Cleaner Indoor Air During Wildfires Challenge

Announcement of Phase 2 Winners – February 20, 2024

Photos show a good air quality day (left image), and a poor air quality day (right image) when Hoopa Valley was impacted by the Red Salmon Complex in Sept 2020; Photos courtesy of Brian McCaughey

Overview of Today's Webinar

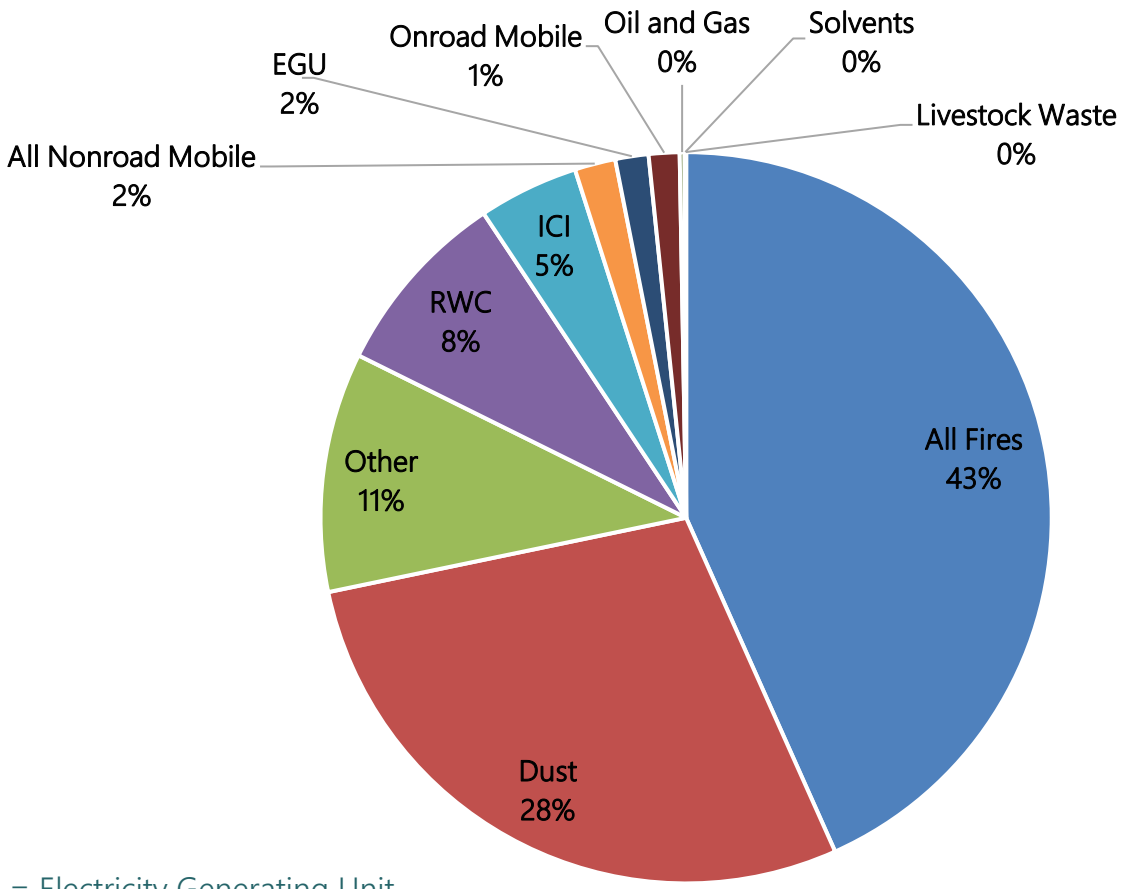
Background and highlights of recent EPA research activities

Brief introduction to the Wildfire ASPIRE Study

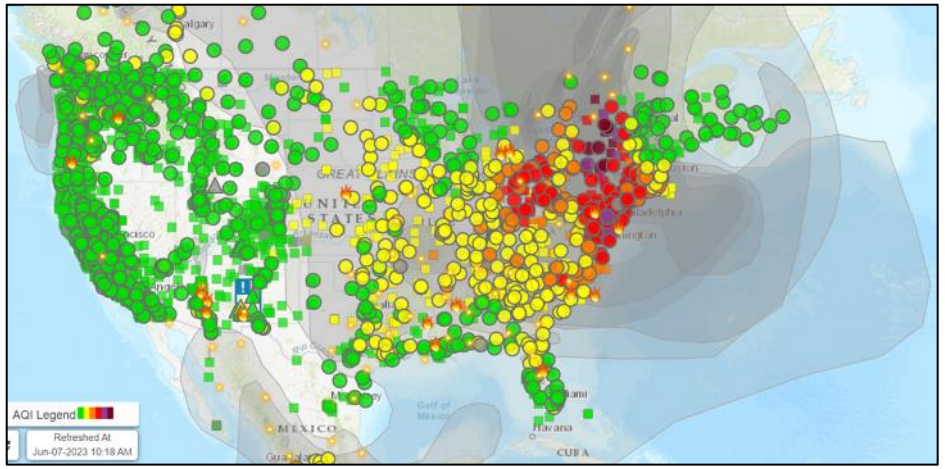
Cleaner Indoor Air During Wildfires Challenge: Phase 2 Winners

Wildland Fire Smoke: A National Issue

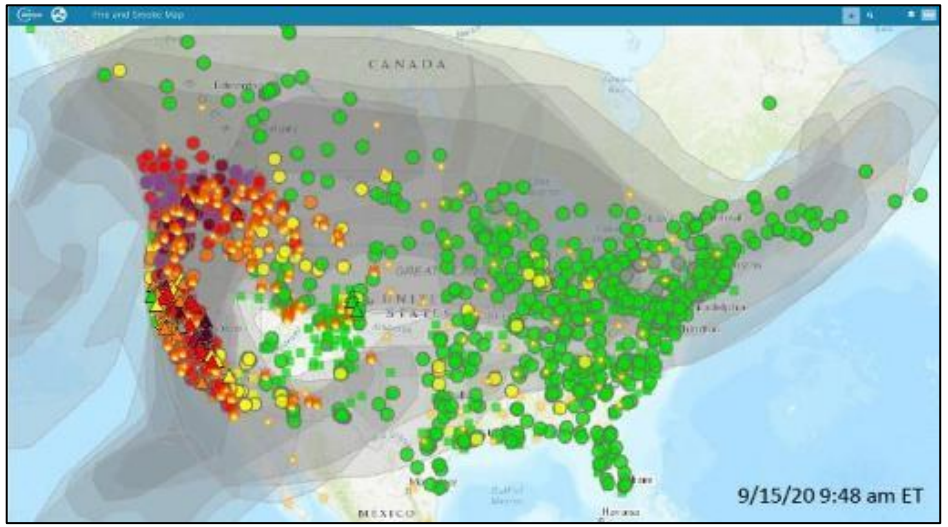
2020 U.S. EPA National Emissions Inventory (NEI): Primary $PM_{2.5}$



EGU = Electricity Generating Unit
ICI = Industrial/Commercial/Institutional (boilers/process heaters)
RWC = Residential Wood Combustion



Source: U.S. EPA. AirNow Fire and Smoke Map (6/7/2023)



Source: U.S. EPA. AirNow Fire and Smoke Map (9/15/2022)

Smoke from wildfires can lead to substantial impacts on air quality and public health

Smoke can infiltrate into the indoor environment

Source: NASA Image Records (2021)

EPA is conducting research to better understand the public health impacts of smoke from both wildfire and prescribed fire and steps to reduce these exposures

Key Research Topics

Emissions from wildland fires

Characterizing wildland fire smoke air quality impacts

Health and ecosystem impacts of smoke

Risk communication and interventions to reduce smoke exposures

Emissions from Wildland Fires

Emerging Technologies

EPA and partners are developing, testing, and applying emerging technologies to better measure and understand smoke emissions and air quality impacts

- Supporting the use of unmanned aerial system measurements in smoke plumes
- Testing performance characteristics of sensors and regulatory monitors during smoke episodes

