NASCSP

National Association for State Community Services Programs

2024 Annual Training Conference

Efficient Homes, Healthy Air: Balancing Indoor Air Quality and Energy Efficiency with Ventilation

September 16 – 20 | Renasant Convention Center | Memphis, TN

BEYOND THE BOX…

TURNING POSSIBILITIES INTO REALITIES

Oak Ridge National Laboratory

Efficient Homes, Healthy Air: Balancing Indoor Air Quality and Energy Efficiency with Ventilation

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Introductions

Bill Eckman

- Program Manager – ORNL-SCEP
- Structural design/construction since 2001
- Building performance/efficiency since 2008
- Former: crew member, energy auditor/inspector, trainer, curriculum developer, business owner, consultant, multifamily auditor, operations and maintenance trainer….

Image 1: Bill Eckman photo – January 2019

Dr. Easwaran Krishnan

- Research Associate Staff at ORNL
- Expertise:
  - Experimental Heat and mass transfer
  - Indoor air quality
  - Energy recovery in buildings

Acknowledgment

Prepared by
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Learning Objectives

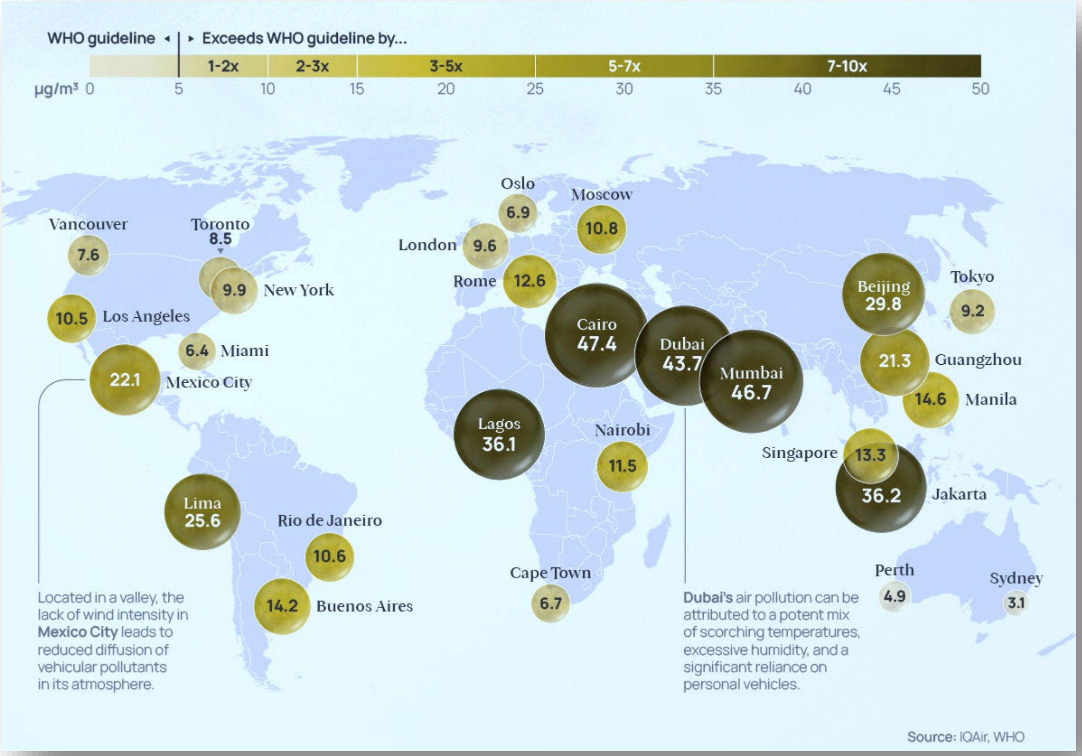
- Identify the impact of low ventilation rates on indoor air quality and occupant health.
- Recognize key indoor pollutants, their sources, and their health impacts.
- Evaluate the role of ventilation systems, air purification technologies, and innovative materials in improving indoor air quality.
- Assess the benefits of continuous ventilation, including the non-energy benefits.
- Understand ongoing efforts to incorporate IAQ improvements into the WAP cost-effectiveness test.

Overview

- Indoor air quality (IAQ) and health
  - Importance of IAQ
  - Common contaminants and health impacts
- Evaluation of ventilation effectiveness
  - Analysis of local ventilation: Kitchen ventilation
  - Kitchen ventilation vs bathroom exhaust
  - Pollutant transport in a residential setting
- New technologies to improve IAQ

Air Quality

- Factors affect air quality:
  - Human activities
  - Natural causes
  - Climate conditions
  - Common outdoor air pollutants: ground level ozone, particulate matter, and allergens



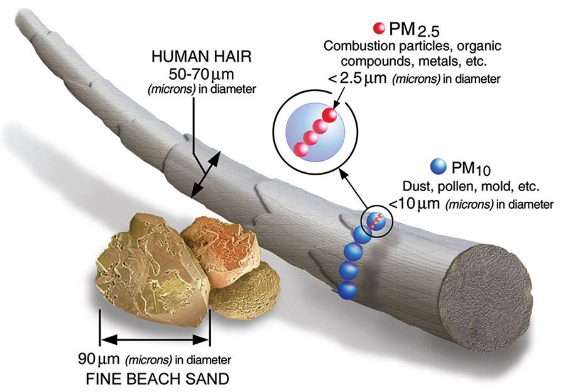
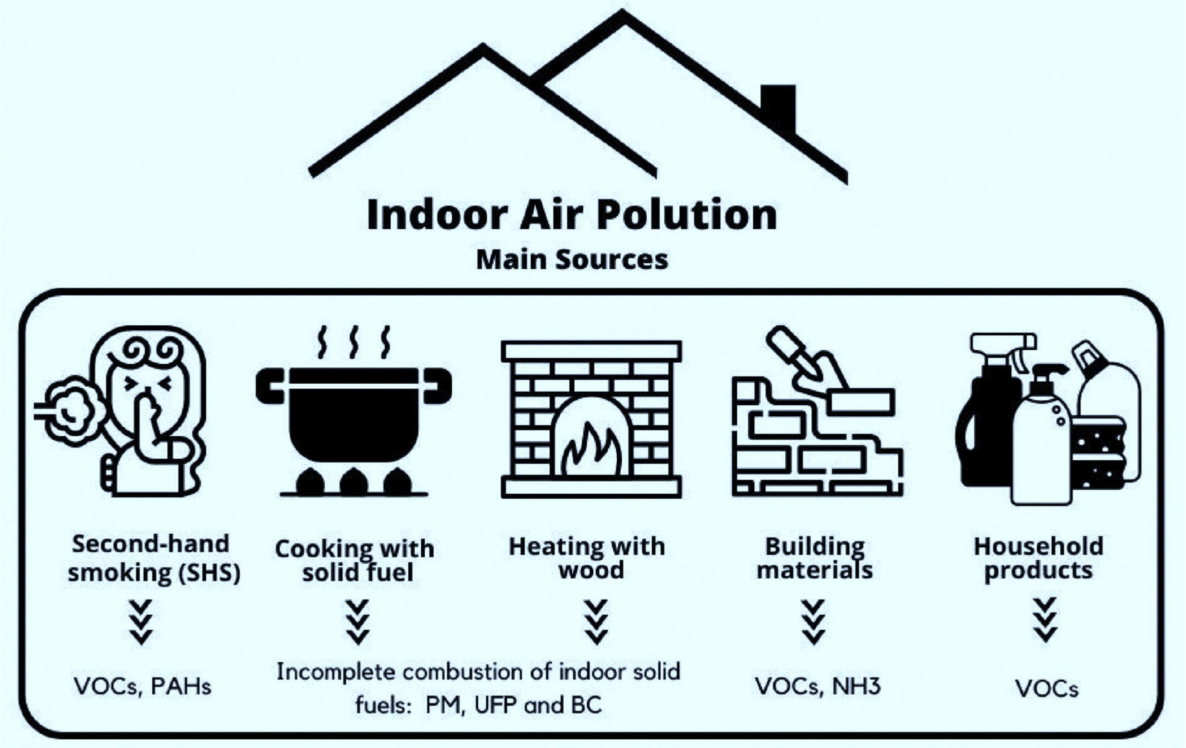


Image sources:
https://www.niehs.nih.gov/health/topics/agents/air-pollution
https://www.wpr.org/environment/new-epa-plan-deal-wandering-and-state-air-pollution
https://www.visualcapitalist.com/mapped-air-pollution-levels-around-the-world-2022/

Indoor air quality

- People spend around 90% of time indoors
- Exposure to indoor pollution: 3.2 million deaths/yr (globally)
- Mostly affected: children, women, and the elderly



Contaminants
Carbon dioxide
Carbon monoxide
Dust
Environmental tobacco smoke
Particulate matter
Nitrogen oxides
Pesticides
Radon
Lead
VOCs
Biological contaminants

source: https://doi.org/10.1016/j.coesh.2023.100449

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Indoor Air Quality and Health

Volatile organic compounds

- Possible carcinogens (benzene in particular), irritants and toxicants.
- Significant asthma risk factors
- Indoor and outdoor sources:
  - Combustion and evaporation, e.g., cigarette smoking, solvent-related emissions, renovations, household products and pesticides

Particulate Matter

- Complex mixture of organic and inorganic chemicals
- Different size fractions: PM10, PM2.5 and Ultra Fine Particles
- Asthma, COPD, lung function and heart health risks
- Indoor sources:
  - Smoking, cooking, wood stoves and furnaces, cleaning, pets etc.

