Interdisciplinar preventive and corrective interventions:
architectural, technical, and behavioural solutions to reduce exposure to indoor and outdoor air pollution

VISIONAIR

Co-funded by the European Union

VYSOKÁ ŠKOLA CHEMICKO-TECHNOLOGICKÁ V PRAZE

UNIVERSITAS CATHOLICA RUŽOMBEROK

SUA Slovak University of Agriculture in Nitra

Sveučilište u Zagrebu

UNIVERSITAS Miguel Hernández

1. Introduction: Framing the Public Health Crisis

1.1. The Unseen Threat and Cognitive Load:

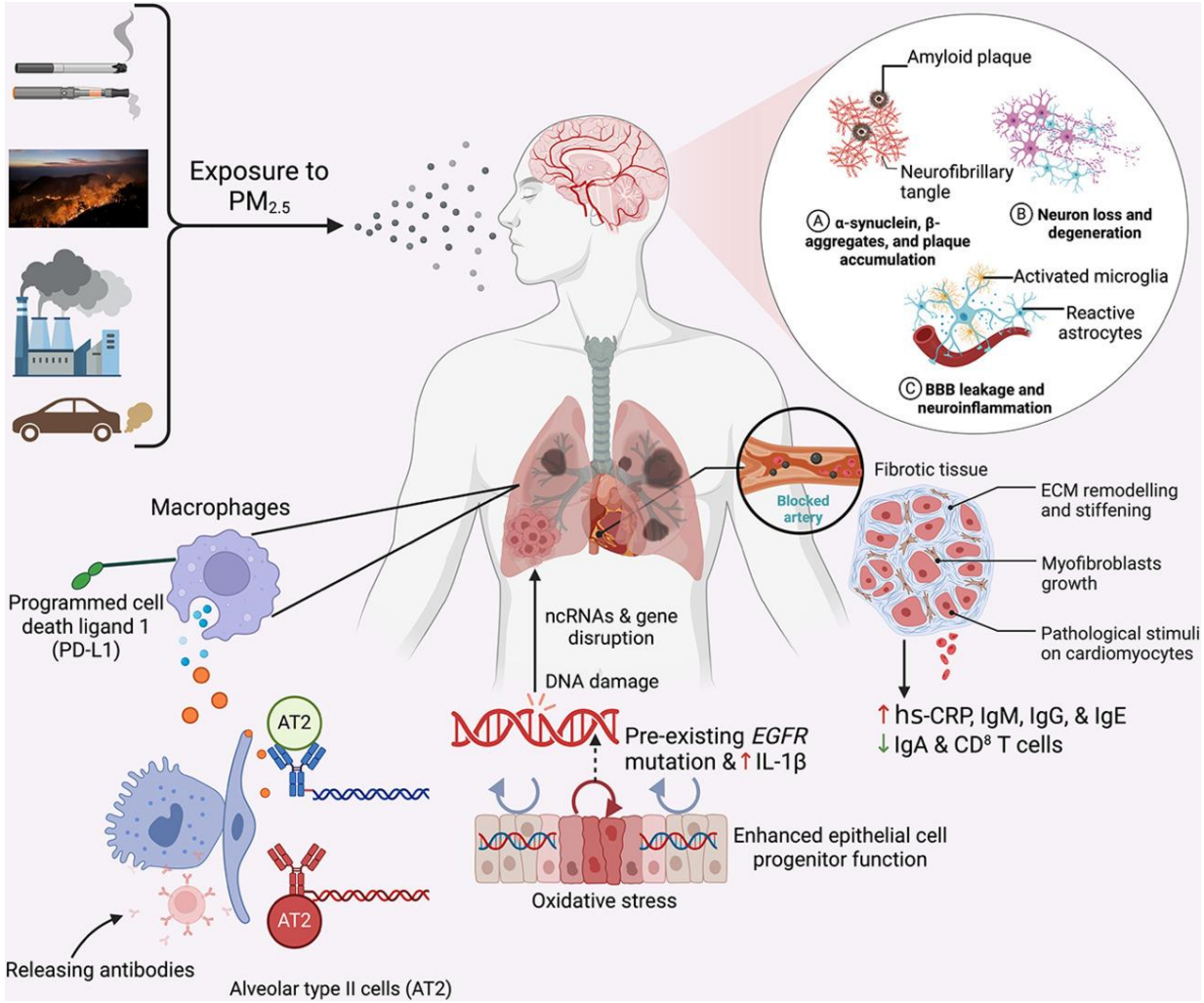
The Scope: Air pollution is the world's largest environmental health risk, responsible for millions of premature deaths annually.



1. Introduction: Framing the Public Health Crisis

1.1. The Unseen Threat and Cognitive Load:

Effects extend beyond respiratory/cardiovascular health to **cognitive function** and **decision-making**, as evidenced by recent neurological studies linking $PM_{2.5}$ exposure to neural disruption.



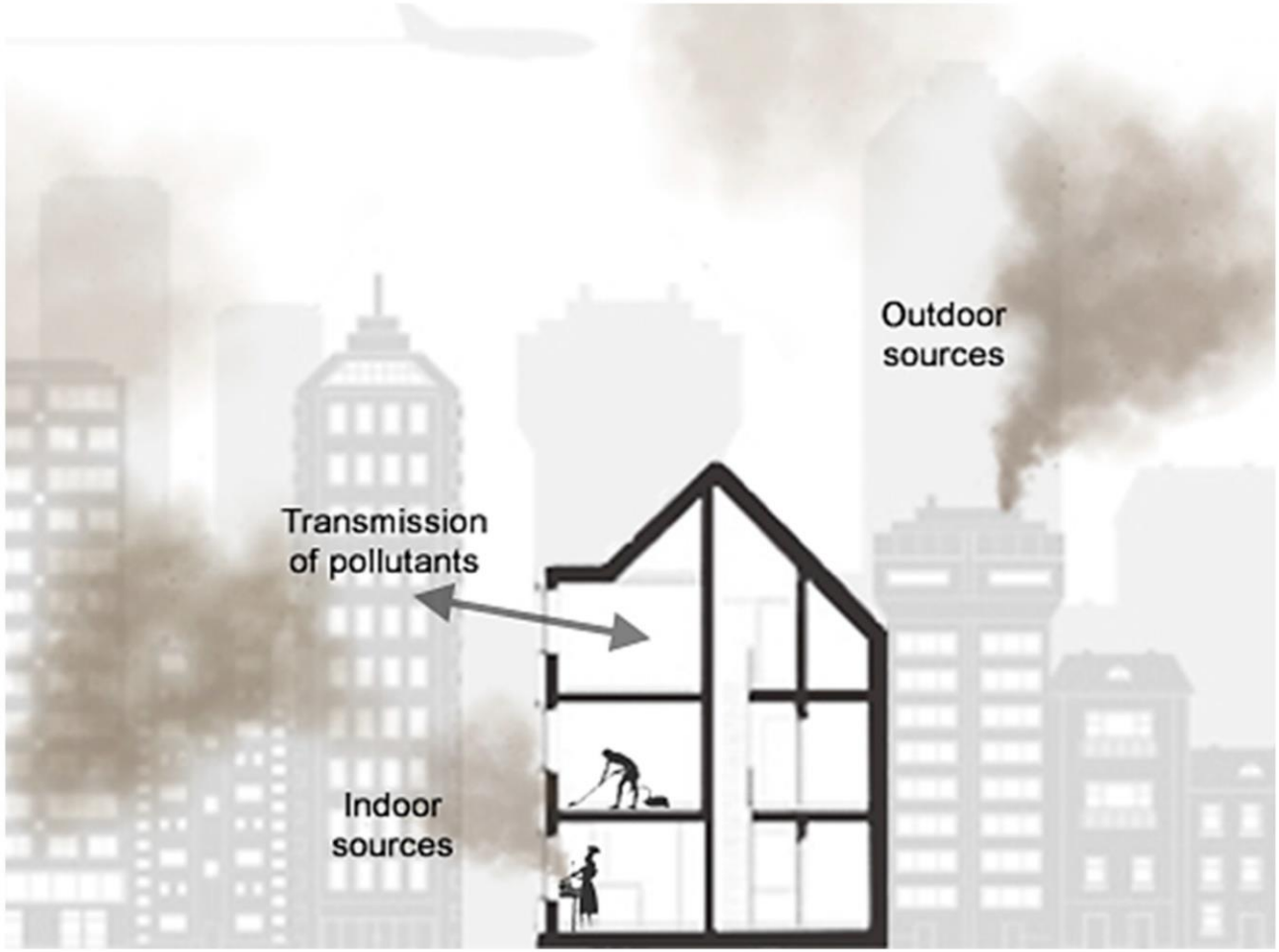
1. Introduction: Framing the Public Health Crisis

