

# A ROADMAP FOR CLEAN AIR IN AMAZON CITIES

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The Amazon is home to more than 30 million people and over half of Brazil's Indigenous population. Its cities, now home to more than 10 million residents, are expanding rapidly. Yet, residents breathe unsafe air every day. Air pollution has become an urban crisis that costs lives, overwhelms health systems, and stifles economic growth.

The pathway to cleaner air in Amazonian cities must be grounded in Brazil's evolving policy frameworks, including the National Policy on Air Quality, the updated CONAMA Resolution 491/2018 with progressive fine particulate matter (PM<sub>2.5</sub>) standards through 2044, the National Climate Change Policy, and the forthcoming 20-Year National Air Quality Plan. These frameworks establish compliance timelines, reporting obligations, and instruments such as the National Air Quality Information System and State and Municipal Plans.

Investments must be aligned with financing cycles and synchronized with federal and state budgets, the Amazon Fund, and MDB operations such as the World Bank's AM Pro-Sustentabilidade and the IDB/GCF Amazon Bioeconomy Fund, to ensure projects can move from planning to disbursement within 12 to 24 months. They must also be connected to international commitments, including Brazil's NDC under the Paris Agreement, the Global Methane Pledge, and the Sustainable Development Goals, which create entry points for co-financing and recognition of air quality improvements as climate and health achievements.

Brazil's hosting of COP30 in Belém will bring global attention to Amazon sustainability, creating a moment to showcase specific measures that unite clean air, climate, health, equity, and economic opportunity. This transformation requires a coalition in which: federal, state, and municipal governments share leadership; the private sector commits to cleaner practices; and civil society, including Coalizão Respira Amazônia and academic partners such as Fiocruz and IMPA, ensures oversight and inclusion.

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## KEY POINTS

- Brazil's evolving policy frameworks set the stage for ambitious clean air action.
  - Investments should align with major funding sources and leverage international climate finance.
  - COP30 in Belém is a chance to showcase integrated solutions for health, climate, and equity.
  - Priority interventions include industrial controls, clean transport, renewable energy, and regional monitoring systems.
  - Cleaner air is the key to unlocking health, prosperity, and climate resilience for Amazonian cities.
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## CONCRETE PRIORITY INTERVENTIONS

The following preliminary list of high-impact priority investments for Amazon Cities (Table 1) stems from this project’s scientific analysis of air pollution, emission sources, and impacts, as well as consultations with key stakeholders, including a regional virtual workshop, in-person discussions in Manaus, and targeted interviews and meetings.

Presented for illustrative purposes only, this table does not prescribe specific actions or scales of intervention, but rather illustrates the magnitude of opportunities and the level of ambition required. Cost ranges are indicative, drawing on international benchmarks and conservative adjustments for Amazon-specific conditions. The list highlights interventions across major emission sources—industrial controls, urban and river transport, and energy access—together with cross-cutting measures such as a Regional Air Quality Monitoring and Early-Warning System in the Amazon Region. Collectively, these proposals point to scalable investments that can deliver cleaner air and maximize health, climate, equity, and economic co-benefits while reinforcing sustainable development pathways in the region.

These proposed investments are intended to inform a future multi-donor, multi-investor regional initiative aligned with federal, state and municipal air quality and climate plans. Clean air investments should prioritize sectors that deliver the fastest and most visible health, climate, equity, and economic co-benefits, while creating synergies with dynamic areas such as bioeconomy, sustainable tourism, and regenerative agriculture.

For example, embedding air quality, health and equity indicators into major investments, such as the World Bank’s AM Pro-Sustentabilidade (US\$592.5M) and the IDB/GCF Amazon

Bioeconomy Fund (US\$598M), would multiply returns, safeguard against unintended impacts, and help ensure that development prompted by these emerging drivers is fully compatible with clean air, health, and climate goals for all.