Kolibri air sampling system attached to a small unmanned aerial system

Emissions from Wildland Fires

Controlled Burns

Controlled burn experiments under different combustion conditions provide a better understanding of emissions from prescribed burns

- More accurate exposure assessment
- Improved understanding of wildland fire contributions to ambient $PM_{2.5}$

Controlled burn of Ponderosa pine needles and dead wood

EQUATES

EPA's Air QUAlity TimE Series (EQUATES) project created a multi-year fire activity and emissions inventory to support the development of improved air quality management strategies

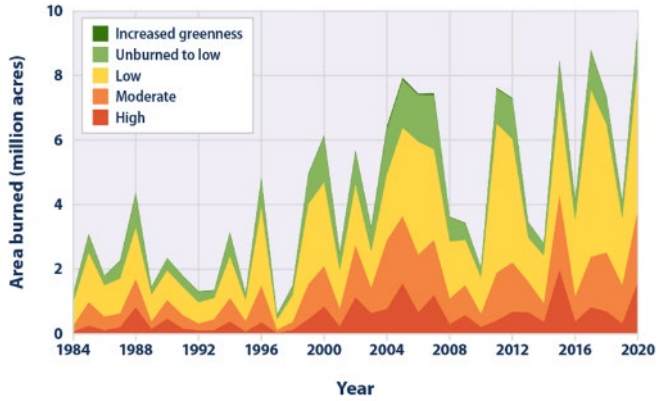


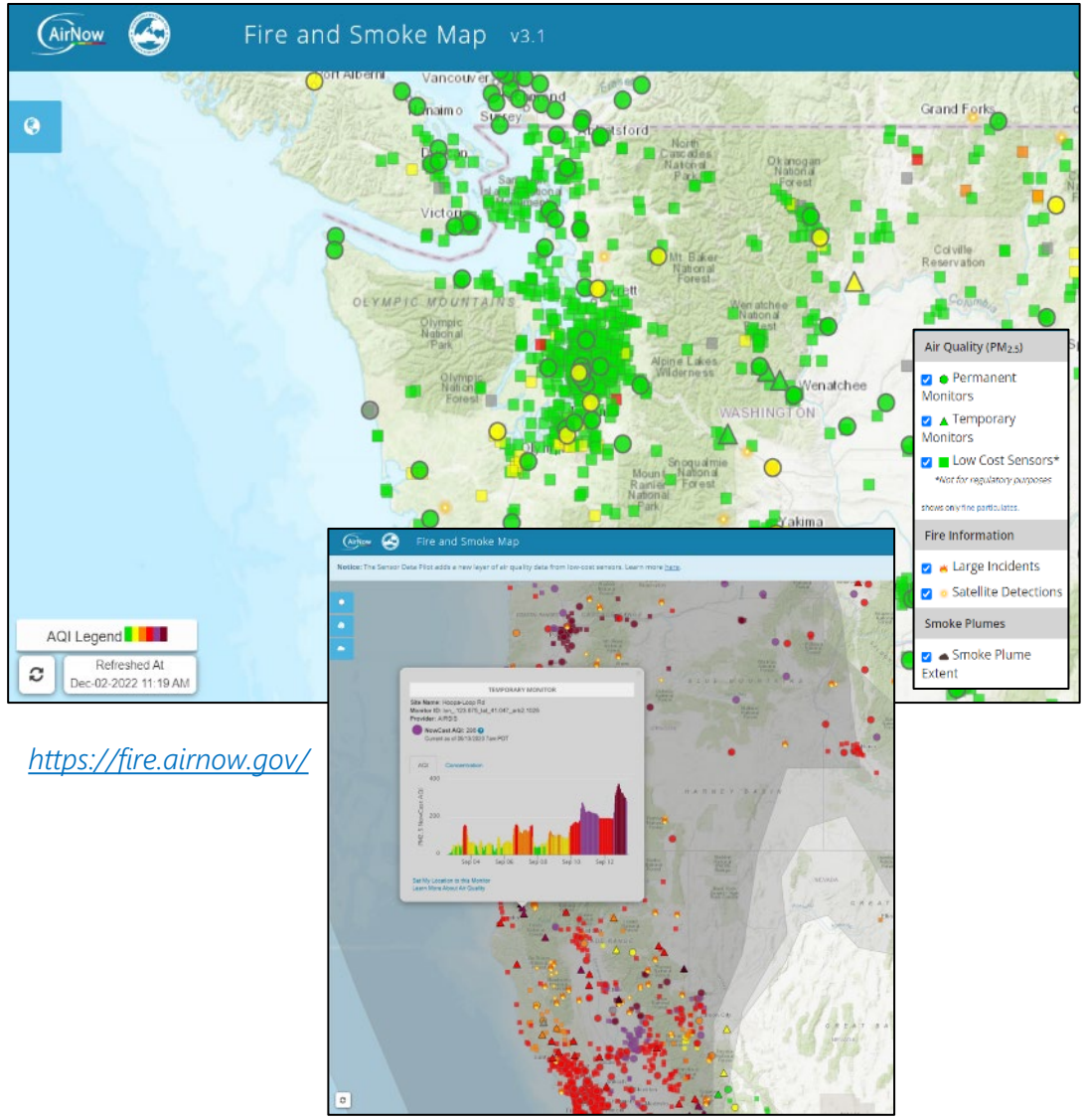
Image: Figure 3; https://www.epa.gov/climate-indicators/climate-change-indicators-wildfires

Characterizing Wildland Fire Smoke Air Quality Impacts

AirNow: Fire and Smoke Map

EPA's research provided quality assurance and bias correction method to enable crowd-sourced $PM_{2.5}$ sensor data (PurpleAir) to be included as a layer on the [AirNow Fire and Smoke Map]

Improves spatial coverage of Air Quality Index (AQI) information in areas without regulatory-grade monitors



https://fire.airnow.gov/

Characterizing Wildland Fire Smoke Air Quality Impacts

Wildfire Smoke Air Monitoring Response Technology (WSMART)

EPA loans monitoring equipment to supplement existing state, local, and tribal air agencies

In partnership with the Interagency Wildland Fire Air Quality Response Program, EPA also loans monitoring equipment to Air Resource Advisors (ARAs) deployed to major wildfires to support smoke monitoring and forecasting

Vehicle add-on mobile monitoring system (VAMMS)

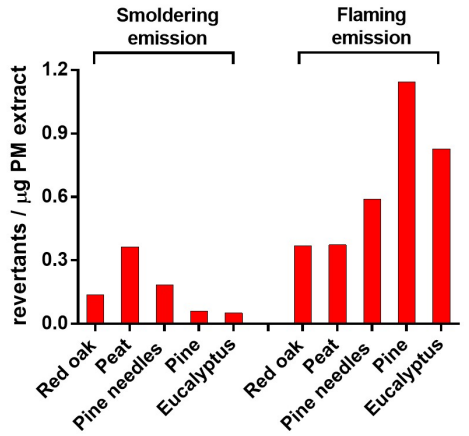
ARA operating monitoring equipment in the field

Health and Ecosystem Impacts of Smoke

Health Impacts

EPA researchers are improving the understanding of the relationship between smoke exposure and health

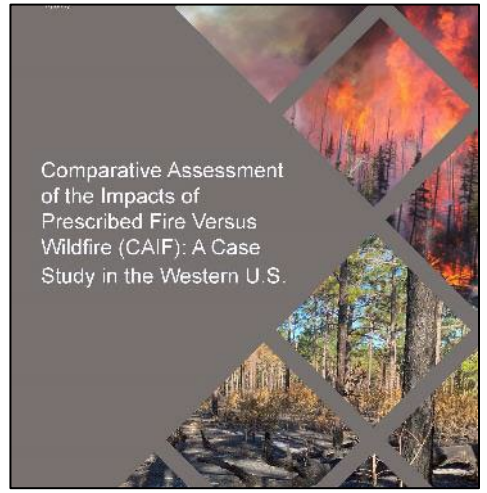
- Animal toxicological studies examining different smoke exposure durations, PM emissions from wood types (e.g., peat, eucalyptus) and combustion phases (e.g., flaming vs. smoldering)
- Epidemiologic studies examining different at-risk populations, exposure durations, and exposure assessment methods



Kim et al . (2018). EHP 126:1.