1.1. The Unseen Threat and Cognitive Load:

Dual Exposure Reality: People spend 80-90% of their time indoors.

Therefore, **Total Daily Exposure** is a function of both:

- Outdoor Air Pollution (outdoor sources like traffic) and
- Indoor Air Pollution (indoor sources like Volatile Organic Compounds and cooking).

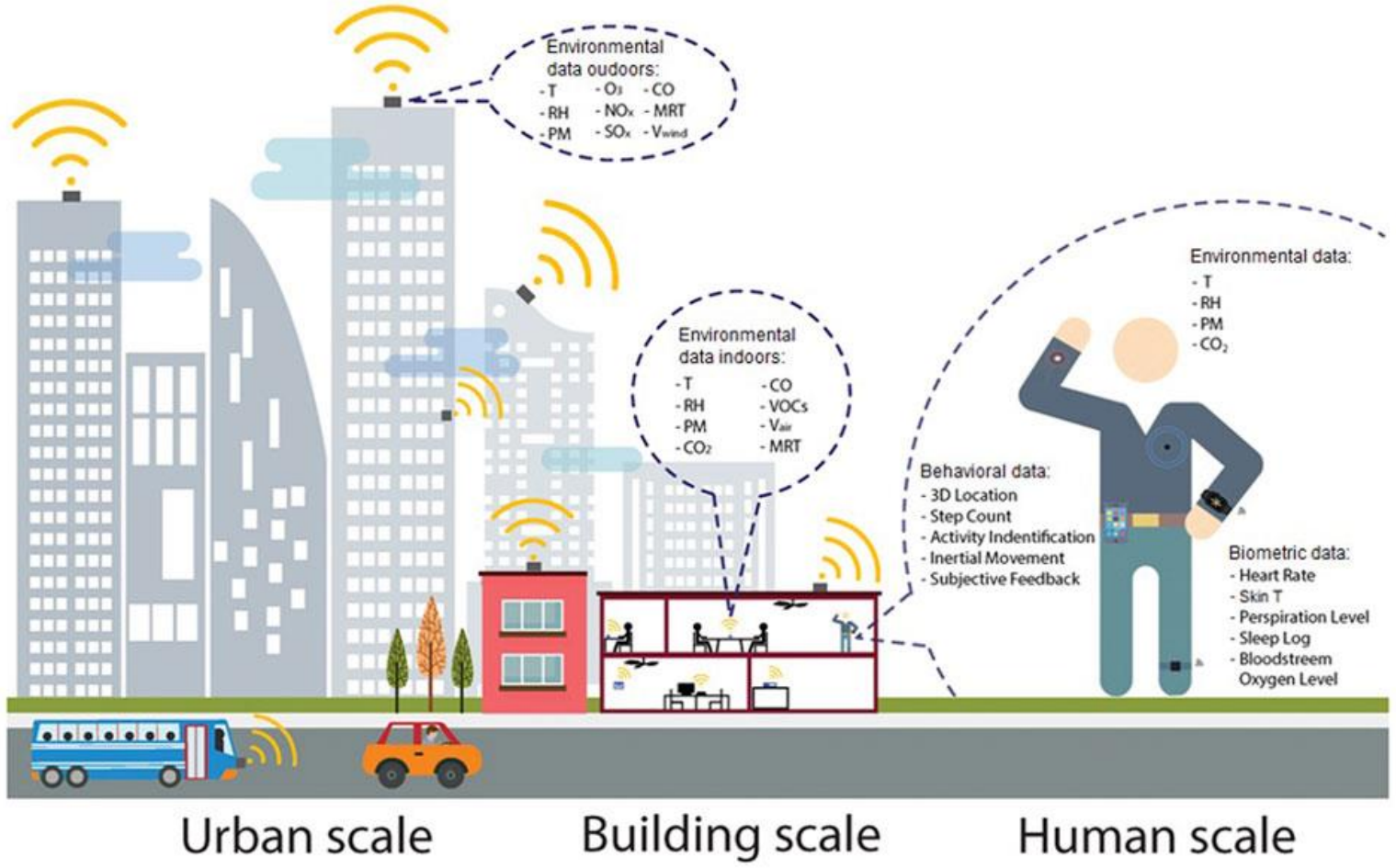


1. Introduction: Framing the Public Health Crisis

1.2. The Interdisciplinary Imperative :

Traditional approaches have been fragmented:

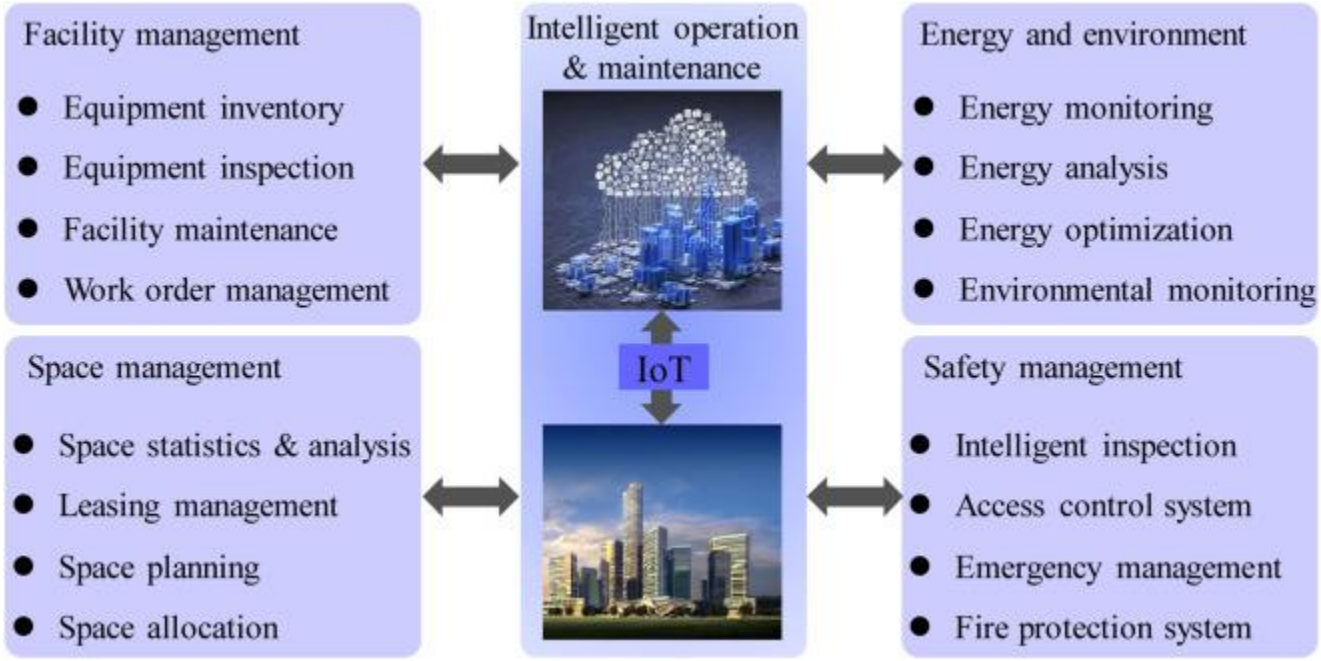
- Engineers focus on systems.
- Architects on design.
- Public health on epidemiology.



1. Introduction: Framing the Public Health Crisis

1.2. The Interdisciplinary Imperative :

The Call for Synergy: We need an integrated framework where **preventive strategies** (source control, urban planning) are complemented by **corrective interventions** (filtration, ventilation), all leveraged by **behavioural adoption.**



1. Introduction: Framing the Public Health Crisis

Roadmap:

We will explore a **three-pillar approach**: Architectural, Technical, and Behavioural solutions, demonstrating their specific roles and necessary points of intersection.

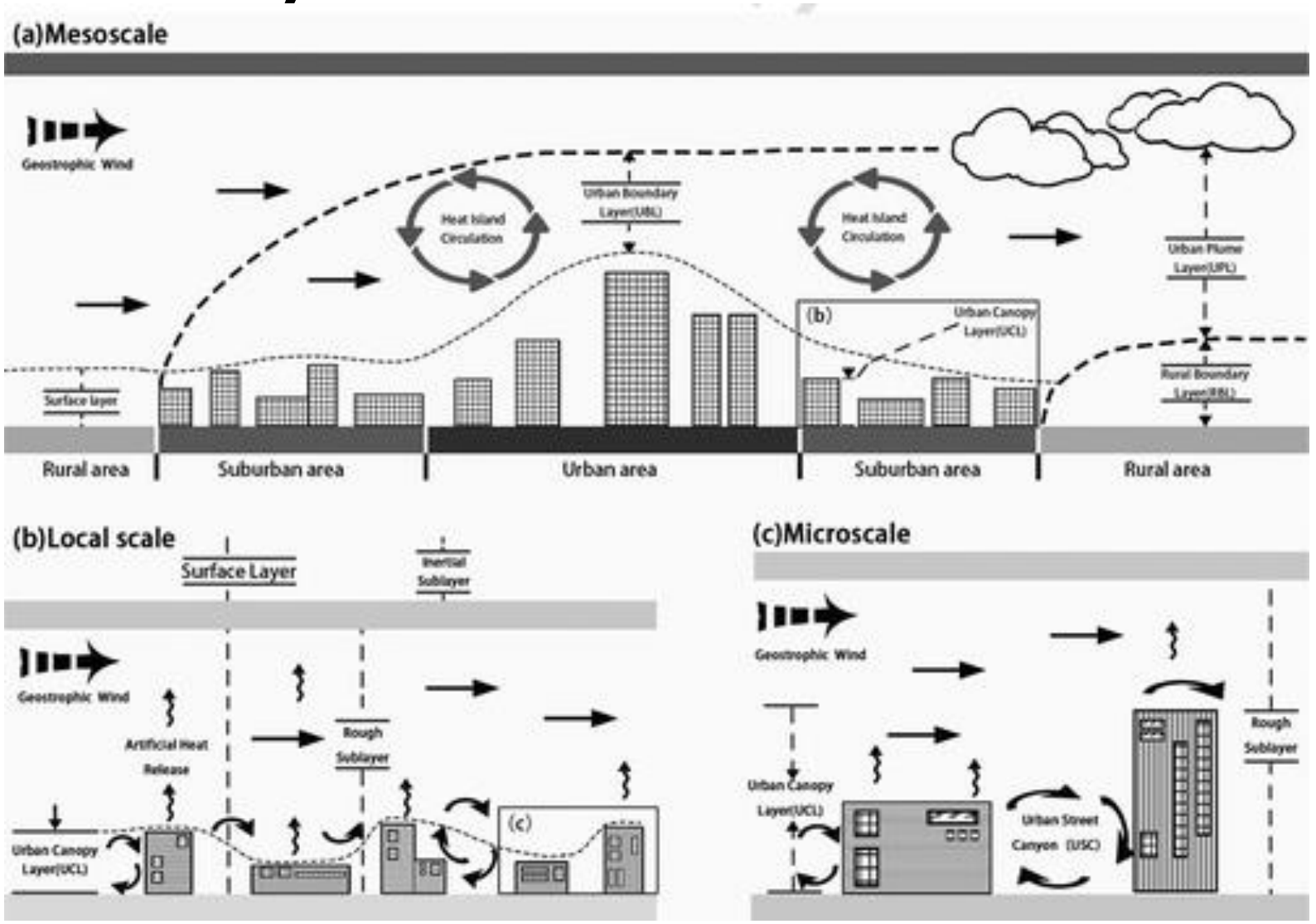


2. Pillar I: Architectural and Urban Mitigation (Preventive and Passive)

2.1. Strategic Urban Design:

Urban Morphology and Airflow: The layout of streets and building density directly impacts pollutant accumulation and dispersion.

Urban Ventilation Wedges (preserving corridors for wind flow) are crucial for flushing OAP, particularly in densely populated cities.