Nitrogen Dioxide

- Increased number of asthma attacks and inhaler use, and reduced lung capacity
- Increased respiratory symptoms and risk of worsening COPD
- Sources:
  - Combustion produced by motor vehicles, outdoor sources involving combustion,
  - Gas appliances and kerosene heaters

Factors affecting Indoor Air Quality

- Housing characteristics
- Occupancy, activity patterns
- Seasonal and climatic influences
- Dwelling location
- **Ventilation**

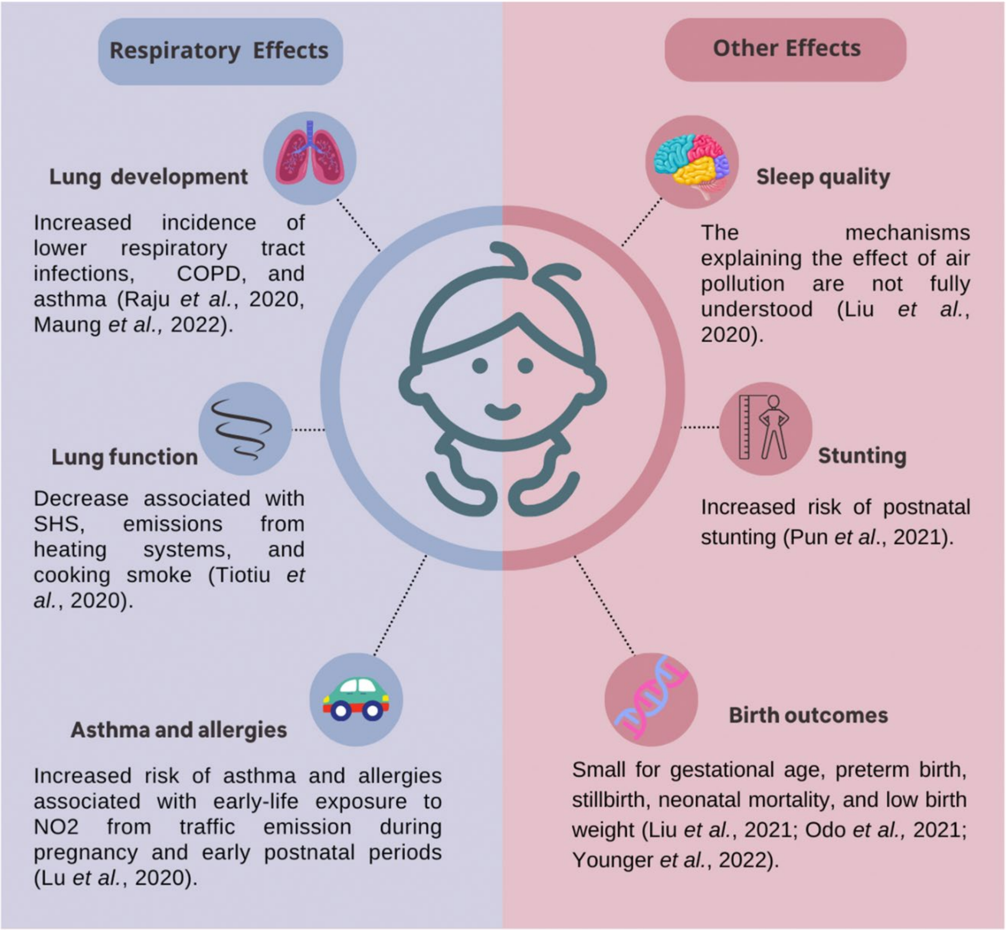
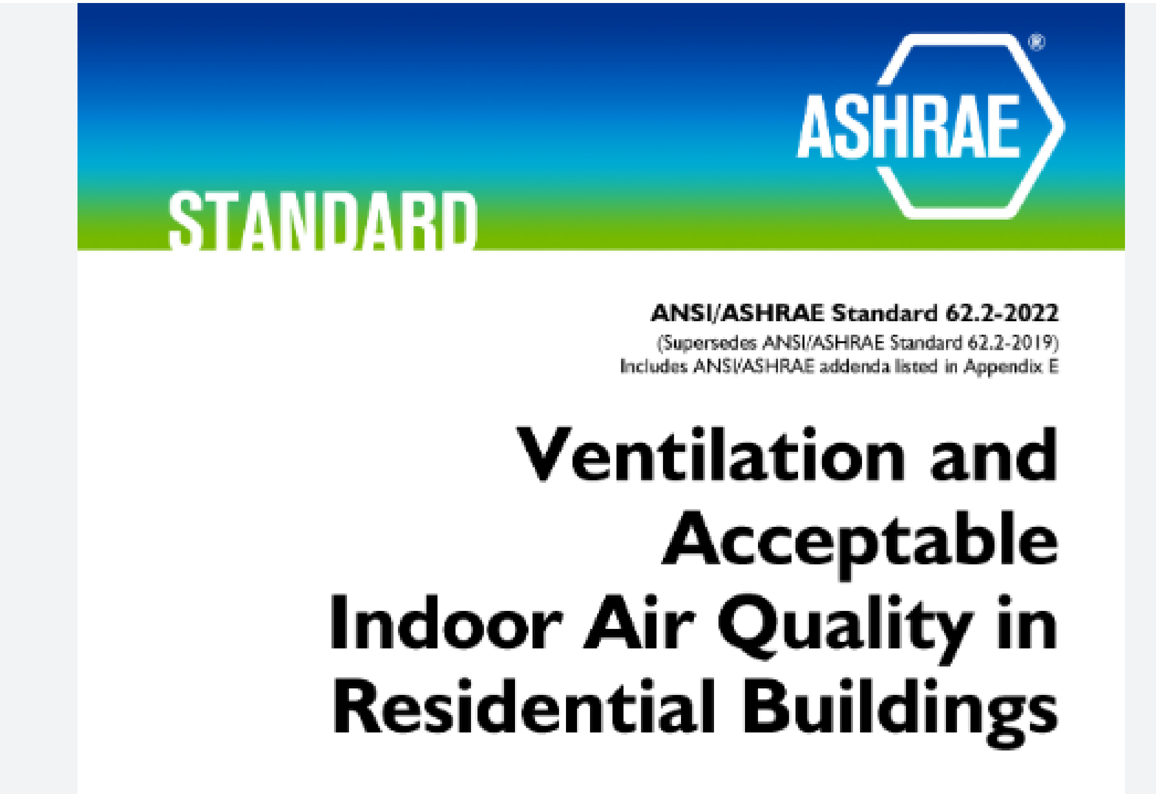


Image source: https://doi.org/10.1016/j.coesh.2023.100449

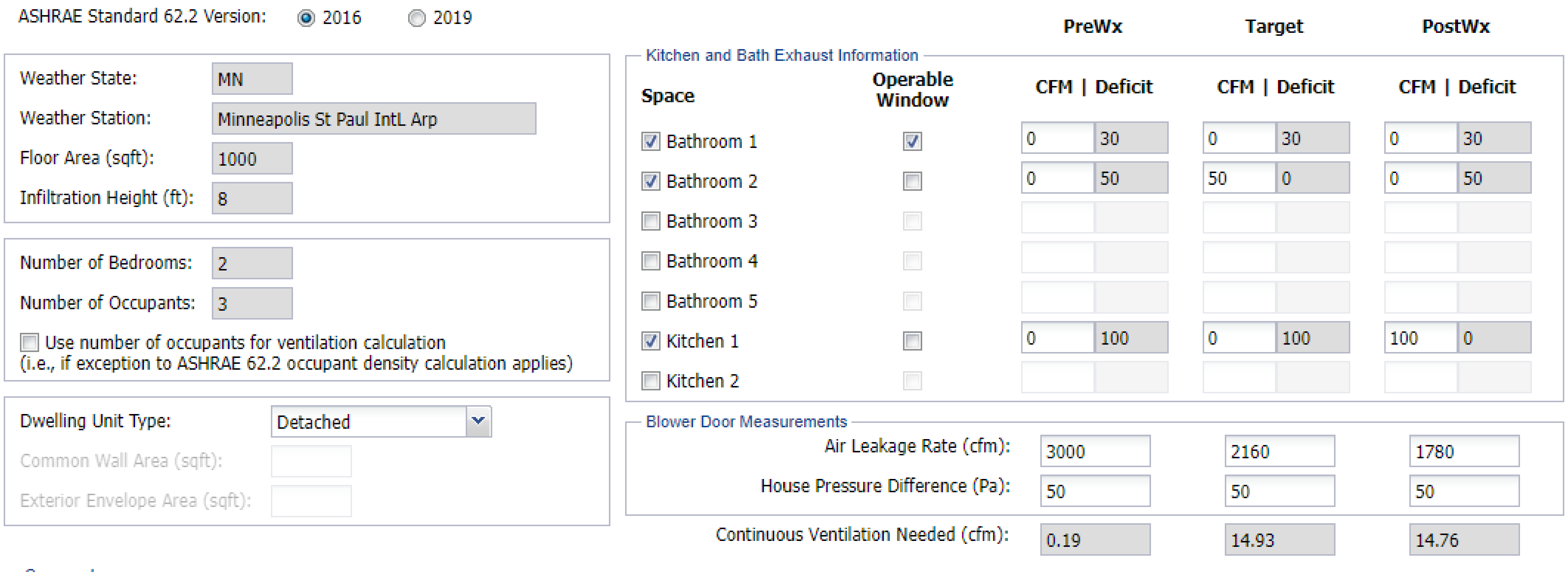
ASHRAE 62.2 Standard

- Adequate ventilation is crucial for enhancing IAQ
- ASHRAE 62.2
  - Outlines minimum required ventilation rates
  - Suggests using continuous running exhaust fans to increase ventilation rate