EPA led an interagency assessment - Comparative Assessment: Prescribed Fires vs. Wildfires, findings include:

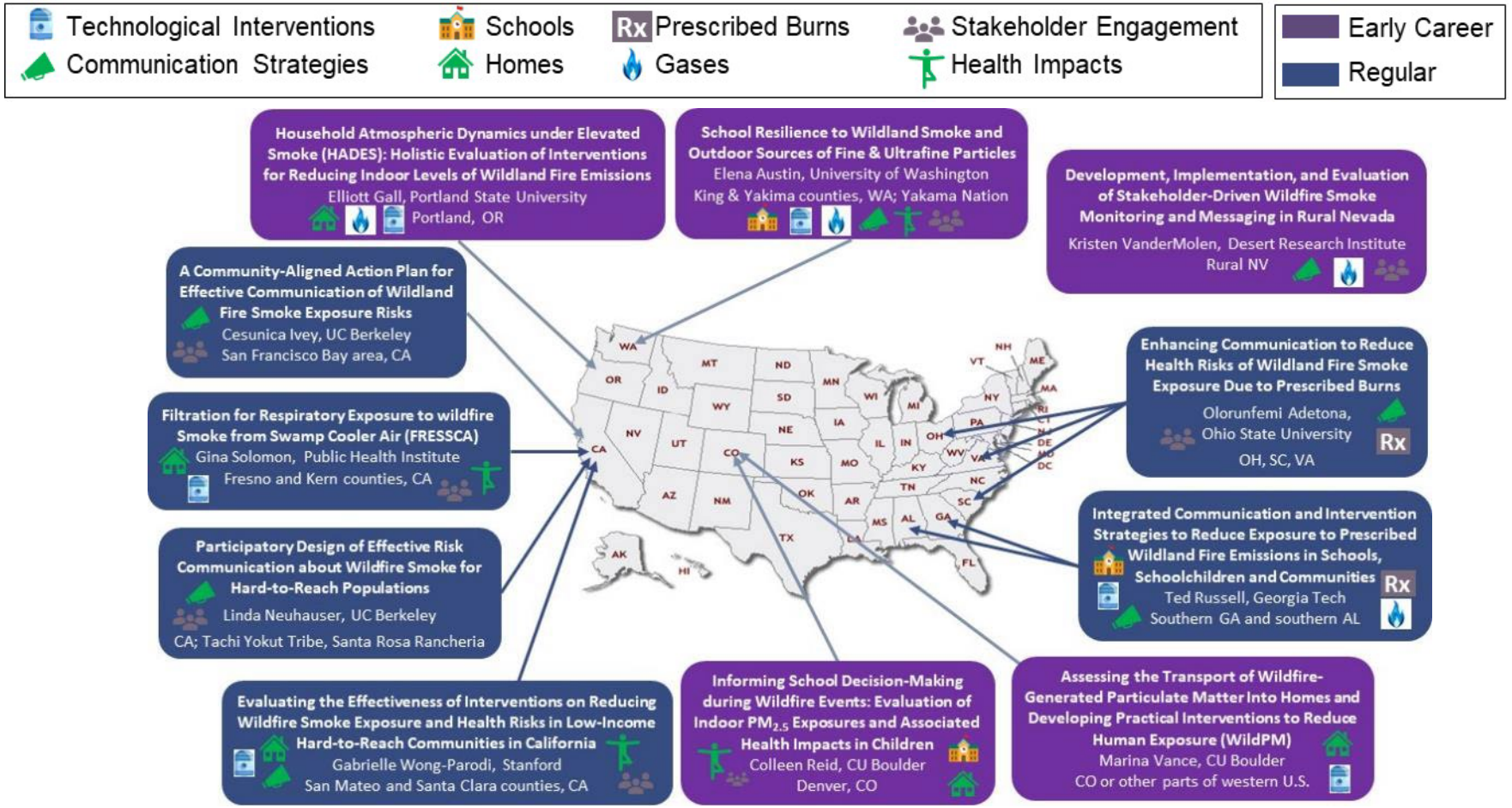
- Prescribed fire can reduce the overall size of a future wildfire and associated smoke-related health impacts
- Prescribed fire can result in smoke-related air quality and public health impacts, but potentially at a much smaller scale compared to a wildfire



Risk Communication and Interventions to Reduce Smoke Exposure

Science to Achieve Results ("STAR") "Interventions" Grants

Interventions and Communication Strategies to Reduce Health Risks of Wildland Fire Smoke Exposures



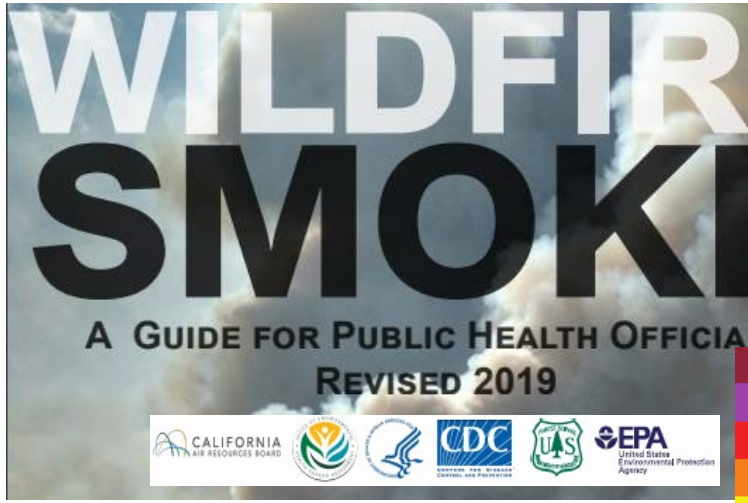
Risk Communication and Interventions to Reduce Smoke Exposure

Public health outreach: helping the public understand how fires impact their health, including providing real-time information during fire events.

- AirNow
  - Fire and Smoke Map
- Wildfire Smoke: A Guide for Public Health Officials
- Smoke Sense App
- Smoke Ready Communities

Preparedness resources

- Clean Air Spaces
- Respirator Use
- DIY Air Cleaners: safety evaluations; smoke reduction evaluation
- Air Sensor Toolbox
- Wildfire Smoke and Buildings



Information Clearinghouse: Smoke Ready Toolbox

Continuing Medical Education (CME) Courses

- Particle Pollution and Your Patients' Health
- Wildfire Smoke and Your Patients' Health

Wildfire ASPIRE Study

Advancing Science Partnerships for Indoor Reductions of Smoke Exposures

Smoke from Red Salmon Fire impacting Hoopa Valley, Oct 2020
AQI: Hazardous

Learn more at:
https://www.epa.gov/air-research/wf-aspire

Problem

- Frequency and magnitude of wildland fires is increasing
- Many U.S. communities are exposed to wildland fire smoke for days, weeks, or even months
- Smoke can infiltrate from ambient air to the indoor environment

Research Focus

- What science is available to support recommendations for communities to develop cleaner air spaces in larger buildings (e.g., schools, community centers)?
- What interventions are effective for reducing indoor smoke exposures and related risks?