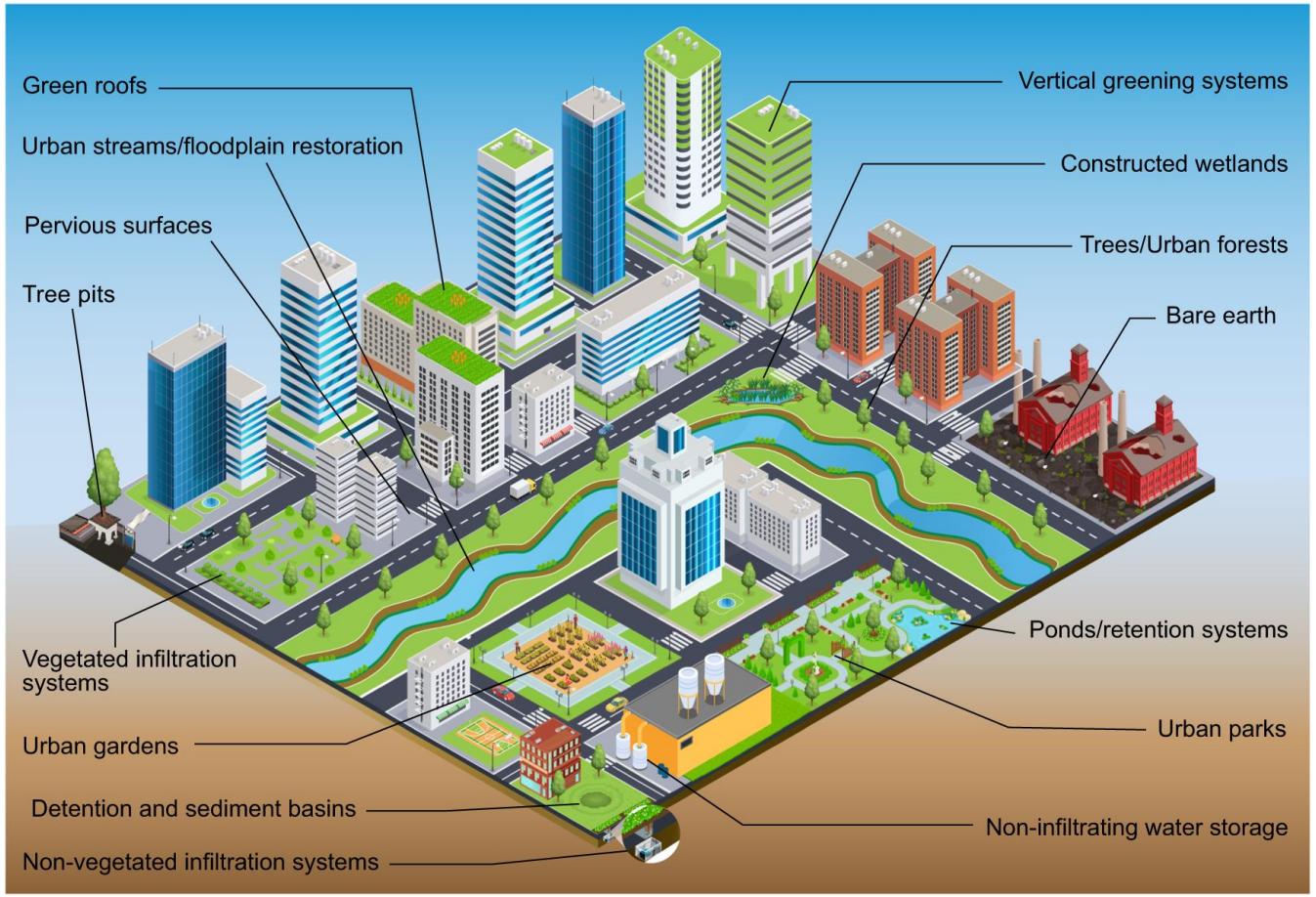
2. Pillar I: Architectural and Urban Mitigation (Preventive and Passive)

2.1. Strategic Urban Design:

Green Infrastructure (GI): Moving beyond aesthetics.

Green roofs and bio-facades act as **physical barriers and biological sinks**, promoting the deposition of coarse and fine PM (e.g., green barriers in school playgrounds have shown quantifiable reductions).

GI must be strategically placed, as effectiveness varies based on local wind and pollutant profiles.



2. Pillar I: Architectural and Urban Mitigation (Preventive and Passive)

2.2. The Passive Building Envelope:

Source Control via Materials: This is the most crucial preventive measure for IAP.

The industry shift to low- or zero-VOC materials (paints, flooring, adhesives) reduces pollutant *generation*.

This is a **mandate for architects** and construction engineers (e.g., using certifications).

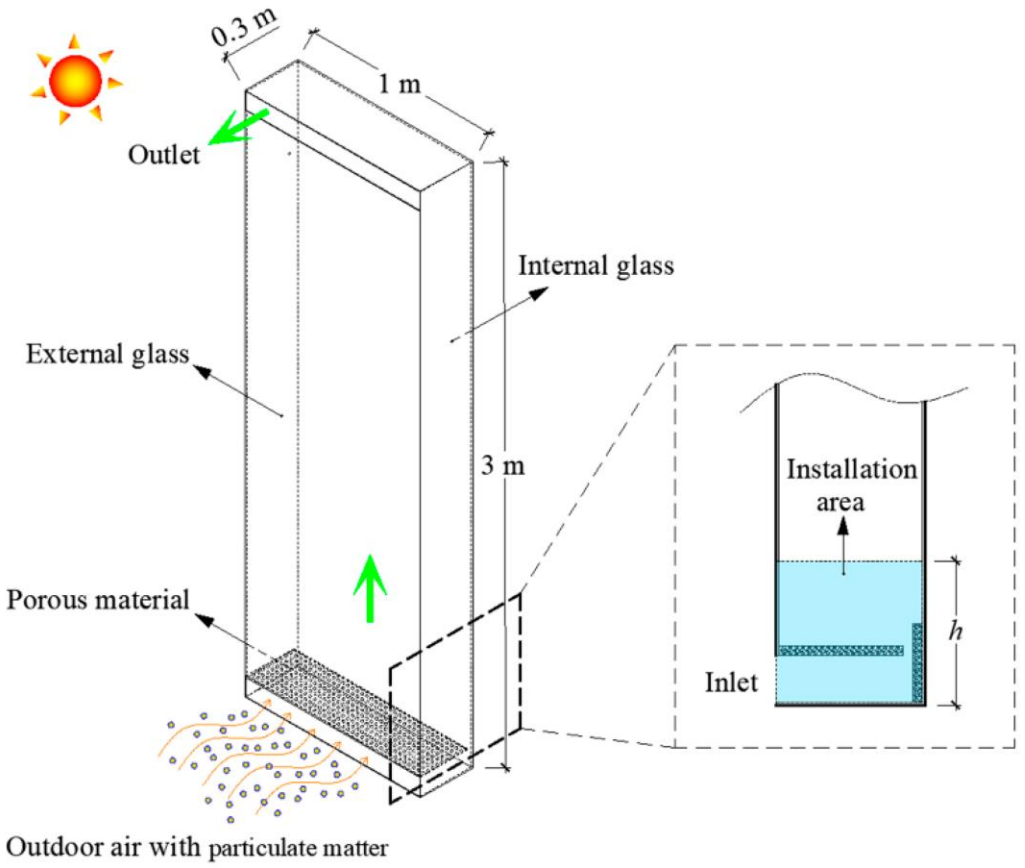


2. Pillar I: Architectural and Urban Mitigation (Preventive and Passive)

2.2. The Passive Building Envelope:

Airtightness and Filtration Readiness: A well-sealed envelope prevents random, uncontrolled infiltration of polluted OAP.