## AMAZON REGION AIR QUALITY MONITORING AND EARLY-WARNING SYSTEM

Special mention should be made of the opportunity to invest in the development of a regionwide, integrated and coordinated Air Quality Monitoring and Early-Warning System for the Legal Amazon, identified through technical analysis and stakeholder consultations as a priority cross-cutting action to enable clean air efforts across the region. Effective monitoring is the backbone of smart investments: it ensures accountability, guides enforcement, and proves health and climate gains. In the Amazonian context, a region-wide, integrated and coordinated regional system is essential, moving beyond fragmented, city-by-city initiatives toward a shared platform that reflects the ecological and transboundary realities of the region. When integrated with early-warning systems and health surveillance systems, it also provides timely alerts on fires, pollution peaks, and health risks—protecting communities and enabling performance-based finance.

This system should also be anchored in the development of:

- **Regional emission inventories, atmospheric models, and analytical tools** capable of pinpointing sources and hotspots in near real-time, allowing authorities to distinguish between fire-related, transport, industrial, and waste-burning emissions, improving both policy design and enforcement.
- **Integration with national systems**, including MonitorAr, INPE Queimadas, MapBiomass Fogo, and Vigiar, a program under the Unified Health System (SUS, Sistema Único de Saúde), so that air pollution, fire, weather, and health data are merged into a unified early-warning and response platform.
- **Institutional partnerships** with IMPA, Fiocruz, INPA, and federal and state universities to ensure scientific credibility, public health relevance, and operational sustainability.

**TABLE 1. PRELIMINARY CLEAN AIR INVESTMENTS FOR AMAZON CITIES: CLEAN AIR ACTIONS WITH CO-BENEFITS FOR HEALTH, CLIMATE, EQUITY, AND ECONOMY**

PRIORITY AREA	PROPOSED INTERVENTION	SCALE AND COST	POTENTIAL PARTNERS
Industrial emissions	Install advanced controls (filters, scrubbers, SCR) and Continuous Emissions Monitoring Systems (CEMS) in priority factories in the Manaus Free Trade Zone and in Pará's industrial/mining hubs.	~US\$ 50–70M (phased)	SUFRAMA, state env. agencies, WB/IFC, private sector
Bioeconomy and innovation	Launch “Clean Air–Positive Bioeconomy Zones” (zero-burning, renewable energy, clean logistics for agroforestry, açaí, aquaculture and forest products) in 2 pilot regions	~US\$ 60–80M	IDB/GCF Amazon Bioeconomy Fund, Centro de Bionegócios, private investors
Urban transport (land)	Deploy 200 battery-electric buses in Belém and Manaus, with depots and chargers; prepare expansion projects for +500 by 2027	~US\$ 110–135M	CAF/, IDB, municipalities
River and port transport (large ships and freight)	Transition passenger and freight fleets to low- and zero-emission propulsion (electric-hybrid ferries, LNG/hydrogen pilots) and install shore power in major ports (Manaus, Belém, Santarém, Santarém)	~US\$ 150–200M (first wave)	PAC Mobilidade, WB, IDB, CAF, port authorities, private shipping
Cross-sector: fire & land use	Expand community fire brigades and PES pilots in Pará & Amazonas, linked to city-level AQ alerts and enforcement	~US\$ 20–25M	Amazon Fund, GIZ, USAID, ICMBio, state civil defense
Cross-sector: Regionwide monitoring and early-warning	Establish a Regional Air Quality Monitoring and Early-Warning System with regulatory stations, low-cost sensors in high-exposure sites, and QA/QC hubs integrated with MonitorAr, INPE Queimadas, MapBiomass Fogo, Fiocruz, SUS, and state agencies.	~US\$ 12–15M + O&M	MMA, Fiocruz, IMPA, universities, CAF, philanthropy

SCR: Selective Catalytic Reduction; CEMS: Continuous Emissions Monitoring Systems; SUFRAMA: Superintendência da Zona Franca de Manaus (Manaus Free Trade Zone Superintendency); WB: World Bank; IFC: International Finance Corporation; IDB: Inter-American Development Bank; GCF: Green Climate Fund; CAF: Development Bank of Latin America; LNG: Liquefied Natural Gas; PAC: Programa de Aceleração do Crescimento (Growth Acceleration Program); BNDES: Banco Nacional de Desenvolvimento Econômico e Social (Brazilian Development Bank); ESCOs: Energy Service Companies; QA/QC: Quality Assurance/Quality Control; INPE: Instituto Nacional de Pesquisas Espaciais (National Institute for Space Research); SUS: Sistema Único de Saúde (Unified Health System); Fiocruz: Fundação Oswaldo Cruz (Oswaldo Cruz Foundation); IMPA: Instituto de Matemática Pura e Aplicada (Institute for Pure and Applied Mathematics); MMA: Ministério do Meio Ambiente (Ministry of the Environment); O&M: Operations and Maintenance; PES: Payment for Environmental Services; GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit (German Corporation for International Cooperation); USAID: United States Agency for International Development; ICMBio: Instituto Chico Mendes de Conservação da Biodiversidade (Chico Mendes Institute for Biodiversity Conservation); AQ: Air Quality