Community Connections

- Missoula Public Health (MPH)
- Hoopa Valley Tribal EPA (HPVTEPA)
- Central California Environmental Justice Network (CCEJN)

Wildfire ASPIRE Study – Multiple Research Components

- **Web Summit** – Gather Federal, state, local, and tribal experts to quickly understand the state-of-the-science and work underway related to indoor air quality during smoke events
- **Field studies** - Monitor indoor/outdoor $PM_{2.5}$ concentrations in commercial and public buildings under typical conditions and opportunistically when smoke events occurred (Missoula, MT and Hoopa, CA)
  - Inspections conducted to understand how building characteristics, ventilation systems, or occupant practices affect $PM_{2.5}$ concentrations
- **Laboratory studies** – Assess safety and effectiveness of Do-It-Yourself air cleaners
- **ASPIRE-Health** - Evaluate Do-It-Yourself air cleaners' impacts on indoor air quality and health in homes (Hoopa and Tulare County, CA)
- **Prize-based Challenge** – Stimulate development of low-cost and sustainable methods to reduce outdoor air pollutants in homes during wildfire smoke or high pollution episodes

https://www.epa.gov/air-research/wf-aspire

Cleaner Indoor Air During Wildfires Challenge

Vision Shared by 10 Partner Organizations

Encourage development of new, effective, low-cost approaches to clean fine particulate matter ($PM_{2.5}$) from indoor air, particularly during high concentrations due to smoke events or other high-pollution episodes

Award a range of solution types to meet different needs: very low-cost, provides cooling, has an alternative power source

Challenge Overview

Challenge focused on specific criteria:

- Remove fine particles ($PM_{2.5}$) during smoke and high air pollution episodes (technical performance criteria specified in the Challenge)
- Are low-cost to purchase, operate, and maintain (including filters or any other consumables)
- Are easy to use, not too noisy, and meet safety requirements
- Include additional desirable criteria such as cooling a room without drawing in smoky air; adding a battery or other option for operation during power outages; reducing other air pollutants, such as VOCs

Detailed written concepts submitted by Solvers in Phase 1 (2021)

Phase 1 winners invited to submit prototypes for evaluation in Phase 2 (2022/2023)

Phase 2 Evaluations

Prototypes progressed through a series of qualitative and quantitative tests

- Potential electrical, mechanical, and/or chemical hazards
  - Disqualified prototypes if one or more safety hazard was observed or anticipated to occur when operating the prototype during a smoke event lasting up to 14 days; no further testing was conducted
- Ozone generation
  - Disqualified prototypes which generated ozone at or above 50 parts per billion (ppb); no further testing conducted
- "Must have" and "Desirable" Challenge criteria evaluations

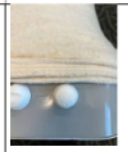
	Criteria Tested	Description	Target
Must Have Criteria	$PM_{2.5}$ reduction	Reductions in $PM_{2.5}$ concentrations starting at ~ 150 $\mu g/m^3$	Time to reach 80% reductions (30 $\mu g/m^3$); testing will stop at steady state conditions or 1 hour, whichever is reached first
	Costs	Expected consumer cost	$\leq$ $100 USD
	Noise	Measure noise levels during operation	$\leq$ 55 dBA
	Ease of use	Assess operator effort to set-up, operate, and maintain	Consider number of steps to set up and maintenance and power requirements evaluate size for residential use
Desirable Criteria	Cooling	Evaluate airflow and temperature	Increased output airflow and/or decreased temperature
	Operating costs	Evaluate annual estimated costs, availability of replacement parts, and generated waste	Low annual costs to operate and maintain, easy access to replacement parts, minimal waste
	Alternative power source	Estimate run time and performance using alternative power source	Higher points if alternative power source is included in initial cost and supports longer run times
	Reduction of other pollutants	Measurement of VOCs and/or other pollutants	VOC reductions (%) during same timeframe as reaching 80% $PM_{2.5}$ reductions
Bonus	Evaluator's judgment	Characteristics not captured in other judging elements, but relevant to Challenge goals	

Phase 2 Laboratory Testing

Evaluated "Must have" and "Desirable" performance features for each prototype

- Assessed the removal rate of a simulated wildfire smoke inside a small chamber
- Measured air flows, noise levels, and air cleaner temperatures in a typical indoor environment
- A non-technical user assessed the ease of installation and use

Cleaner Indoor Air during Wildfires Challenge – Phase 2
Ease of Use Evaluation

Evaluation Question	Likert Scale	Response (bullets)	Pictures
iii. How long did the setup of the prototype take? (Open answer)		• Assembly took approximately 3 minutes. • Once the directions became clear, the steps were straightforward to follow.	
iv. After running the air cleaner for 30 minutes, how easy was it to operate the prototype? (use Likert Scale) Provide a short description of challenges faced in operating the air cleaner (e.g., too big, too noisy, too much air flow, etc)? If no challenges were encountered then provide a note stating as such. (Open answer)		• The nozzle is easily readable and offers multiple levels. • The prototype is quite large and requires around 5 feet of space for the cloth to inflate. • It produces a significant amount of noise.	

Phase 2 Review Process

EPA summarized the results of the prototype evaluations for the Phase 2 Judging Panel

Judging Panel included indoor air quality experts, a product engineer, and public health, communications, and risk experts for federal, state, and local agencies, academia, and the private sector

Recommendations from Judging Panel was discussed with Challenge Partners

Input from Judging Panel and Challenge Partners informed EPA's decisions

Thoughts from Challenge Partner…..

Jeffery R. Williams Ph.D.
Air Pollution Specialist
California Air Resources Board

CALIFORNIA AIR RESOURCES BOARD

CHALLENGE WINNERS

Phase 2

WINNING PROTOTYPE

The Cocoon

A Do-It-Yourself (DIY) air cleaner design using a large, tube-shaped fabric filter combined with a box fan, creating a low-cost solution with the potential for widespread use, especially during emergency smoke conditions

Elliott Gall

Brett Stinson

Portland State University

The Cocoon: An Accessible Low-Cost Air Cleaner for Safer Spaces During Wildfires

Department of Mechanical and Materials Engineering
Portland State University

The Cocoon is an air cleaner consisting of:

- a box fan,
- a large “sock”-like fabric filter, and
- a strap or band

The Cocoon is designed to be:

- ***Effective***: > 80% PM2.5 removed in 30 minutes
- ***Inexpensive***: < $60 if purchased new
- ***Accessible & Resourceful***: household materials
- ***Reusable***: fabric can be washed