This design choice *enables* effective **Active Systems**, ensuring that all incoming air passes through a filter, rather than leaking through cracks and joints.

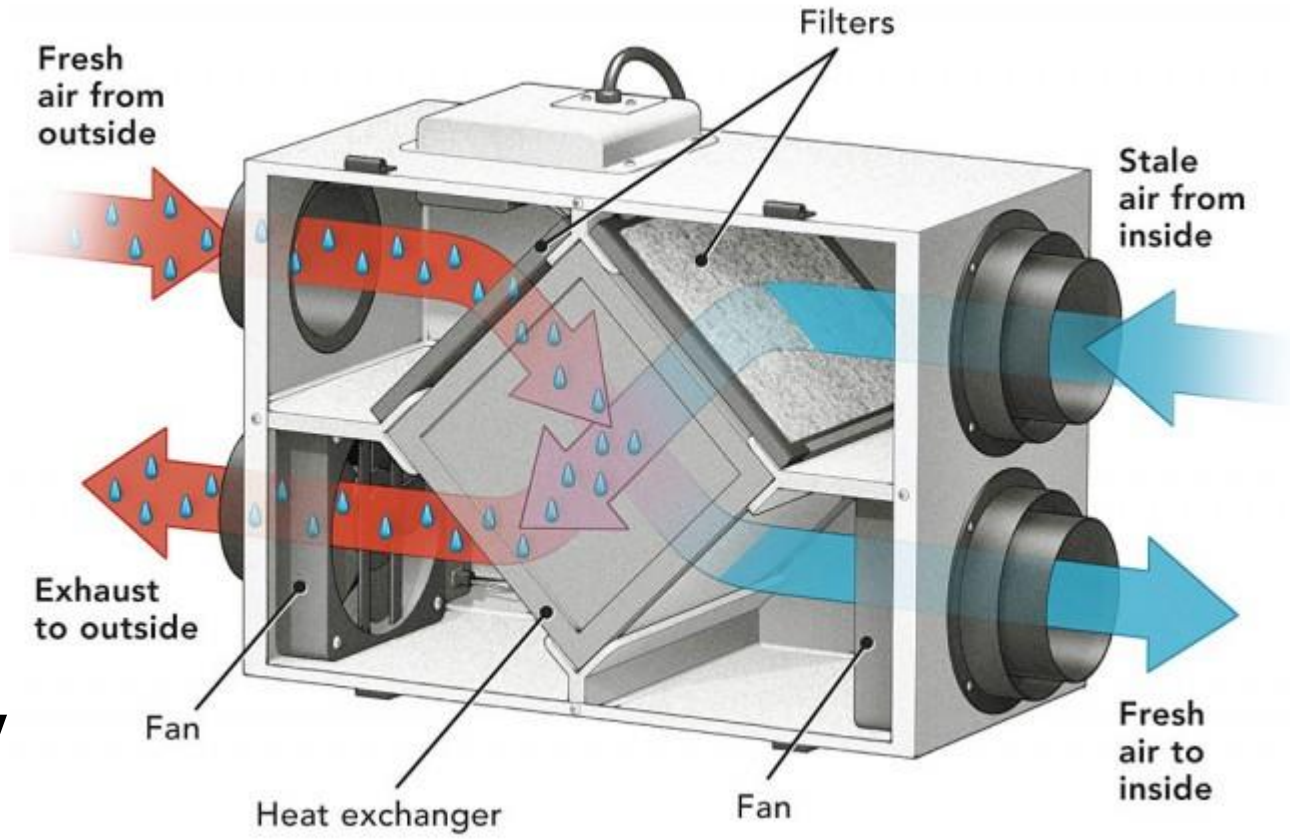


3. Pillar II: Advanced Technical and Engineering Solutions (Corrective and Active)

3.1. Optimized Ventilation and Dilution:

The HRV/ERV Mandate: In climate-controlled environments, **Heat Recovery Ventilators (HRVs)** and **Energy Recovery Ventilators (ERVs)** are essential.

They achieve high air exchange rates (diluting IAP) while recovering up to 80% of the heating or cooling energy, addressing the tension between **energy efficiency** and **air quality**.

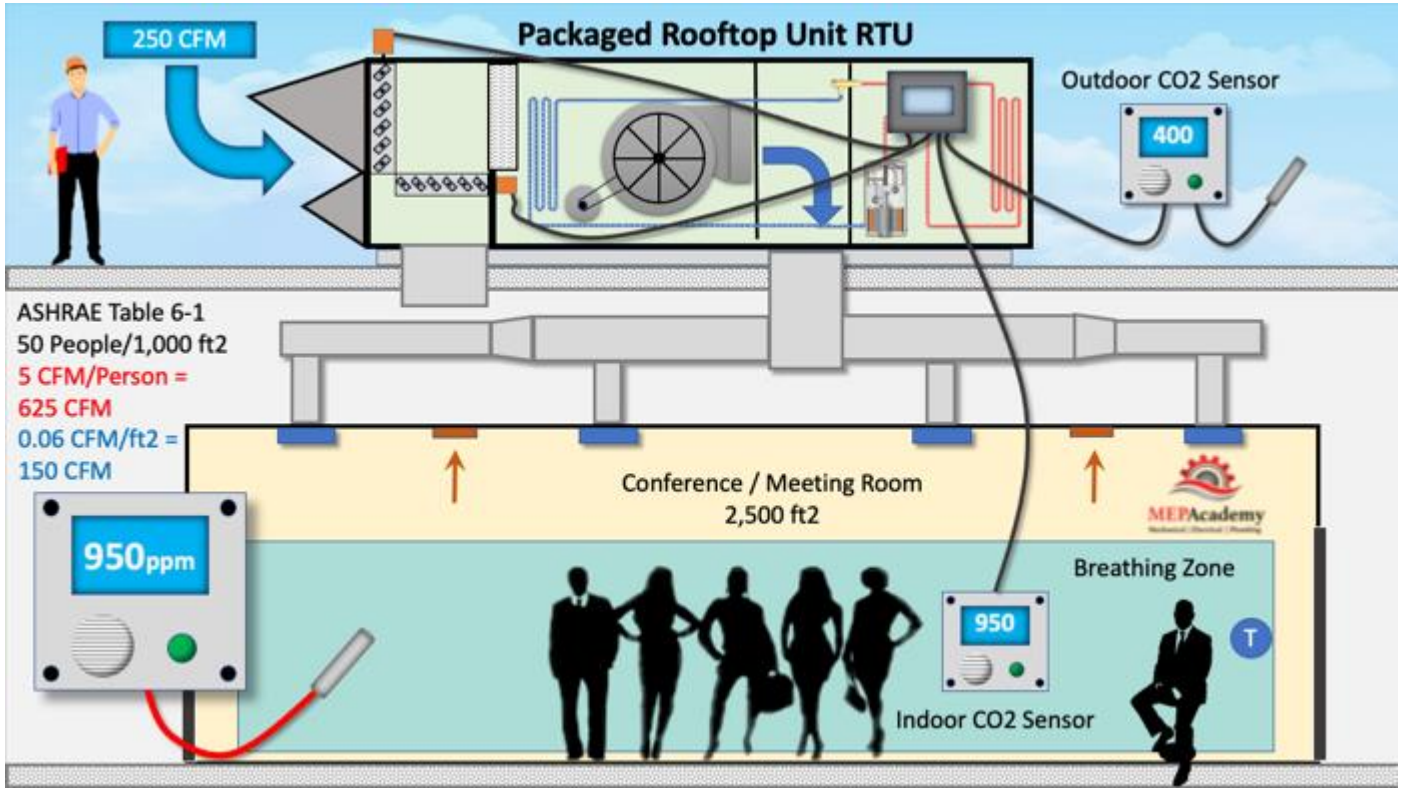


3. Pillar II: Advanced Technical and Engineering Solutions (Corrective and Active)

3.1. Optimized Ventilation and Dilution:

Demand-Controlled Ventilation (DCV): Integrating smart sensors (CO_2 ,VOCs, humidity) to modulate airflow.

