** | | | |
| 780,000 | Contribution of crop residue burning to India's PM2.5 | 13% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of stubble that can be sent to bio-pellet plant in 2030 | 10% | Expert interviews: at 7%, India needs ~50M tonnes annually; currently only ~5% of stubble goes to TPPs, this number can be 2x by 2030 |
| | % of PM2.5 reduction by solution = 13% * 10% | 1.3% | |
| | DALYs averted by solution | 780,000 | |
| **Improved cooking solutions** | | | |
| 1,300,000 | Contribution of residential combustion for cooking to India's PM2.5 | 21% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | PM 2.5 reduction by improved cooking solutions | 65% | Expert interviews: ~60% reduction by Tier 3 cookstoves and ~80% by tier 4/5 cookstoves; hence weighted averaged 65% |
| | # of improved cooking solutions required | ~53 M | GAIA, Global Alliance for Clean Cookstoves, 2013<br>Dalberg study targeted transitioning 56 million households; As per PMUY, ~100M households given LPG given connections, hence remaining ~50M need improved cooking solutions |
| | No. of households in 2030 | 379 K | WEF, These will be the World's Most Populous Countries by 2030, 2022<br>Assuming 4 people per household |
| | Adoption of cooking solutions | 45% | Duke University, Adoption and Short-term Impacts of Improved Cookstoves in Rural India, 2017 |
| | % of PM2.5 reduction by solution = 21% * 65% * 53 M / 379 K * 45% | 2.1 (~2) % | |
| | DALYs averted by solution | ~1,300,000 | |

| DALYs reduced by the solution | Rationale | | Source |
|---|---|---|---|
| in no. of days | Description | Data | |
| **MRS** | | | |
| 800,000 | % PM2.5 contribution by road dust | 3% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | PM 2.5 reduction by MRS | 45% | IJERT, An Audit of Mechanised Road Sweeping Operations in National Capital of India- A case Study, 2020<br><br>Indore audit: assuming reduction in RSPM and PM2.5 similar; triangulated with Toronto study |
| | % of PM2.5 reduction by solution = 3% * 45% | ~1.5% | |
| | DALYs averted by solution | 800,000 | |
| **APCDs and CEMS** | | | |
| 1,500,000 | % PM2.5 contribution by boilers | 3% | Economic Times, KPI Green Energy's expenses up over 88% as Q4 profit jumps 91%, 2025<br><br>TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | PM 2.5 reduction by installing cyclone separator | 70% | Expert interviews, benchmarked to sector averages |
| | % of PM2.5 reduction by solution = 3% * 70% | 2.4% | |
| | DALYs averted by solution | 1,500,000 | |





| DALYs reduced by the solution | Rationale | | Source |
|---|---|---|---|
| in no. of days | Description | Data | |
| **FGD** | | | |
| 230,000 | % PM2.5 contribution by TPPs | 3% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | TPP capacity without FGD installed and without bids awarded | 20,174 | Other sources estimate 6-14% including indirect PM2.5 creation from SO2 and NOx; we only consider direct PM2.5 for aggregate comparison |
| | Total TPP capacity without FGDs (including Category C) | 94,049 | Expert interviews, benchmarked to current sector trends |
| | PM 2.5 reduction by installing FGD | 60% | Expert interviews, benchmarked to current sector trends |
| | % of PM2.5 reduction by solution = 3% * 20,174/94,049 * 60% | 0.4% | |
| | DALYs averted by solution | ~230,000 | Expert interviews, benchmarked to current sector averages |
| **Construction safeguards** | | | |
| 230,000 | Contribution of construction to India's PM2.5 | 3% | TERI, Development of Spatially Resolved Air Pollution Emission Inventory of India, 2021 |
| | % of PM2.5 reduction by solution = 0.25 * 3% | ~0.8% | Expert interviews, benchmarked to reduction in PM2.5 due to construction safeguards in Delhi-NCR |
| | DALYs averted by solution | ~450,000 | |
| **LCS** | | | |
| Low-cost sensors serve as monitoring tools rather than mitigation measures, so they do not directly reduce PM2.5 concentrations and therefore do not avert DALYs. | | | |