Healthy Buildings Research Lab

Portland State UNIVERSITY

Healthy Buildings Research Lab

The origin of the cocoon: an analogy

Cloth face mask

is to

N95 face mask

as…

The Cocoon

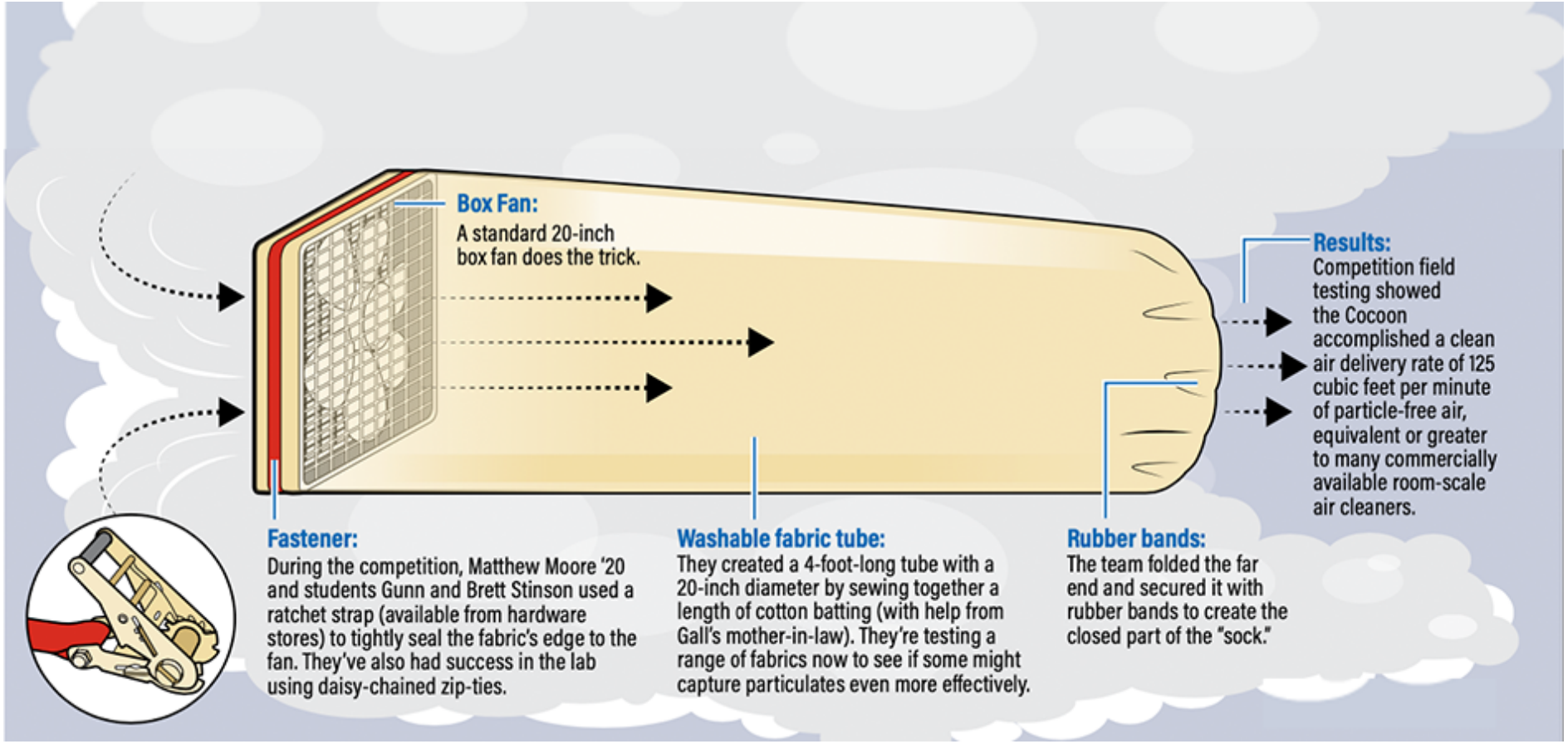
is to

3-stage HEPA air cleaner

Photos: (clockwise, from upper left): Fruit of the loom, amazon.com; 3M V-flex, digikey.com; Cocoon, photo Brett Stinson; B-Air RA-650, lasko.com

Overview of The Cocoon

Cost: ~$40-60 if purchasing materials new
Goal: Build with materials "on-hand" to drive cost to 0, allow for immediate use in emergency

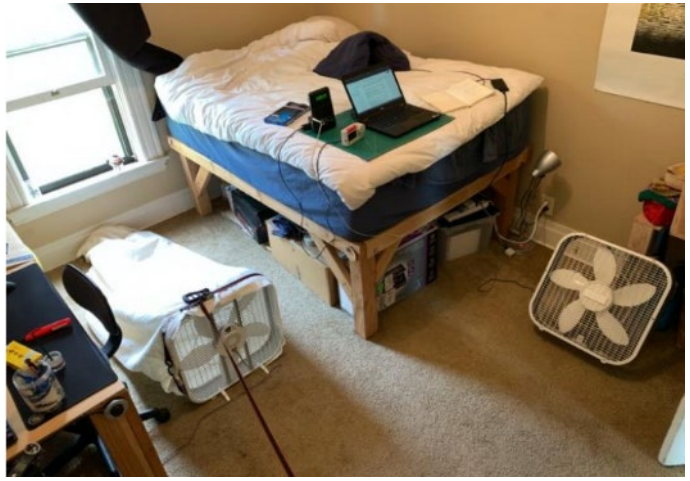


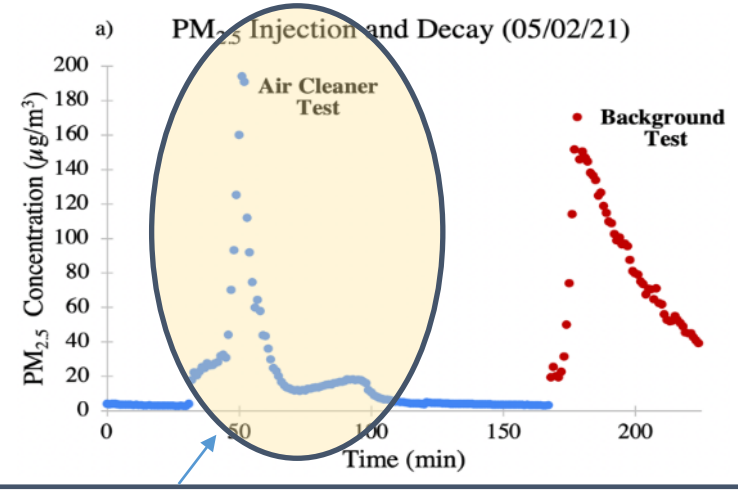
Graphic: https://www.pdx.edu/mechanical-materials-engineering/news/portland-state-team-wins-epas-cleaner-indoor-air-during-wildfires-challenge

Healthy Buildings Research Lab

Results show effectiveness

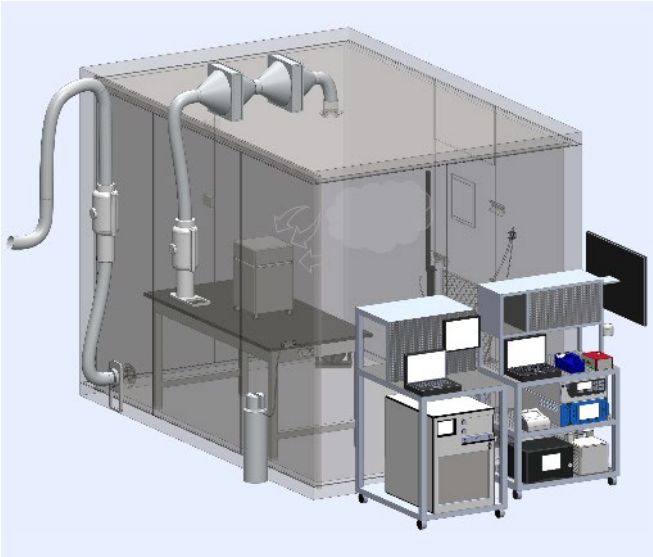
Field testing

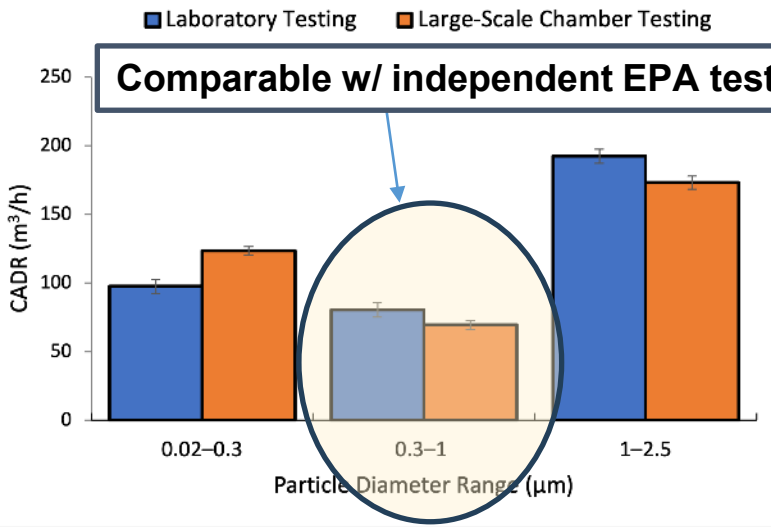




Reduced $PM_{2.5}$ by 80% in ~15 minutes in a field test

Lab testing





Comparable w/ independent EPA testing: ~65 m^3/h CADR

Healthy Buildings Research Lab

What's next?

Scan the QR code with your phone's camera to learn more or contact Dr. Gall at gall@pdx.edu

Future goals:

- Testing of other household fabrics
- Alternative methods of construction
- CADR with repeated washing
- Experimentally backed DIY guide and dissemination
- Scalable design for production
- Test for other emergency scenarios
  - e.g., other particle releases (e.g., tear gas)

The team:

Brett Stinson

Kathy Ryan

Mikayla Reed

Matthew Moore

Warren Gunn

Elliott Gall

CHALLENGE WINNERS

Phase 2

WINNING PROTOTYPE

Metalmark Clean Air Device

A novel approach using a unique, nanostructure material coated filter to capture smoke particles. A thermal catalytic oxidation self-cleaning process allows renewal of the filter, extending its useful life.