This moves from a costly *constant flow* to a more efficient *flow on demand*, ensuring air quality where and when it's needed (e.g., lecture halls based on occupancy).

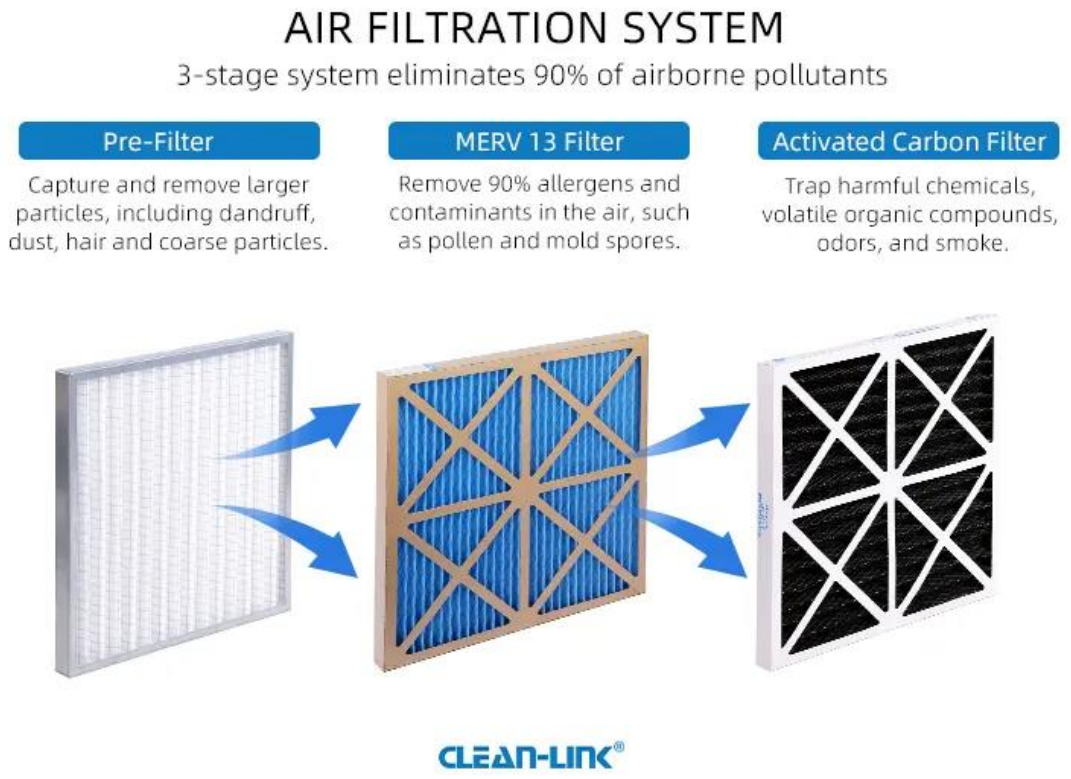


3. Pillar II: Advanced Technical and Engineering Solutions (Corrective and Active)

3.2. Advanced Filtration and Scrubber Technologies:

Particulate Removal: High-efficiency filters (MERV 13+ or ISO ePM1) are non-negotiable for capturing $PM_{2,5}$ and finer aerosols, including viruses.

Regular replacement is a critical, often overlooked, technical necessity.

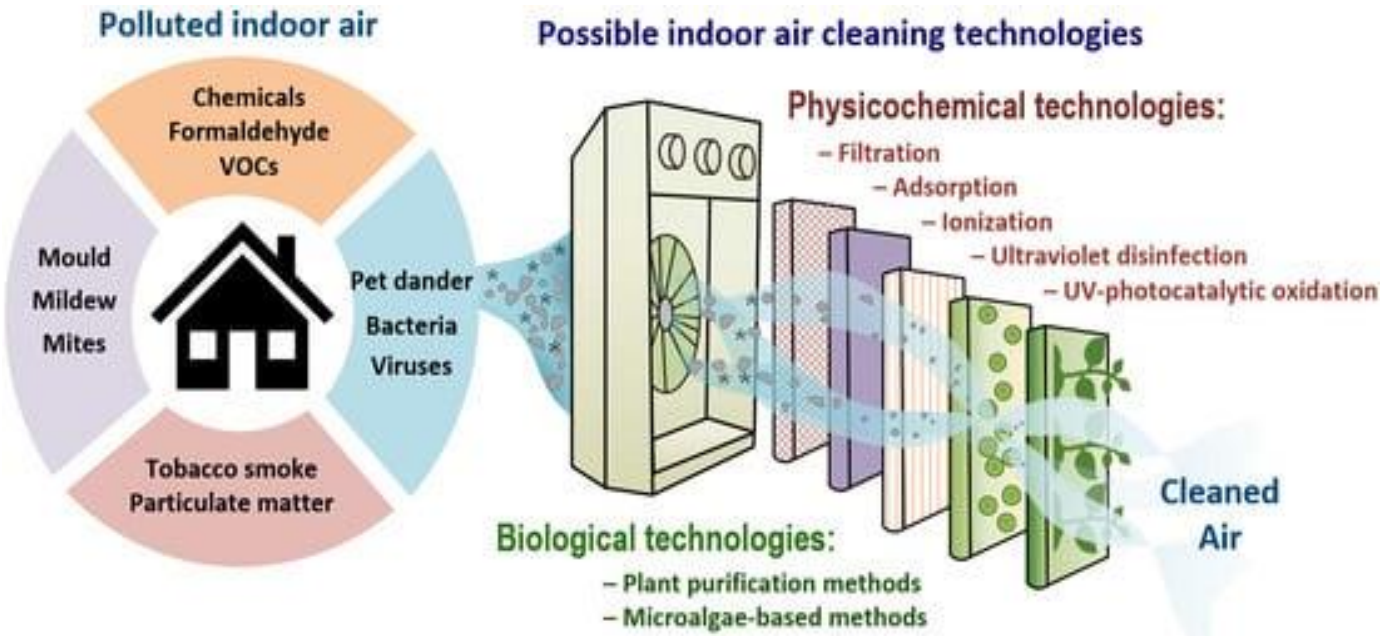


3. Pillar II: Advanced Technical and Engineering Solutions (Corrective and Active)

3.2. Advanced Filtration and Scrubber Technologies:

Gas Removal: For gaseous pollutants (VOCs, NO_2, O_3), specialized systems are needed:

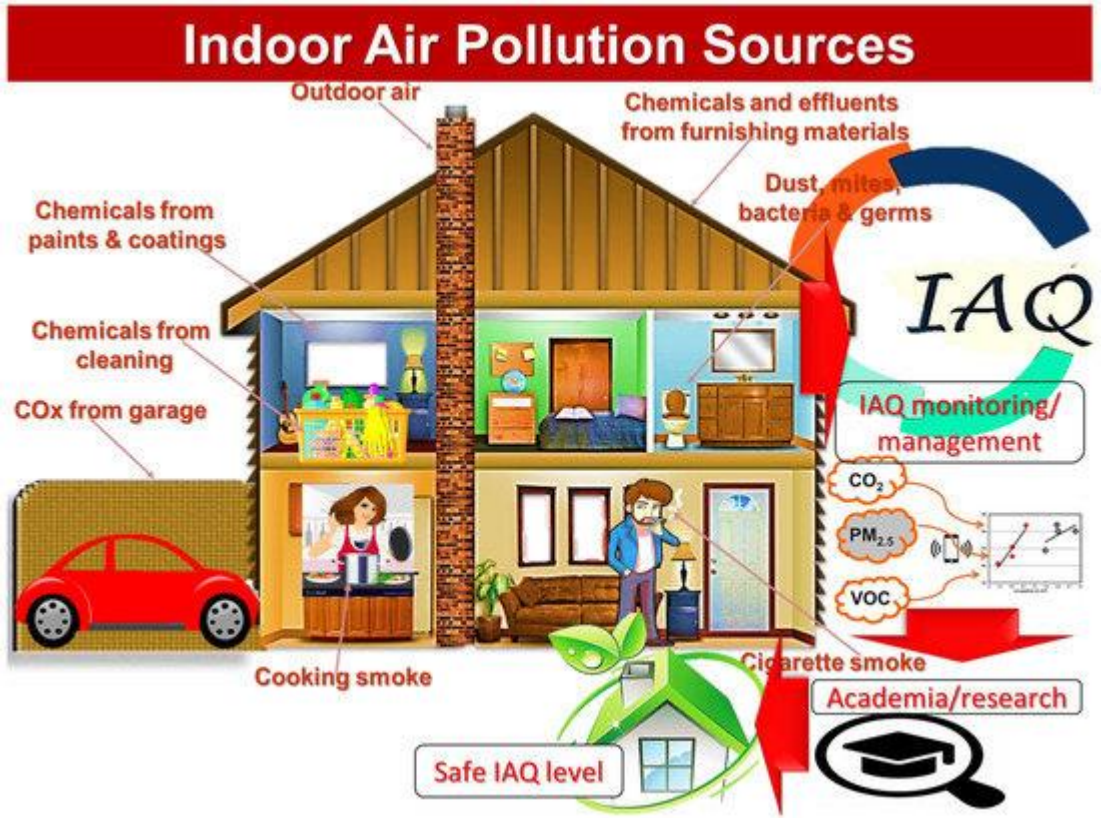
- **Activated Carbon Filters:** Used for physical adsorption of gas molecules.
- **Photocatalytic Oxidation (PCO):** Uses UV light and a catalyst (TiO_2) to break down pollutants at a molecular level (though proper design is needed to avoid undesirable by-products).



4. Pillar III: Behavioral and Operational Strategies (Effective Adoption)

4.1. The User as an Air Quality Manager:

- **Behaviour as a Source of IAP:** Many IAP sources are behavioural: cooking practices (using high heat without ventilation), smoking, and improper use of cleaning agents.
- Field studies show that modifying simple behaviours (e.g., *always* using range hoods) can reduce exposure by significant margins.



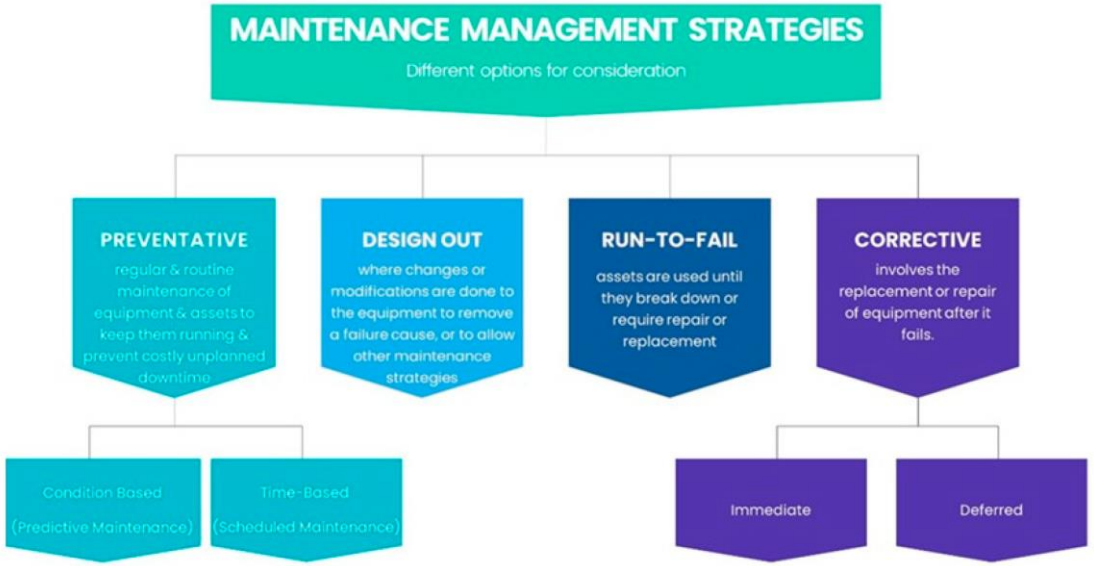
4. Pillar III: Behavioral and Operational Strategies (Effective Adoption)

4.1. The User as an Air Quality Manager:

Maintenance Compliance: The most sophisticated HVAC system fails if filters are not changed.