Kitchen Ventilation – Energy Perspective

- Calculation of a single-family by WAweb



Kitchen ventilation – IAQ Perspective

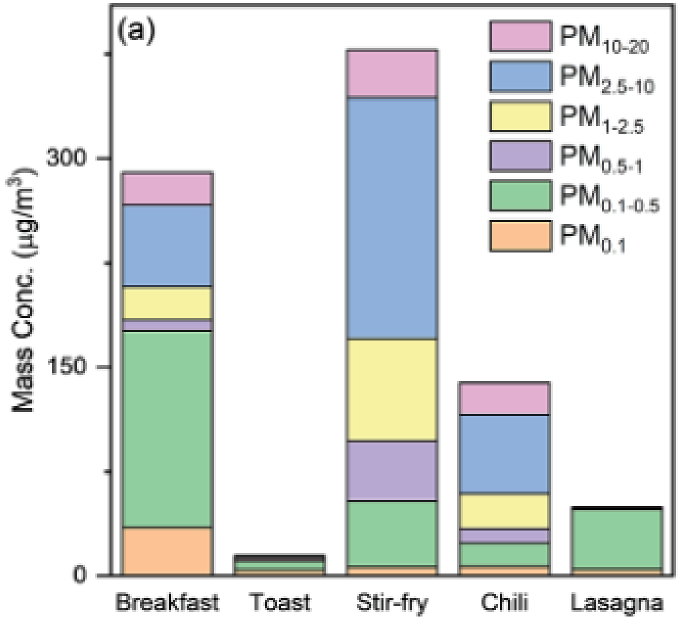
- Preference: capture cooking pollutants near the source
- Limitation: flow rate and particle size can reduce performance

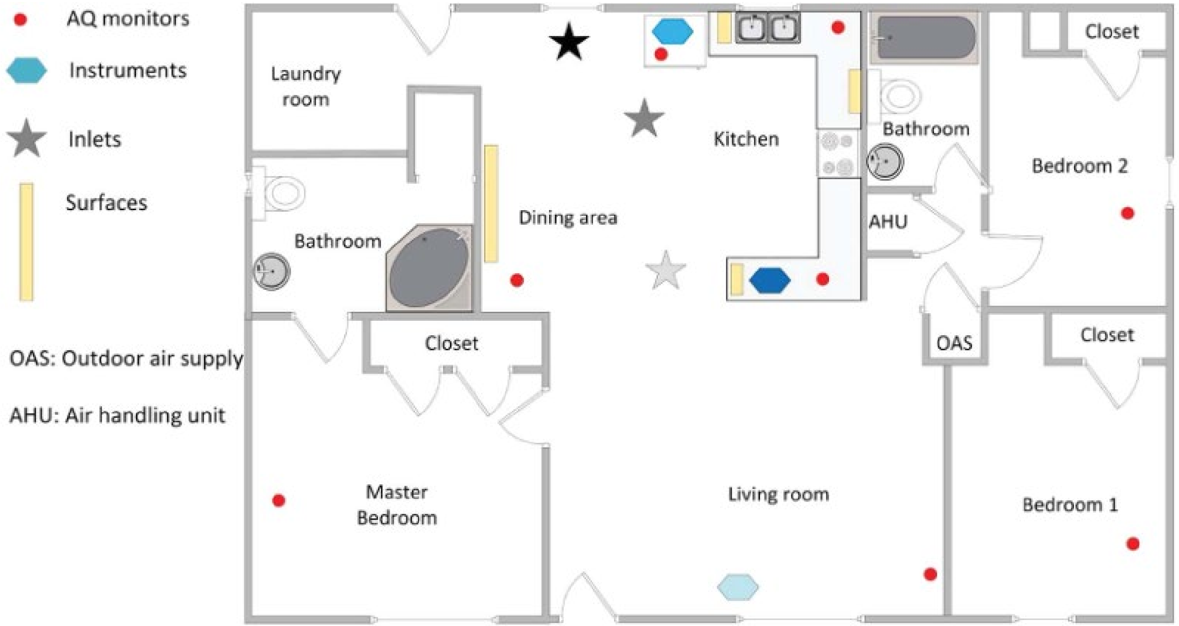
https://www.arvaappliances.com/blog/blowing-smoke-or-why-kitchen-ventilation-matters

Case Studies: Cooking and Ventilation

- Single-story residential layout
  - Central living room
  - Kitchen adjacent dining area
  - Three bedrooms
  - Two bathrooms
- Cooking activity measurements conducted at the UTest House[1]

UTest House on the J. J. Pickle Research Campus of the University of Texas at Austin[1]





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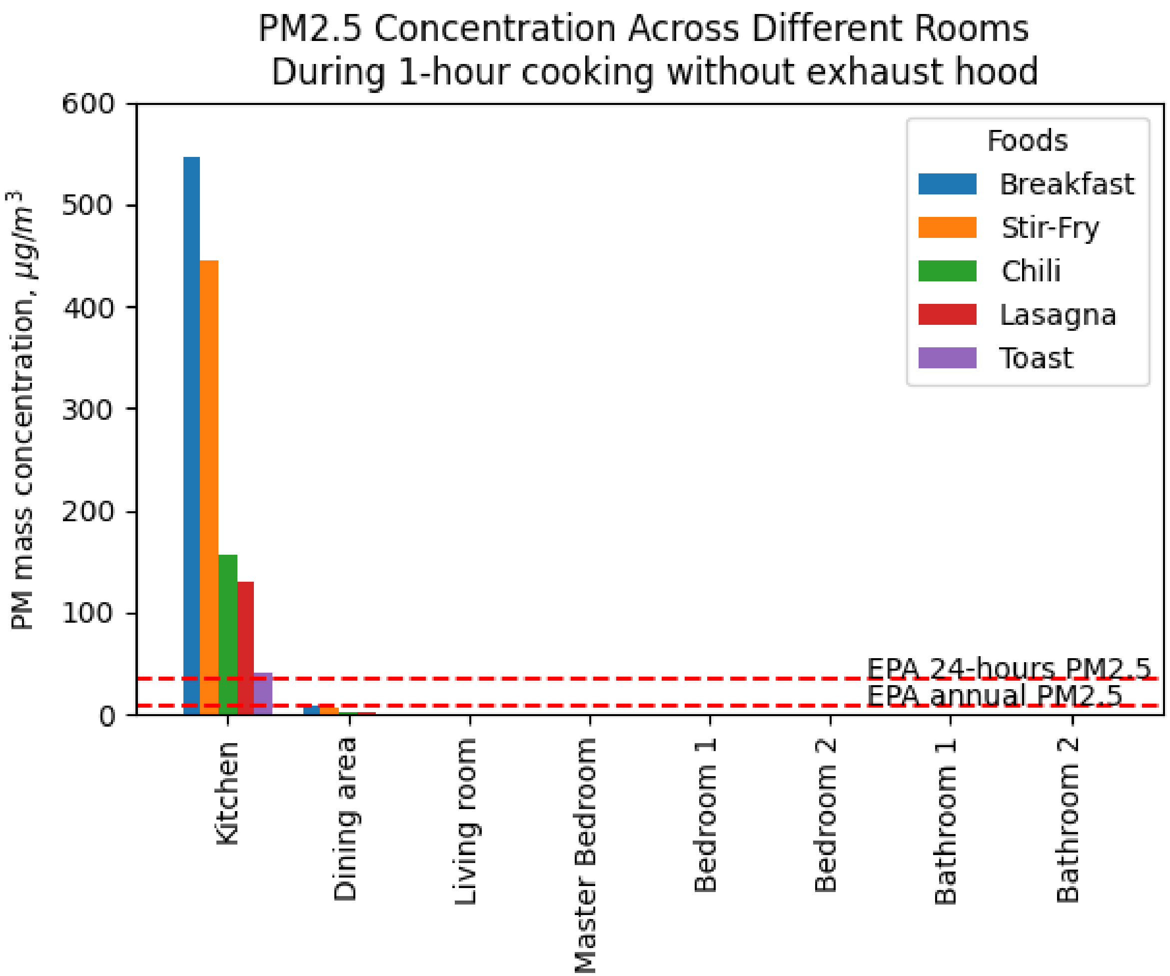
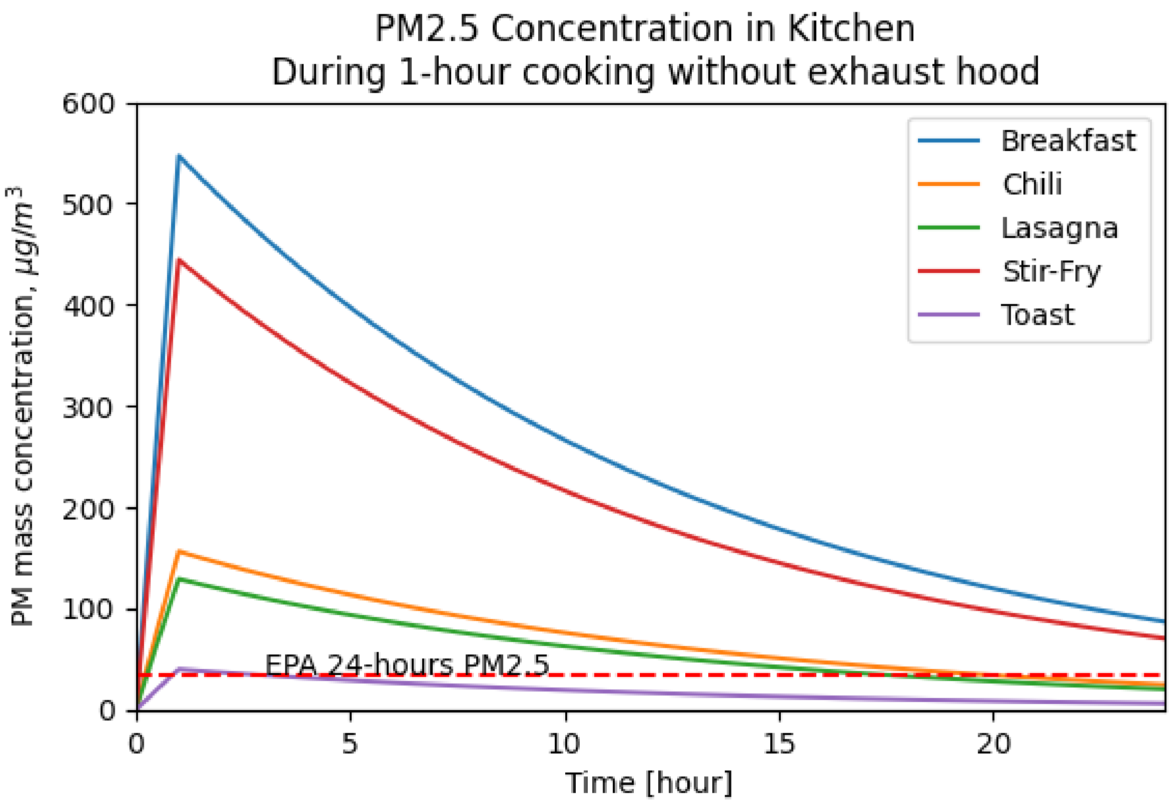
Kitchen Exhaust Hood