Metalmark Innovations, PBC
and its engineering consultants from Alogus Innovation and Design

We're Living with the Consequences of Climate Change & Deteriorating Air Quality

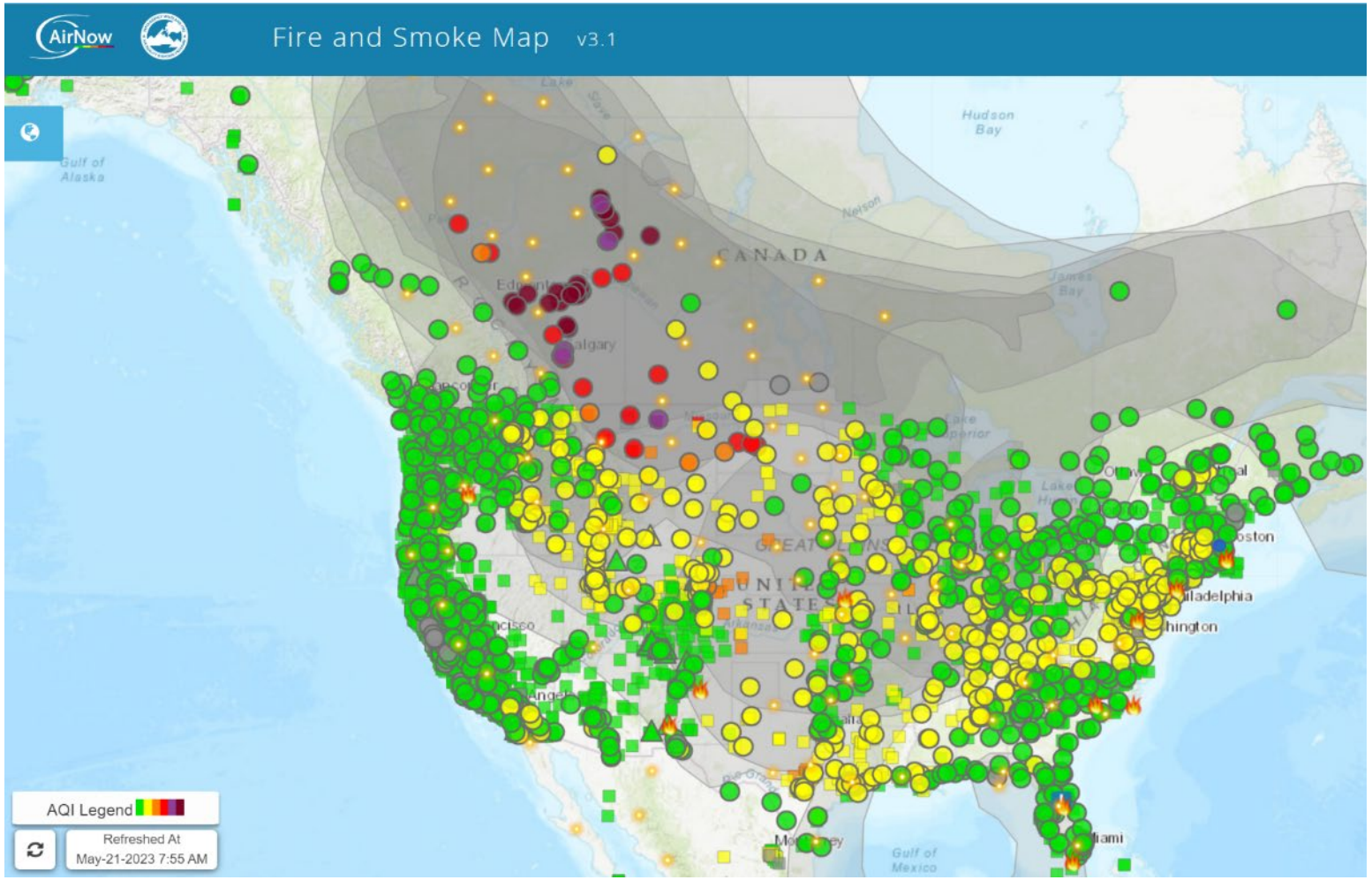
The time to adapt to climate realities is **NOW**.

May 19, 2023, CNN News

"Smoke from Canadian fires is pouring into the US and could linger for days"

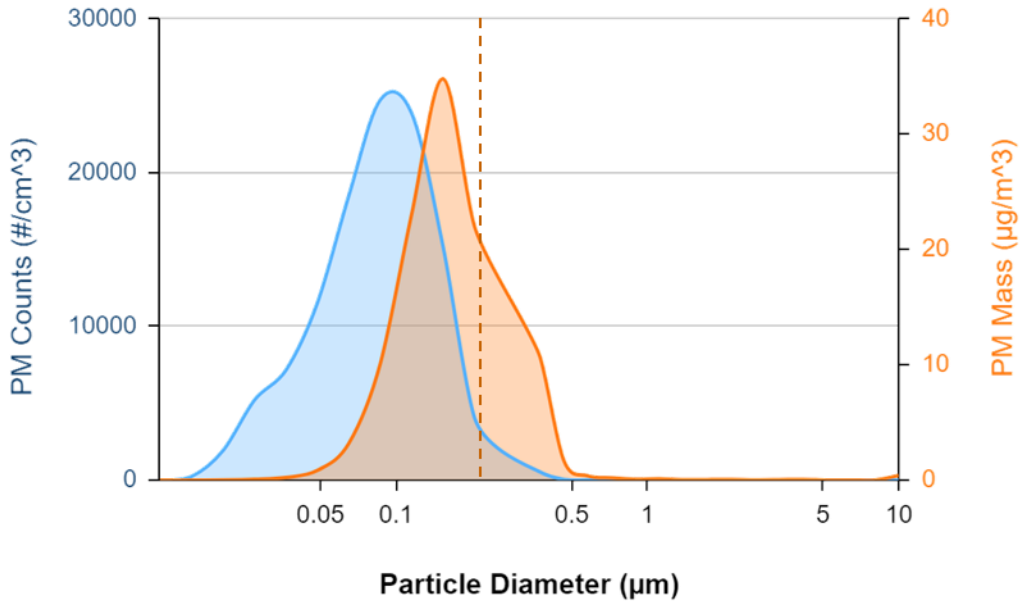
American Lung Association

"...nearly 36% of Americans—119.6 million people—still live in places with failing grades for unhealthy levels of ozone or particle pollution."



Smoke and Indoor Particle Size Distribution

Smoke is ~100% submicron (< 300 nm/< 0.3 µm)

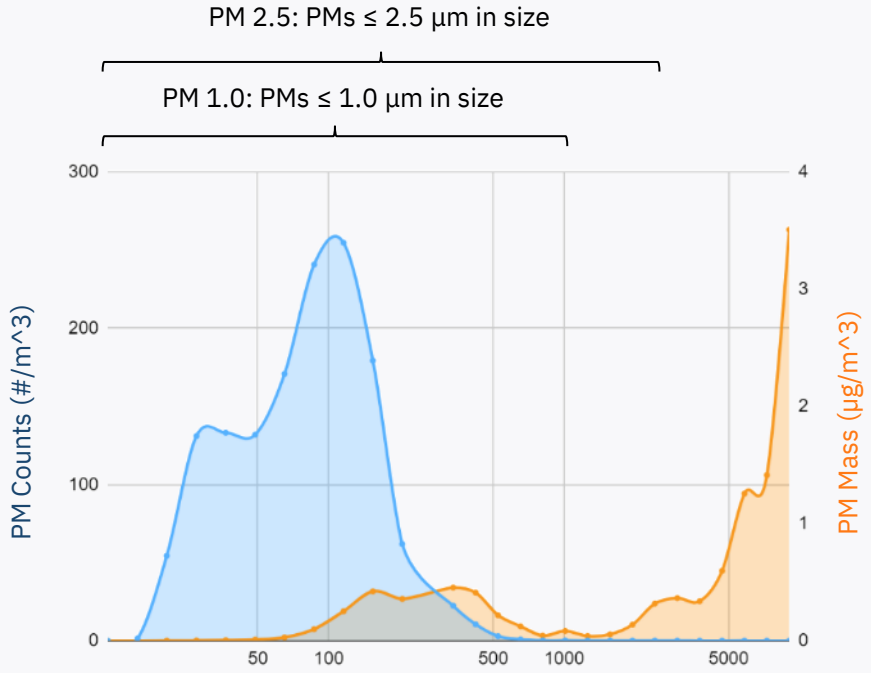


Measurement Technique

Optical Particle Sizer (OPS) and Scanning Mobility Particle Sizer (SMPS) were used to measure pine needle PM distribution.