## D. Computation of cost savings by solution

| Cost Savings in no. of days | Rationale: Description | Rationale: Data in US$ | Source |
|---|---|---|---|
| **E-buses** | | | |
| 5.1 billion in 1 year<br><br>(~25 billion in 5 years) | # of additional e-buses in India 2025-2030 | **187,904 (~188,000)** | Calculated in section VII, pathway A, part A: Transport |
| | Annual savings in TCO for one intra-city (9m) bus | ~4,100 | WRI, Procurement of Electric Buses<br><br>Cost per km is 1.33% less than diesel counterpart; buses average 150 km daily |
| | Annual savings in TCO for all intra-city (9m) buses = 4132 * 188,000 * 70% | ~0.5 billion | 70% intracity buses |
| | Annual savings in TCO for one inter-city (12m) bus | ~19,000 | WRI, Procurement of Electric Buses<br><br>Cost per km is 18% less than diesel counterparts; buses average 350 km daily |
| | Annual savings in TCO for all inter-city (12m) buses = 19,740 * 188,000 * 30% | ~1.1 billion | 30% intercity buses |
| | Annual savings in TCO for all e-buses = 1.1 + 0.5 | ~1.6 billion | |
| | Total annual oil cost savings | ~3.5 billion | NITI Aayog, Mobilising Finance for EVs in India, 2021<br><br>Assuming 10-year lifetime of an e-bus |
| | Total cost savings = 1.6 + 3.5 | ~5 billion | |
| **E-trucks** | | | |
| ~1.2 billion over 1 year | # of additional e-trucks in India 2025-2030 | **10,000** | Calculated in section VII, pathway A, part A: Transport |
| | Annual savings in TCO for one MDT | ~6,100 | NITI Aayog, Transforming Trucking in India, 2022 |
| | Annual savings in TCO for all MDTs = 6100 * 10,000 * 0.5 | ~300 million | |
| | Annual savings in TCO for one HDT | 40,000 | Assuming ~50% MDTs |
| | Annual savings in TCO for all HDTs = 40,000 * 10,000 * 0.5 | ~860 million | NITI Aayog, Transforming Trucking in India, 2022 |
| | Annual savings in TCO for all e-trucks = 300 + 860 | ~1.15 (~1.1) billion | |
| | Annual savings in oil imports for one e-truck | ~3500 | Assuming an average e-truck travels 200km a day for 216 days a year, with an average of 7km/litre (extrapolation: 88% of crude oil is imported, and import price being ~85 USD per barrel) |
| | Annual savings in oil imports for all e-trucks | 35 million | |





| Cost Savings in no. of days | Rationale: Description | Rationale: Data in US$ | Source |
|---|---|---|---|
| **Zig-zag kilns** | | | |
| 0.15 billion over 1 year<br><br>(0.75 billion over 5 years) | Annual savings from reduction in coal usage | **~150 million** | New Indian Express, Opportunities and challenges in converting brick kilns to zig-zag tech, 2024<br><br>Saving of 6 M tonnes of coal, triangulated with Shakti Foundation |
| **CBG for solid waste** | | | |
| ~900 million over 1 year<br><br>(~4.5 billion over 5 years) | Total CBG output by 2030 (200 plants * 18 TPD output) | **3,600 TPD** | Calculated in section VII, pathway B, part A: Solid Waste Management |
| | Cost saved by govt on fertiliser subsidies | US$ 176,470 per TPD | CEEW, How can India Invest in Scaling Compressed Biogas?, 2025 |
| | Total costs saved on fertiliser subsidies due to all CBG plants = 3,600 * 176,470 | ~630 million | |
| | Annual DAP fertiliser consumption by India | 10 million tonnes per year | Fertiliser Association of India, Annual Report 2024-25, 2025 |
| | Subsidised price of DAP | US$ 42 per tonne | |
| | Cost savings | 67% | PIB. Ministry of Chemicals and Fertilisers, 2025 |
| | Total annual cost savings to farmers = 10 * 42 * 67% | ~270 million | |
| | Total annual cost savings by CBG for agricultural residue | 900 million | CEEW, How can India Invest in Scaling Compressed Biogas?, 2025 |
| **CBG for agriculture residue** | | | |
| ~810 million over 1 year<br><br>(~3 billion over 5 years) | Total CBG output by 2030 (92 plants * 33 TPD output) | **~3000 TPD** | MoPNG, Benchmarked to Verbio |
| | Cost saved by govt on fertiliser subsidies | US$ 176,470 per TPD | CEEW, How can India Invest in Scaling Compressed Biogas?, 2025 |
| | Total annual costs saved on fertiliser subsidies due to all CBG plants = 176,470 * 3000 | ~540 million | |
| | Annual DAP fertiliser consumption by India | 10 million tonnes per year | Fertiliser Association of India, Annual Report 2024-25, 2025 |
| | Subsidised price of DAP | 42 per tonne | PIB. Ministry of Chemicals and Fertilisers, 2025 |
| | Cost savings | 67% | CEEW, How can India Invest in Scaling Compressed Biogas?, 2025 |
| | Total annual cost savings to farmers = 10 * 42 * 67% | ~270 million | |
| | Total annual cost savings by CBG for agricultural residue | 810 million | |