- Use kitchen exhaust hood to keep short-term exposure within EPA's guidelines

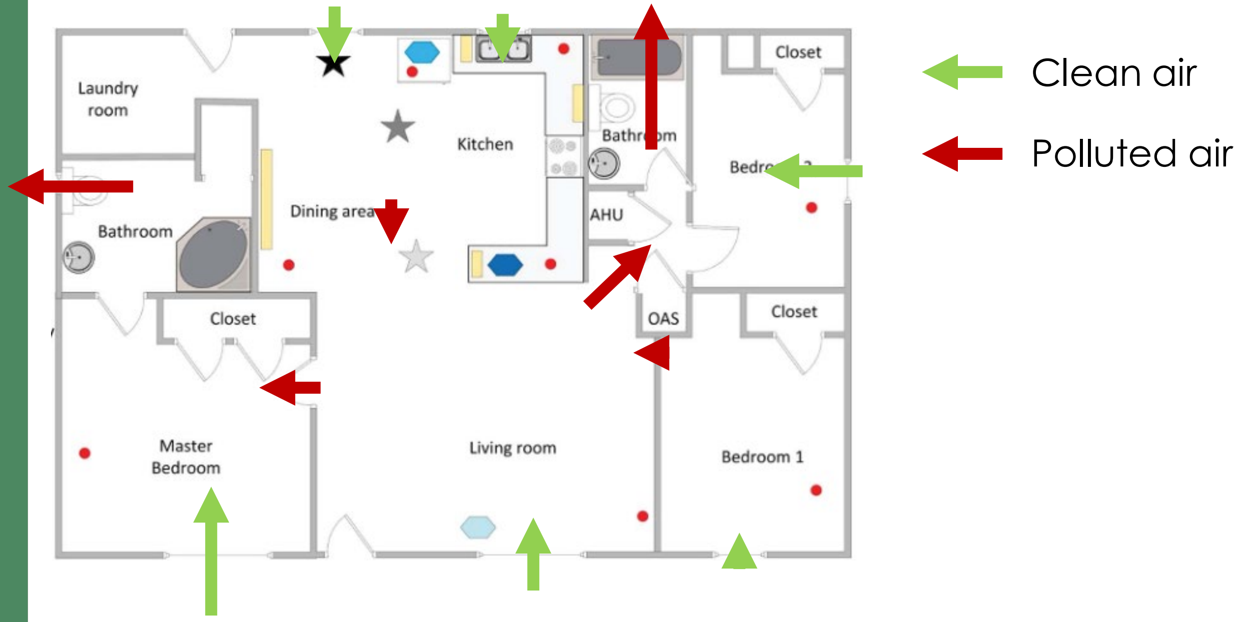


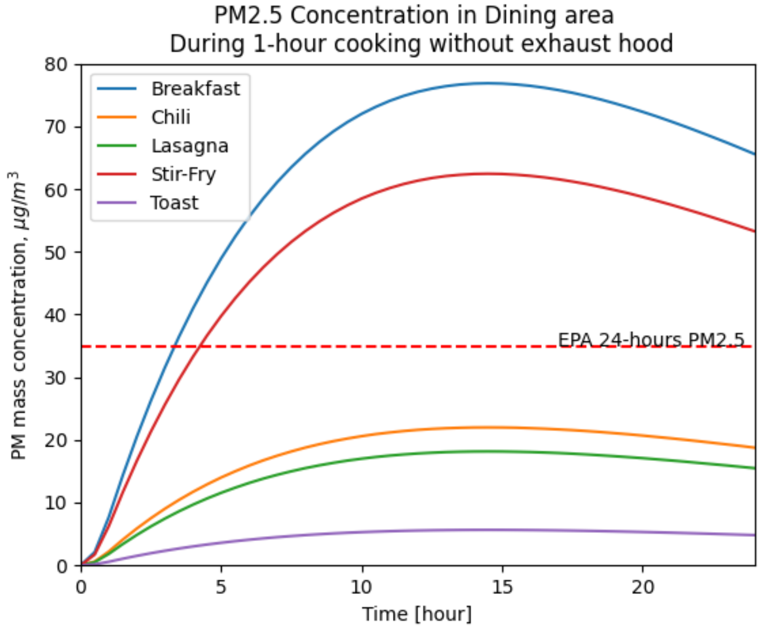


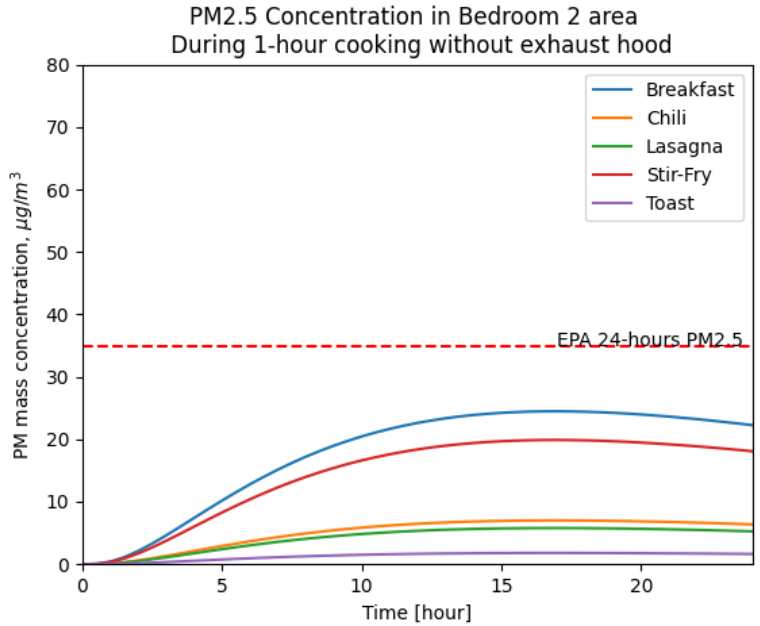
Pollutant Movement in Residential Space (Bathroom exhaust)