Shirman et al. "Evaluation of Filtration Efficiency of Various Filter Media in Addressing Wildfire Smoke in Indoor Environments: Importance of Particle Size and Composition." *Atmosphere*, November 2023.

Interestingly, most indoor particles are also submicron



Measurement Technique

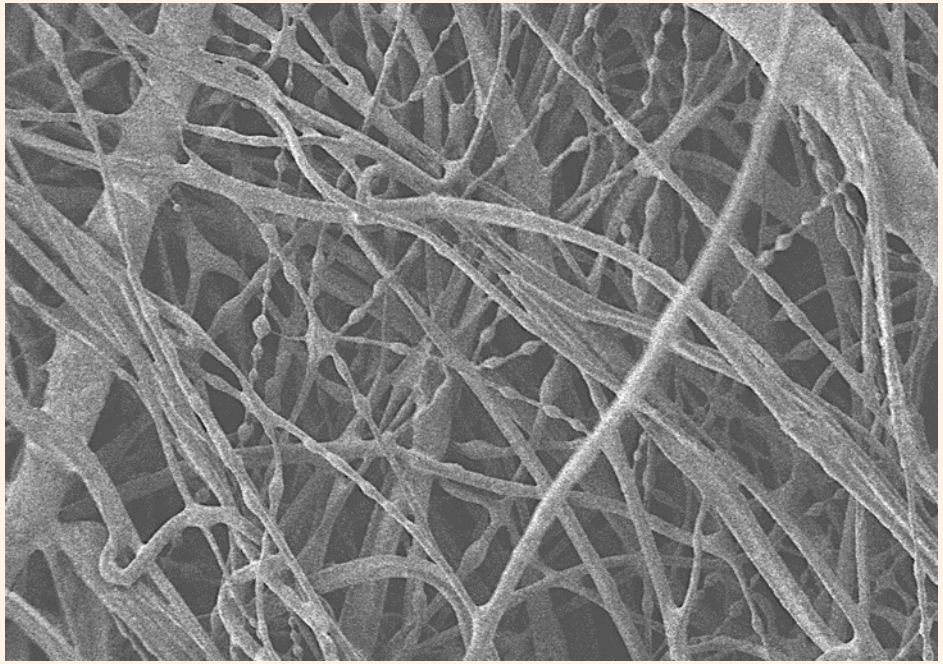
Optical Particle Sizer (OPS) and Scanning Mobility Particle Sizer (SMPS) were used to measure particle concentrations in offices and commercial spaces. Commercial PM sensor data were also used for comparison.

Smoke Is One of the Most Challenging Pollutants for PM Removal

Key findings of peer-reviewed paper on wildfire smoke and HVAC filter media

- Wildfire smoke presents serious health threats due to its particle size (< 300 nm) and composition (chemicals)
- Current filter tests are based on inorganic salts
- Smoke efficiency results show
  - MERV ratings are not sufficiently informative for smoke removal efficiency
  - Charged media removal efficiency of smoke is lower than that of salts
  - Mechanical media have similar or better removal efficiency of smoke than charged media but has upwards of 10x pressure

Pine needle smoke interacts and accumulate on fiber media differently from salts



Measurement Technique

Scanning Electron Microscopy (SEM) was utilized to analyze the problem of filter clogging with pine needle smoke.

Shirman et al. "Evaluation of Filtration Efficiency of Various Filter Media in Addressing Wildfire Smoke in Indoor Environments: Importance of Particle Size and Composition." *Atmosphere*, November 2023.

METALMARK

The Case for a Self-Renewing Air Cleaning System

Metalmark's Prototypes for the EPA's Cleaner Indoor Air During Wildfires Challenge

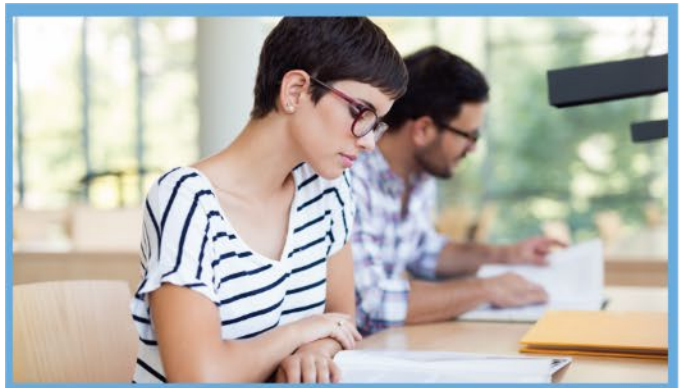
- As few as 1/10th filter replacements (up to 5-year filter life)
- High smoke removal efficiency
- Tested by EPA to meet the Challenge's air cleaning criteria without byproduct emissions
- Patented self-renewing system & proprietary filter

Metalmark Tatama™

Designed for commercial buildings with climate/health nexus in mind

- Better IAQ & health
- Lower building energy use

Target Applications



UNIVERSITIES AND SCHOOLS

OFFICES

MEDICAL FACILITIES

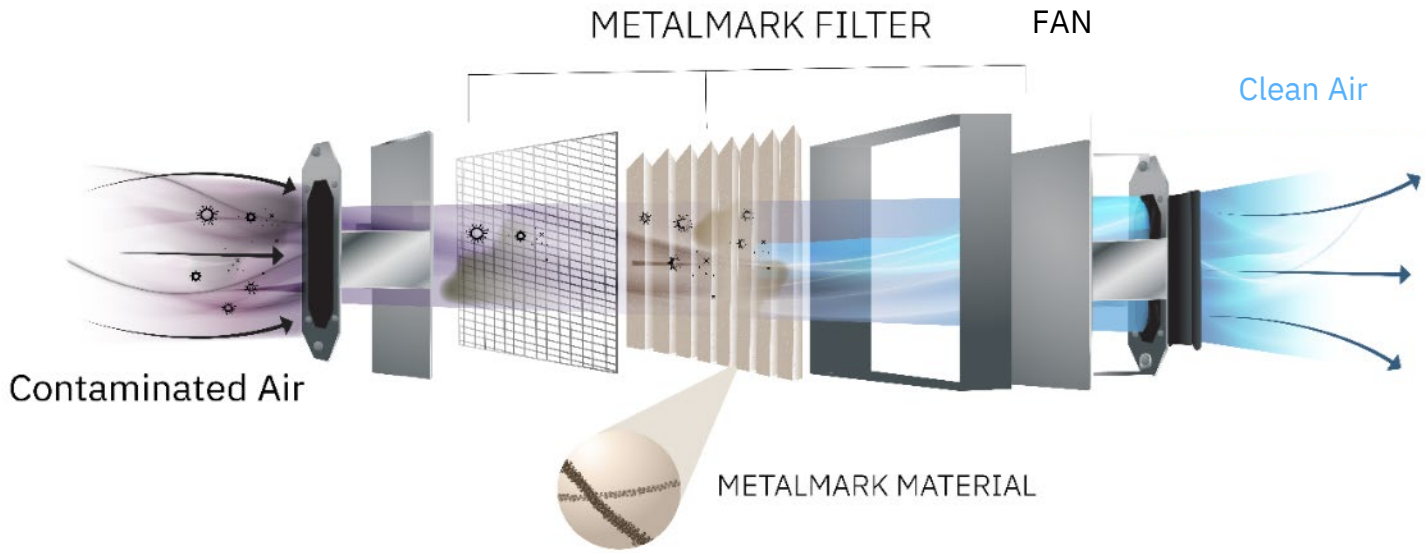
Coverage

Metalmark Tatama™: Patented 2-Stage Air Cleaning Technology

Third-party lab tested: proven efficacy against bacteria, viruses, smoke, as well as no harmful byproduct emissions