# Endnotes

## I. Executive Summary

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## II. Context: Air Pollution as an Economic Opportunity

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[31]California Dept of Transportation, Review of Street Sweeping Measures for Reducing PM Road Dust Emissions

[32]Linearity Assumption – This report, consistent with the report in 2021, assumes that the impact of increasing or decreasing pollution linearly translated into higher or lower level of presenteeism. This assumption has been taken as several academic papers (e.g. study by Neidell et al) mapped pollution levels across the range of 25 to 175 and found a linear relation to hold within these intervals.



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[34]Center for Effective Global Action, More than particulates matter: Multiple pollutants and productivity in Indian call centers, 2025

[35]Department of Economics, Goethe University Frankfurt & University of Vienna, Air Quality, Knowledge Worker Performance, and Adaptation: Evidence from GitHub, 2023

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[38]Economic Times, Significant dip in footfall at commercial, tourist places in Delhi due to pollution claims recent study, 2022

[39]New Indian Express, Delhi Pollution: Breathless in capital, no respite from toxic air, 2025

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[41]Center for Research on Energy and Clean Air, Quantifying the Economic Costs of Air Pollution from Fossil Fuels, 2020

[42]The safe PM2.5 threshold was derived using a weighted average approach based on the proportion of India's population considered sensitive to air pollution exposure. As per demographic data, approximately 35.98% of India's population falls within sensitive groups (children, elderly, and individuals with chronic respiratory diseases). Using reference safe limits—35 µg/m³ for sensitive groups and 55 µg/m³ for the general population—the weighted average safe exposure level was calculated as:
Safe PM2.5 = (0.3598 × 35) + (0.6402 × 55) = 47.8 µg/m³

[43]Projected based on weighted PM2.5 distribution data from sensors in urban and rural areas; A. CPCB , 2023; B. IQAIr

## IV. Analysis of Opportunities Across Sectors and Solutions

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[62]Key initiatives currently active include PM E-DRIVE and Voluntary Vehicle-Fleet Modernisation Programme

[63]Business Standard, FAME III: India to replace 800k diesel buses with electric over 7 years

[64]Business Standard, India's e-bus sales likely to grow 3.6-fold in FY27, projects CareEdge

[65]These figures represent the gross impacts of deploying approximately 200,000 e-buses, and do not account for net effects arising from the phase-out of internal combustion engine (ICE) buses, such as potential job or revenue losses during the transition.

[66]Expert interviews

[67]Ibid.

[68]NEBP will add 50,000 e-buses and PM e-Bus Sewa will add 38,000 e-buses. PIB, Press Release: Press Information Bureau, 2024; Ministry of Heavy Industries, PM e-Bus Sewa-Payment Security Mechanism (PSM) Scheme, 2024

[69]Expert interviews, benchmarked to current market rates

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[72]CCMV360, PM E Drive Scheme Cuts Subsidies for Electric Buses: New Rate Set at Rs 10,000 per kWh, 2024

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