- Airborne pollutants from kitchen can spread to other rooms
- Ventilation pathways can influence pollutant distribution

Air flow paths with bathroom exhaust ventilation

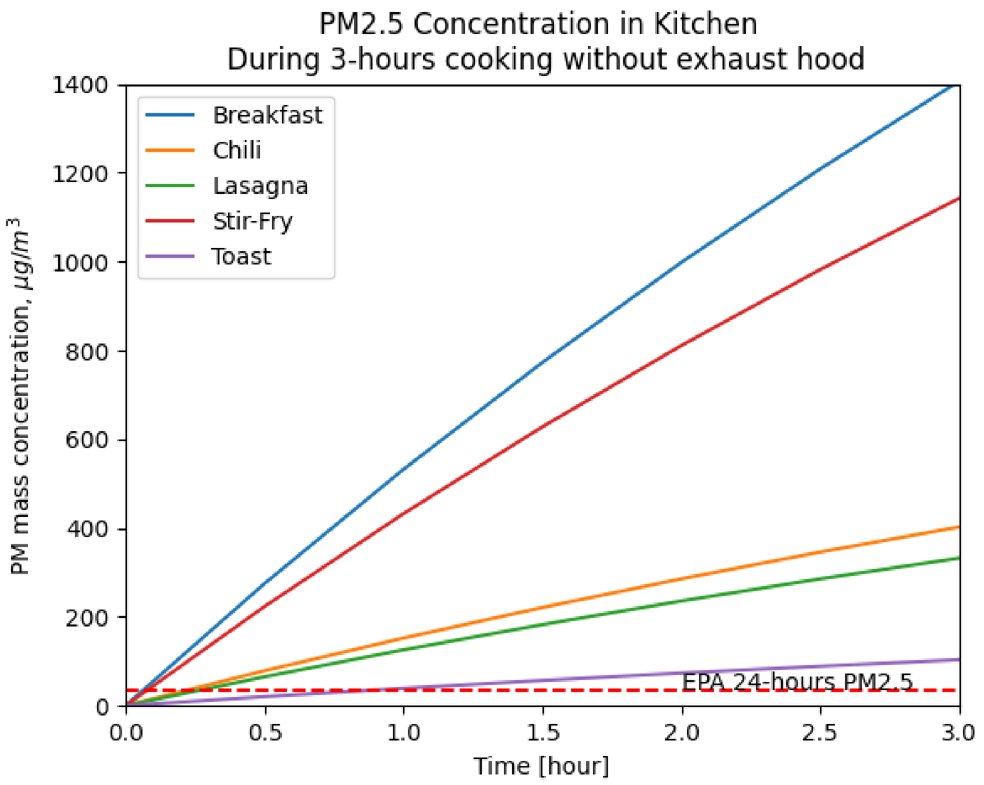


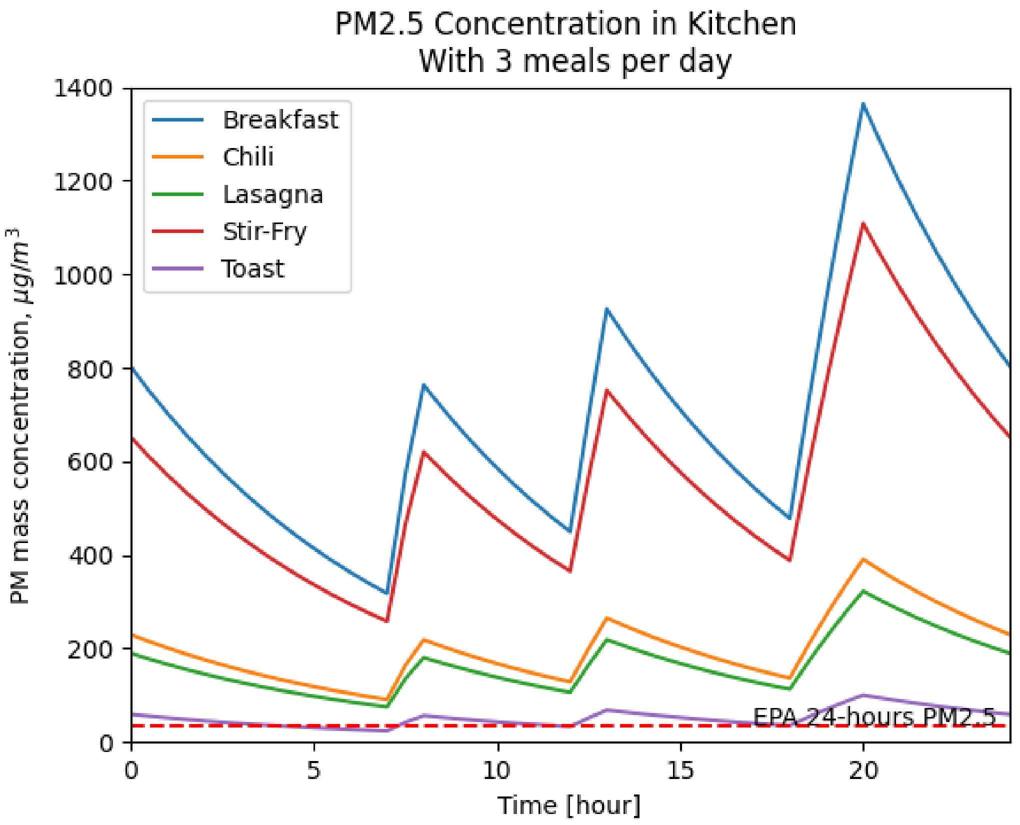




Impact of Cooking Duration on Air Quality

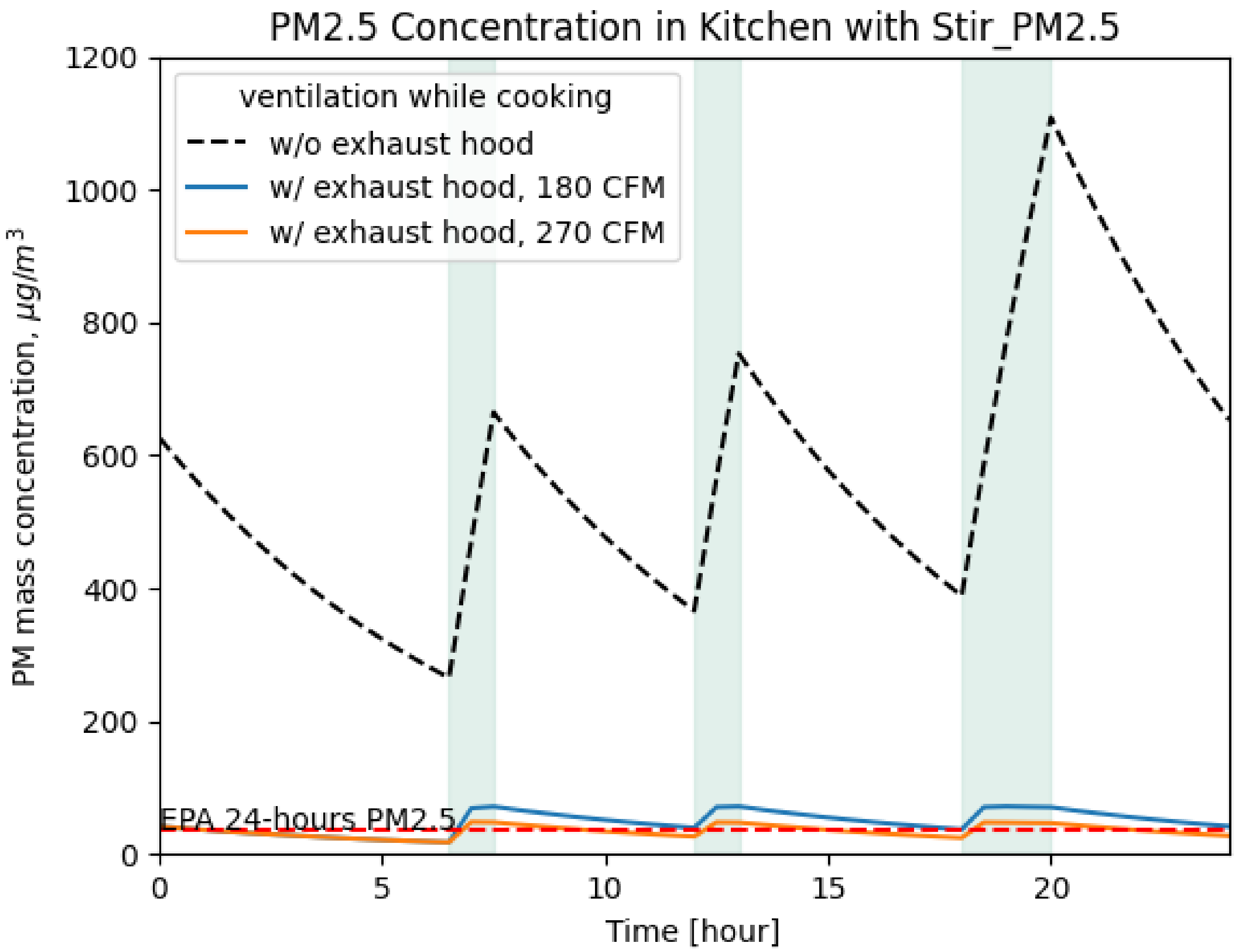
- Pollutant emissions rise almost linearly with cooking duration
- Pollutants accumulate between two cooking sessions