## Network Design

### • Regulatory (reference-grade)

#### monitoring stations:

Each medium-sized city (100,000–500,000 inhabitants) should host at least one regulatory station; larger cities (Manaus, Belém, São Luís) should operate three to five stations strategically distributed across compliance, hotspot/source-oriented, population exposure, background, and research sites.

### • Key pollutants and parameters

**to be measured:** PM<sub>2.5</sub>, PM<sub>10</sub>, ozone, NO<sub>2</sub>, CO, SO<sub>2</sub>, BC, and VOCs where relevant. Meteorological parameters (temperature, humidity, wind speed/direction, precipitation, solar radiation) are also critical to interpret pollution patterns and model transport.

### • Calibrated low-cost sensor networks:

Calibrated low-cost sensors showing representative concentrations across cities, with a focus on high-exposure and community settings such as schools, health facilities, transport corridors, ports, and fire-prone areas. This complements reference-grade data, expands coverage cost-effectively, and enhances near-real-time hotspot detection.

### • Regional QA/QC, training, and calibration hubs:

Shared regional hubs for quality assurance/quality control, calibration, training, and data management—reducing municipal burdens, ensuring comparability across cities, and building long-term capacity for operation and maintenance.

## ESTIMATED COSTS

The following cost ranges are derived from international benchmark sources and current market values. Combining federal and state budgets, multilateral development banks, philanthropy, and private sector contributions (e.g., corporate social responsibility) through blended finance will be essential to sustain the system and prepare it for performance-based mechanisms.

- Regulatory (reference-grade) stations:
  - Individual equipment for core criteria pollutants and meteorology totals approximately US\$ 240 000–270 000, including analyzers for PM<sub>2.5</sub>, PM<sub>10</sub>, O<sub>3</sub>, NO<sub>2</sub>, SO<sub>2</sub>, CO, calibration systems, datalogger, and meteorological tower.
  - With site installation (power, climate control, fencing), the complete installed cost averages US\$ 260 000–300 000 per station.
  - However, by adopting modular configurations, enabling local assembly of shelters and system components, and employing selective instrumentation, such as multipollutant or hybrid analyzers focused on priority pollutants (e.g., PM<sub>2.5</sub>, O<sub>3</sub>, and NO<sub>2</sub>), optimized regulatory-grade stations can realistically range between US\$ 120,000 and US\$ 180,000. This range represents a realistic lower bound for well-designed, locally adapted installations in Amazon-region cities.
  - Annual operations and maintenance per station: approximately US\$ 8 000–12 000 depending on logistics, calibration frequency, and staffing.
- Low-cost sensor units:
  - US\$ 400–2 000 per unit, depending on sensor type, housing, connectivity, and calibration requirements.
  - Annual operations and maintenance: roughly US\$ 200–400 for recalibration, data management, and replacement cycles.
- Regional QA/QC hubs:
  - US\$ 400 000–600 000 per hub (including calibration labs, training facilities, data servers, and staff).
- Estimated total investment for a 10-city integrated regional network:
  - Assuming ~25 reference-grade stations and ~250 low-cost sensors, the aggregate investment is approximately US\$ 10–14 million, plus ~US\$ 1–1.5 million/year for operations and maintenance.

## EXISTING FOUNDATIONS AND SYNERGIES

Several initiatives already provide strong foundations to build an integrated clean air and health agenda for Amazonian cities, as shown in Table 2. In monitoring and early warning, the federal *MonitorAr* program, Fiocruz, INPA, IMPA, and state agencies are building a strong regional base, complemented by *MapBiomias Fogo* and INPE's *Queimadas* system for fire detection. The *Coalizão Respira Amazônia* reinforces this ecosystem with over 180 low-cost sensors across the Legal Amazon, generating open data and linking citizen monitoring with Fiocruz's new Air Quality and Health Surveillance system. In parallel, the Fundação Amazônia Sustentável (FAS) is advancing solar electrification and community-based energy solutions that cut fossil fuel use and improve health. Alongside broader efforts in transport innovation, waste management, green industry, and major multilateral financing programs, these initiatives show that the technical, social, and financial pillars are already aligning to embed clean air and health into the Amazon's development trajectory.