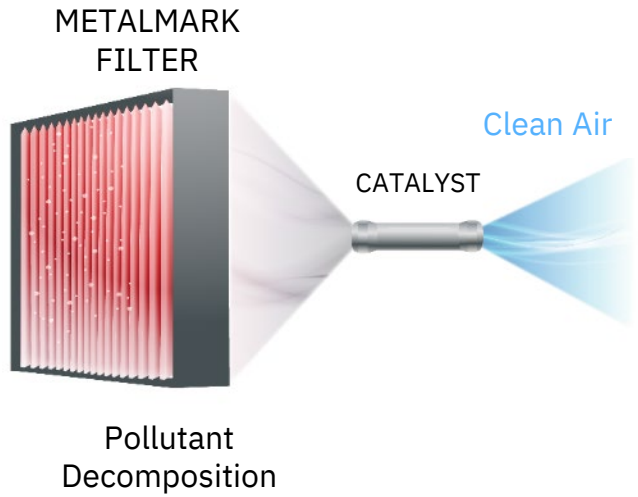
Stage 1

Air Cleaning



Stage 2 (1x/month)

Filter Self Renewal with Catalytic Cleaning



Metalmark Tatama™ Installed

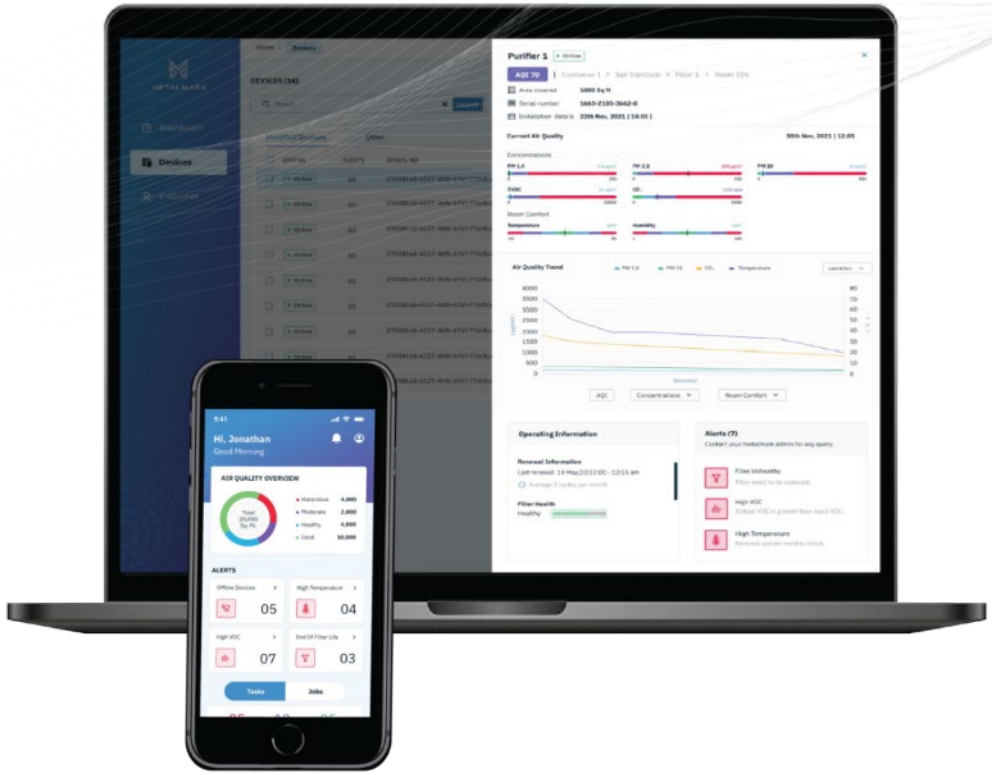
In-ceiling Installation

Ceiling Register

Ceiling Register

IAQ Data Transparency
Smart Operations

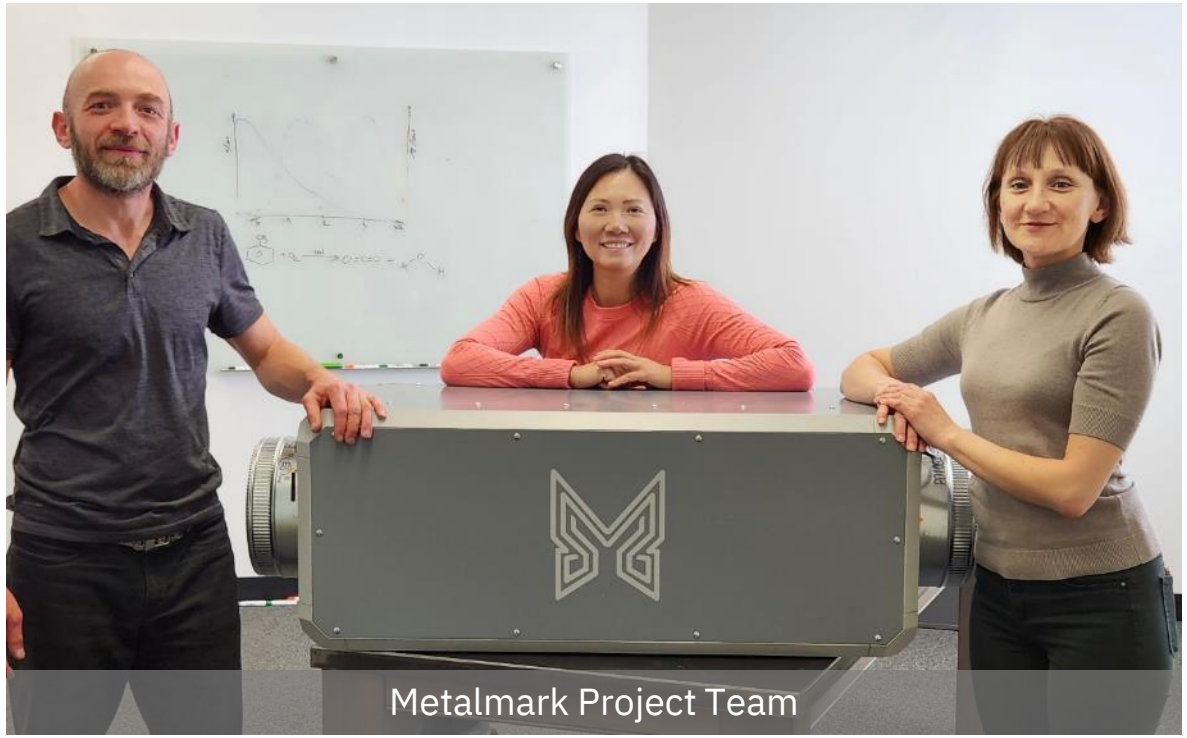
A Smart, Distributed, & Targeted IAQ Solution that Reduce Ventilation Energy Use



Value Propositions

- ✓ As few as 1/10th filter replacements (up to 5-year filter life)
- ✓ As low as 1/3 total lifetime cost
- ✓ Net energy savings
- ✓ Easy building integration & retrofits
- ✓ Effective

Thank You!



Metalmark Project Team

Metalmark's Engineering Consultants (Alogus)

Questions?

Learn more about the *Cleaner Indoor Air During Wildfires Challenge* and Phase 2 winners at:
https://www.epa.gov/air-research/winners-cleaner-indoor-air-during-wildfires-challenge

Smoke plumes over Missoula, MT Aug 2017