Use Exhaust Hood During Cooking

- Exhaust pollutants directly by using the hood while cooking



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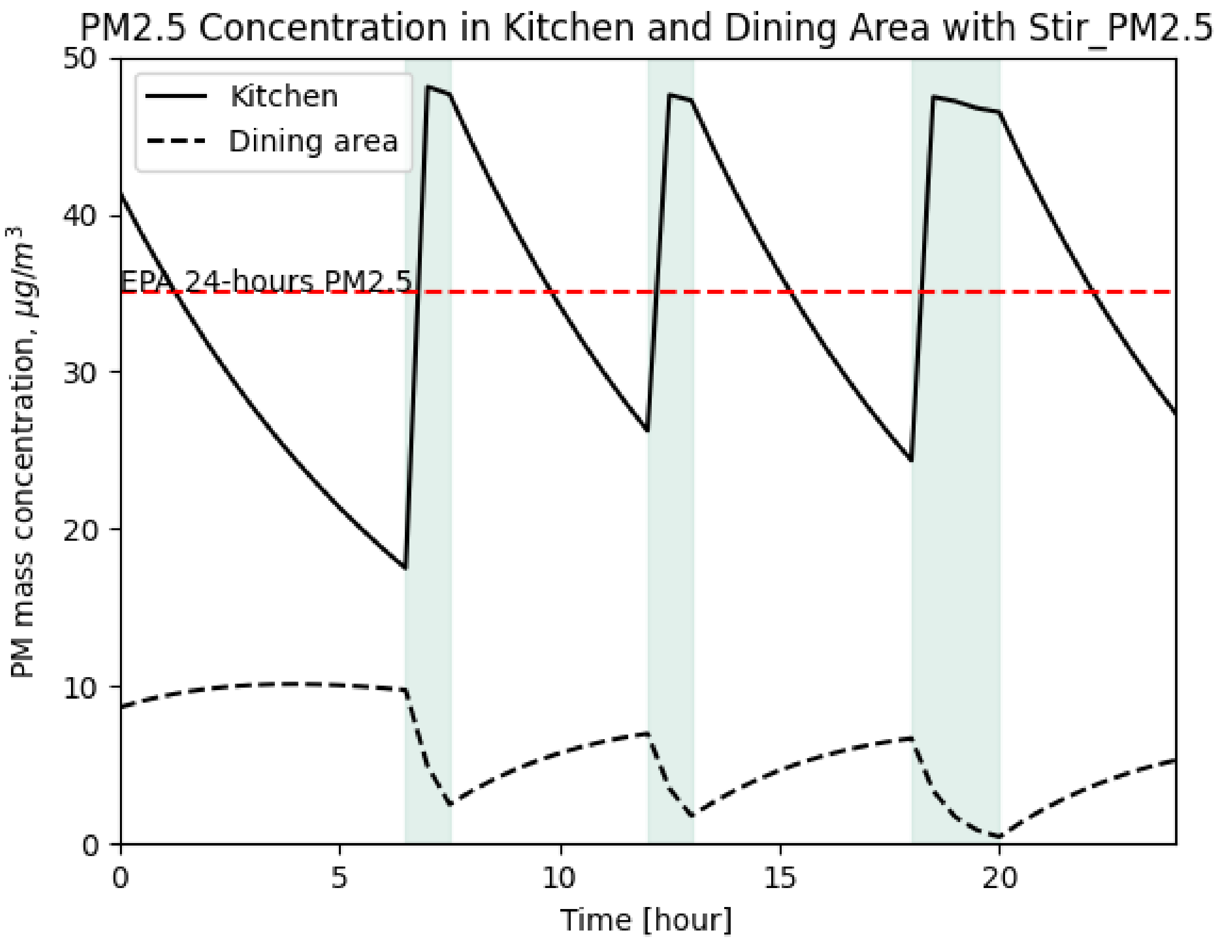
Use Exhaust Hood While Cooking

- Exhaust pollutants directly by using the hood while cooking
- Airflow towards kitchen while cooking



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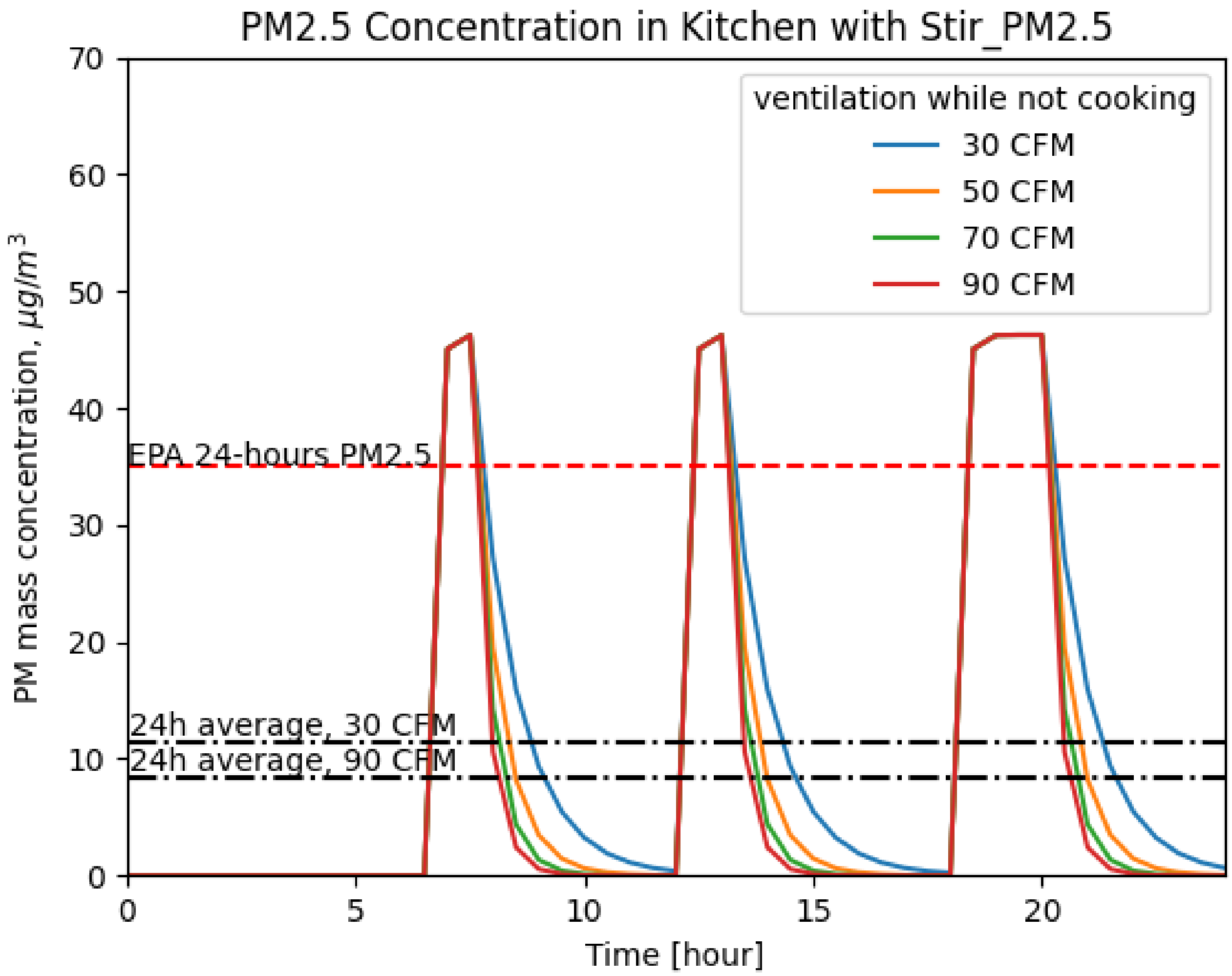
Continuous Exhaust for Improving Air Quality

- Keep kitchen exhaust running after cooking to maintain PM2.5 levels within EPA standards