## A CALL TO ACTION

The future of the Amazon depends largely on what happens in its cities. Building on the shared vision outlined in this report, Brazil can advance a coordinated set of clean air investments, endorsed by governments, financed by development banks and climate funds, and co-owned by communities and businesses. This is not only an environmental imperative, but also a health, climate, equity, and economic opportunity of global relevance.

The promise is clear:

- Thousands of lives saved each year through reduced exposure to PM<sub>2.5</sub> and toxic pollutants.
- Billions unlocked in economic value by cutting health costs, boosting labor productivity, and enabling sustainable industries.

- Rapid reductions in climate pollutants, including methane, black carbon, and other SLCs, accelerating progress towards Brazil's NDC and global climate targets.
- Justice and dignity restored to vulnerable and marginalized populations disproportionately burdened by pollution.

To seize this promise, coordinated action across Amazonian cities — involving federal, state, and municipal governments, civil society, communities, and the private sector — is needed to:

- Prioritize high-impact, multi-benefit investments that directly target the main pollution sources, from transport and fossil-fueled power generation to waste burning and illegal fires.
- Coordinate across federal, state, and municipal levels, sharing leadership and aligning with national clean-air policies and standards.
- Advance monitoring and transparency by deploying regional networks, strengthening emission inventories, and integrating ground-based and satellite data.
- Secure co-financing from subnational and national budgets, complemented by international partners, investors, and climate funds, to support sustainable urban development and inclusive economic growth.
- Align clean air investments with climate action, and sustainable economic transformation, ensuring that air quality actions deliver co-benefits.

Cleaner air is the bridge that unites health, climate, equity, and prosperity. ***For Amazonian cities, the time to act for clean air, and to breathe freely, is now.***

TABLE 2. CURRENT AND ONGOING INITIATIVES TO ACHIEVE CLEANER AIR IN AMAZONIAN CITIES

TYPE	CURRENT INITIATIVES
Monitoring and early warning systems	Coalizão Respira Amazônia is expanding air quality monitoring in the Amazon Legal with over 180 low-cost sensors, providing open data to support science, policy, and community awareness on pollution and health.
	The federal MonitorAr program, IMPA (Institute for Pure and Applied Mathematics) projects, Fiocruz (Oswaldo Cruz Foundation), and several universities form a base for a regional monitoring and alert network.
	The National Institute of Amazonian Research (INPA) contributes infrastructure and scientific expertise, complemented by hydrometeorological programs.
	MapBiomass Fogo and INPE's (National Institute for Space Research) Queimadas system are operational tools for fire management, ready to be linked with local monitoring and health alerts.
	A new Air Quality and Health Surveillance Monitoring Platform for the Amazon, led by Fiocruz with support from the Ministry of Environment and Climate Change (MMA), provides a critical anchor.
	State and municipal initiatives, including those led by SEMA (State Environmental Secretariats), bring local capacity to the system.
Energy transition	Solar + storage mini-grids are already replacing fossil fuels in local communities, improving health, reducing emissions, and expanding access.
Transport innovation	NGOs and academic partners have piloted solar-electric boats, demonstrating clean river mobility solutions.
	PAC Mobilidade, a federal program, provides financing opportunities for scaling up river transport electrification.
Waste and urban management	Belém and Manaus are piloting selective collection and composting, creating early entry points for waste sector emissions reduction.
Industry	SUFRAMA's (Manaus Free Trade Zone Authority) green industry initiatives can serve as platforms to introduce industrial emission controls and cleaner production models.
Finance and investment	Large-scale programs such as the World Bank's AM Pro-Sustentabilidade and the IDB/GCF Amazon Bioeconomy Fund together mobilize over US\$1.1 billion, providing leverage to embed clean air and health into the Amazon's bioeconomy growth story.