Behavioural economics and psychology must be applied to maintenance protocols:

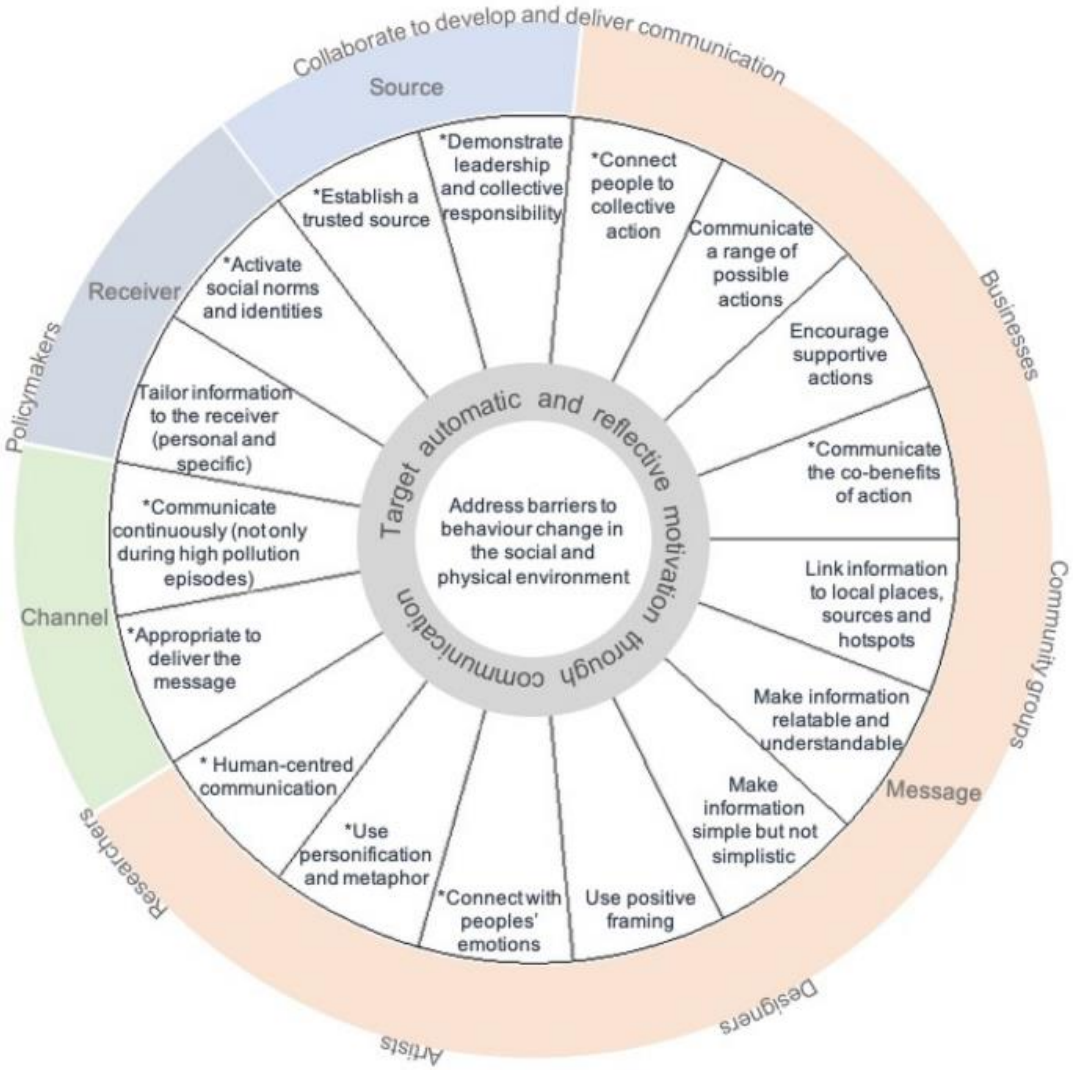
- **Simplification:** Making maintenance easy and clear.
- **Reminders:** Automated or 'nudges' via smart systems.



4. Pillar III: Behavioral and Operational Strategies (Effective Adoption)

4.2. Leveraging Behavioural Science for Exposure Reduction:

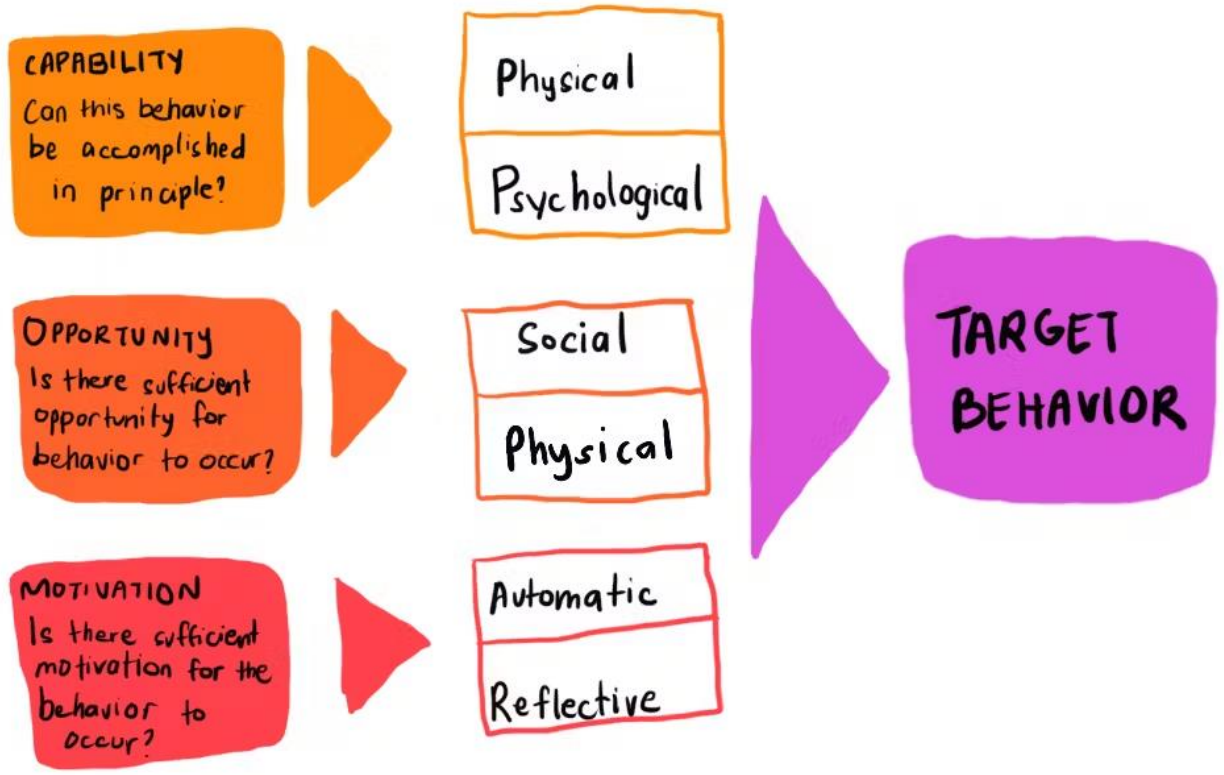
- **Avoidance Behaviours:** Empowering users with **Real-Time Data**.
- Low-cost air quality sensor networks, combined with public communication, allow individuals to make **avoidance decisions** (e.g., closing windows during high-OAP events or choosing alternative commuting routes).



4. Pillar III: Behavioral and Operational Strategies (Effective Adoption)

4.2. Leveraging Behavioural Science for Exposure Reduction:

The COM-B Model: Interventions should target **Capability** (educating users on proper filter disposal), **Opportunity** (providing convenient, safe bike lanes to reduce driving emissions), and **Motivation** (using health-based messaging to encourage low-emission choices).



5. Conclusion

The Triple-A Approach:

Effective air quality management is the intersection of

Architecture (Passive/Preventive),

Active Systems (Technical/Corrective), and

Adoption (Behavioral/Operational).

Failure in any one area compromises the system.