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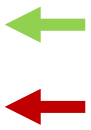
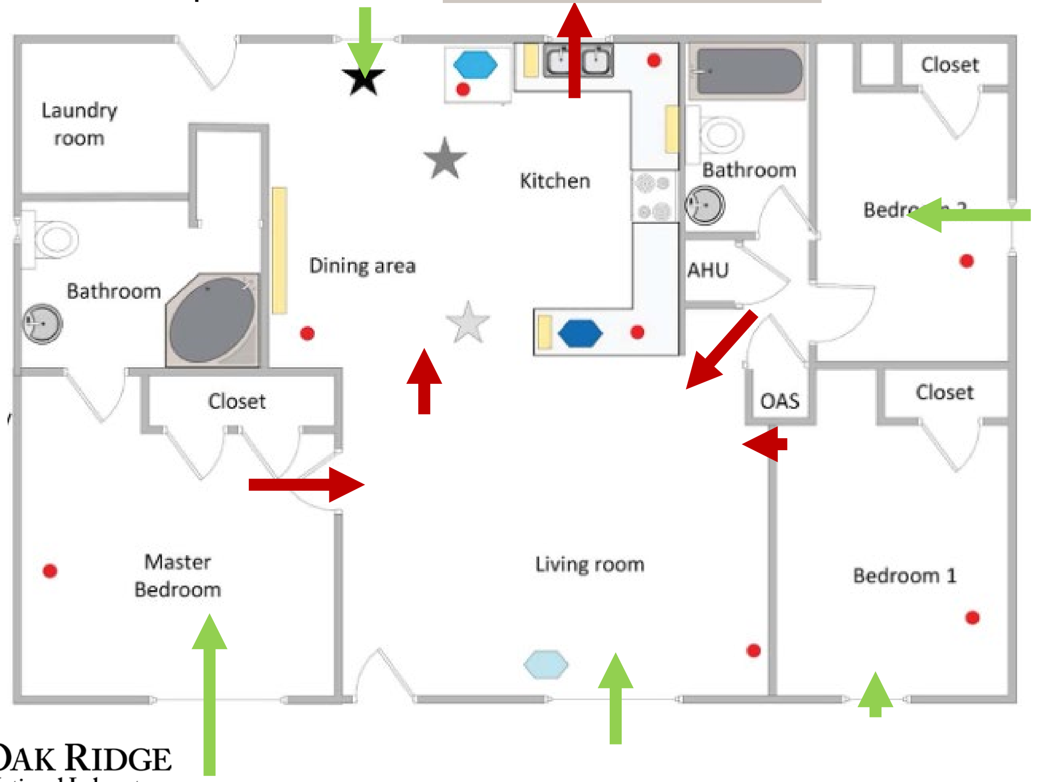
Comparing Kitchen and Bathroom Ventilation Strategies

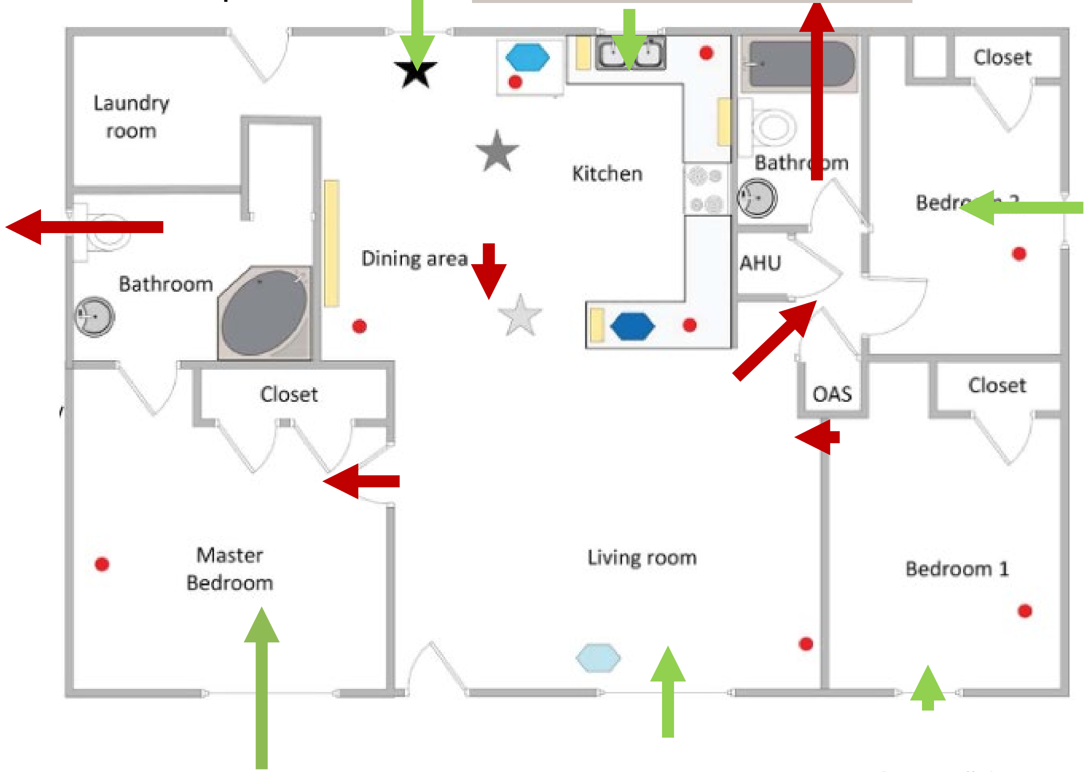
- Kitchen exhaust directs airflow away from frequently used rooms, minimizing contamination



Air flow paths with kitchen exhaust ventilation

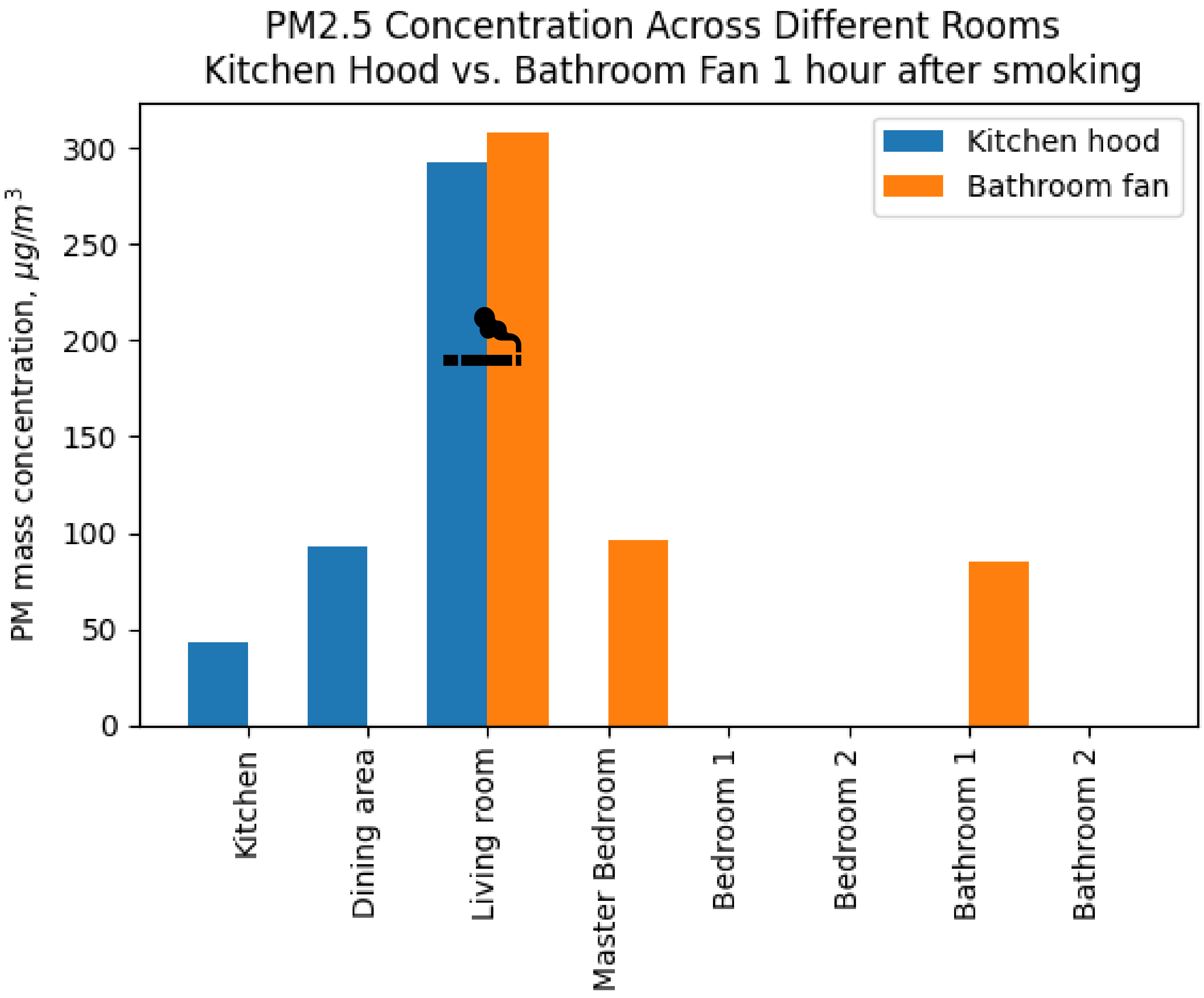


Air flow paths with bathroom exhaust ventilation



Mitigating Air Quality Impact from Indoor Smoking

- Kitchen exhaust hood vs. bathroom fan in controlling PM2.5 concentration across different rooms
- Kitchen exhaust directs airflow, reducing pollutant spread to frequent occupied rooms



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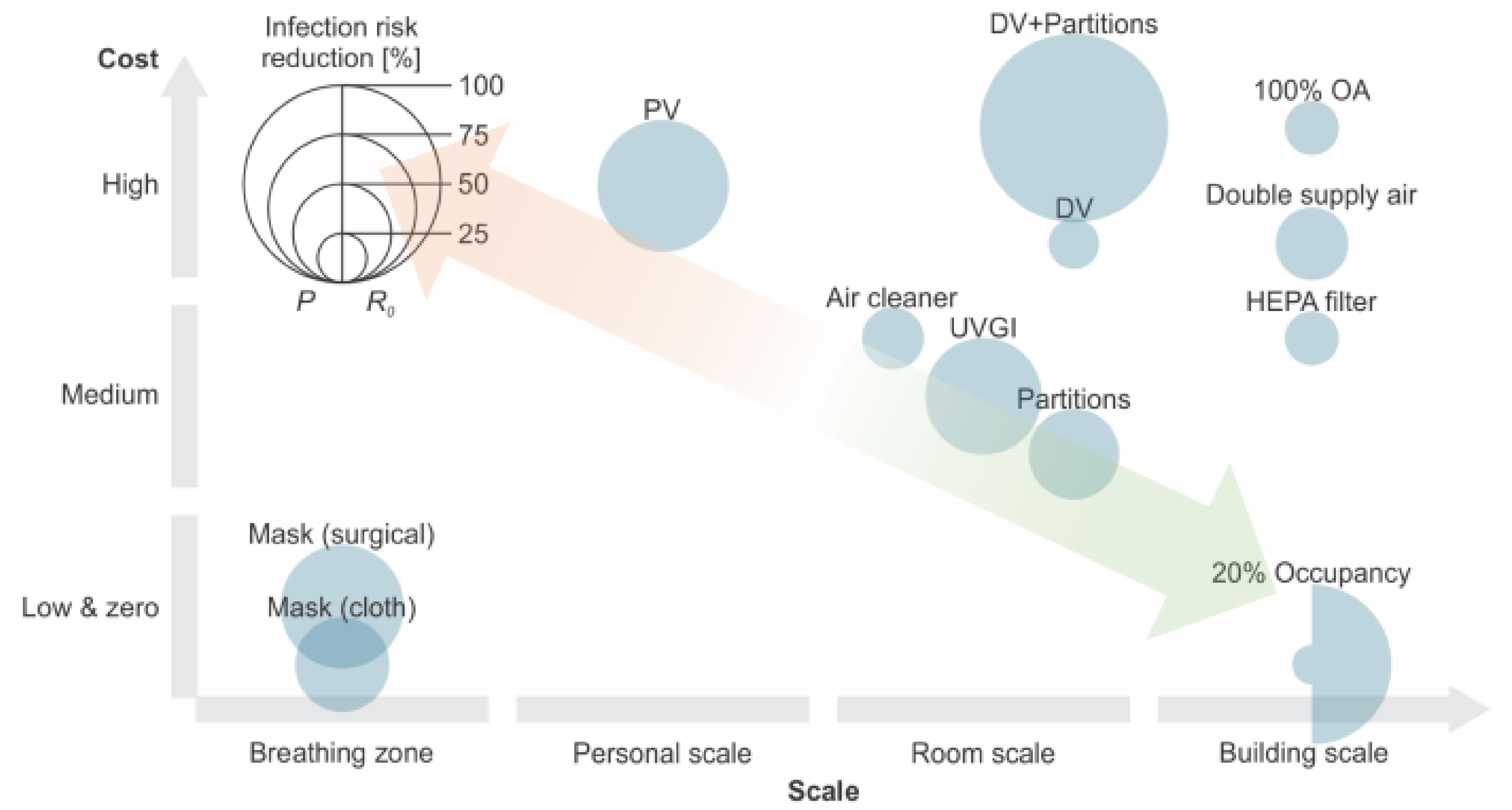
New Technologies to Improve IAQ

Indoor Infection Risk Control Strategies



Infection risk reduction potentials and costs of control strategies in different scales [2]

Metal-Organic-Framework (MOF) Material

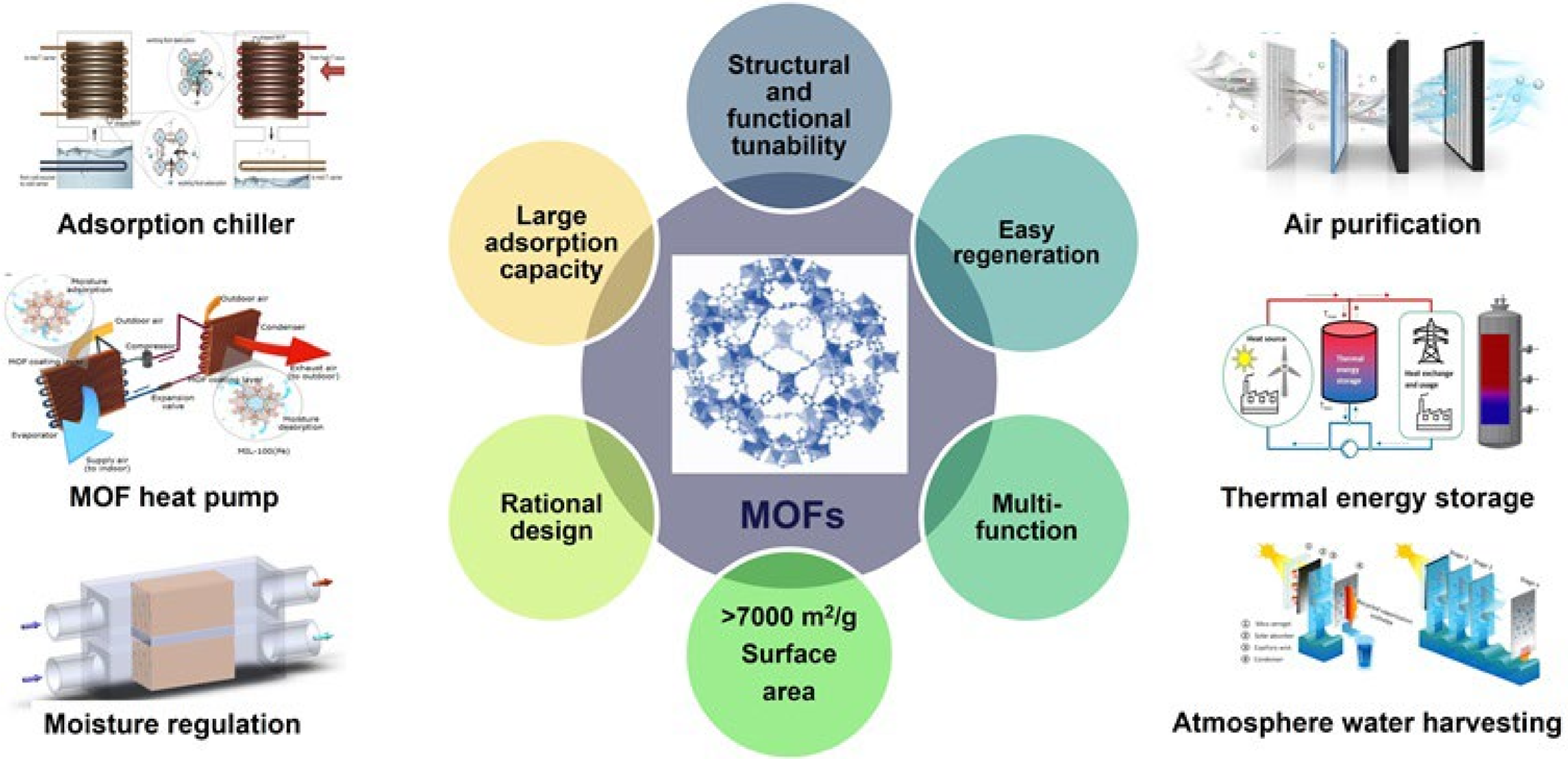


Image source: https://annex92.iea-ebc.org/

Conclusion

- Operate the exhaust fan continuously to enhance ventilation
- Use kitchen exhaust hood while cooking:
  - Directly remove cooking pollutants
  - Redirect airflow to less-occupied areas

Reference

[1] Farmer, D. K., M. E. Vance, J. P. D. Abbatt, A. Abeleira, M. R. Alves, C. Arata, E. Boedicker, et al. "Overview of HOMEChem: House Observations of Microbial and Environmental Chemistry." *Environmental Science: Processes & Impacts* 21, no. 8 (2019): 1280–1300. https://doi.org/10.1039/C9EM00228F.

[2] Shen, Jialei, Meng Kong, Bing Dong, Michael J. Birnkrant, and Jianshun Zhang. "A Systematic Approach to Estimating the Effectiveness of Multi-Scale IAQ Strategies for Reducing the Risk of Airborne Infection of SARS-CoV-2." Building and Environment 200 (August 2021): 107926. https://doi.org/10.1016/j.buildenv.2021.107926.

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Thank you for your attention!

Q&A

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