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Policy and Regulatory Roadmap to Achieve Health-Based Indoor Air Quality Standards

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ABSTRACT

Poor indoor air quality (IAQ) is one of the world's largest unmet public health threats. Although we spend 90% of our time indoors, building codes base IAQ requirements on comfort and harm prevention rather than health and wellness. Post-construction, there is little regulation of IAQ. The cost of unhealthy indoor air is massive, with US healthcare spending of >$45B for respiratory infections and >$39B for allergies and asthma. Yet, while health risks from unhealthy indoor air are increasing due to increasing wildfire frequency, longer allergy seasons, and new respiratory viruses, the momentum for developing and implementing mandatory health-based IAQ standards in the aftermath of the COVID-19 pandemic has waned, with little evidence to date of concrete policy and regulatory advances. In response, this paper outlines a practical, feasible, and actionable policy and regulatory roadmap to achieve health-based IAQ standards, anchored in a bottom-up approach linked to a strategic plan that can scale nationally. First, we review the public health, economic, and national security case for health-based IAQ standards. Second, we establish guiding principles, primary goals, and current state assessment of health-based IAQ standards relative to our guiding principles and primary goals. Third, we present two mini-case studies focused on national energy and life safety codes, which are possible models of the road ahead for health-based IAQ standards. Fourth, we define an action-focused critical path, with clear phases and key stakeholder roles and responsibilities, to achieve health-based IAQ standards. Finally, we conclude with a call to action to provide clear direction for future efforts.

INTRODUCTION

This paper outlines a practical, feasible, flexible, and actionable policy and regulatory roadmap to achieve health-based indoor air quality (IAQ) standards. We propose a high-level critical path anchored on a primary goal and driven by key stakeholders that offers the greatest potential for raising the IAQ floor across the built environment.

THE CASE FOR HEALTH-BASED IAQ STANDARDS

In 2025, mandatory health-based IAQ standards remain an aspiration, not a reality. Despite decades of research and advocacy, significant harm caused by acute and chronic hazards, and heightened public awareness, health-based IAQ for all persists as one of the largest unmet public health needs in the world (ASHRAE 2023). Although we spend 90% of our time indoors, existing IAQ requirements within building codes are based on comfort and prevention of harm rather than health and wellness and apply to design and construction. Post-construction, there are generally no ongoing maintenance and performance requirements.

Moreover, the momentum for developing and implementing mandatory health-based IAQ standards in the aftermath of the COVID-19 pandemic has slowed significantly, with little evidence to date of concrete policy and regulatory advances. While the pandemic demonstrated the critical importance of IAQ, many voluntary interventions in place were slowly forgotten or dismantled once the spotlight turned away from airborne disease transmission and the continuing, significant health burden of COVID-19. To achieve durable change, health-based IAQ standards must be required, not merely recommended. Below is a brief summary of key justifications for health- based IAQ standards. **The Public Health Case:** Poor IAQ is one of the top risks to the health of Americans. Unhealthy indoor air

contributes to chronic diseases like asthma, cardiovascular disease, and lung cancer and plays a major role in spreading

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disease, with up to 18x higher transmission rates of respiratory disease indoors (Bulfone et al, 2021). It is also a key driver of the annual 85.2 million ambulatory-care visits with respiratory illness as the primary driver and with lower respiratory infections being the 8th leading cause of death (Kochanek et al, 2019). Children, seniors, and individuals with chronic health conditions are disproportionately impacted.

The Economic Case: IAQ boosts economic productivity and growth. Increased ventilation in buildings (reduced exposure to indoor air contaminants) is associated with reduced sick days and worker absenteeism (Allen and Macomber, 2022). Lower concentrations of indoor pollutants improve performance and productivity in workplaces and schools (Mendell et al, 2013). US healthcare spending for respiratory infections, allergic rhinitis, and asthma are greater than $80 billion annually (Duan et al, 2023). Mitigating the long-term health effects of IAQ would protect Americans and reduce healthcare burdens on families and the economy. One study estimates the US economy could gain $23 billion annually with improved air quality due to a 35% decrease in sick leave (Milton et al, 2000).

The National Security Case: IAQ safeguards America's national security and critical infrastructure. Poor IAQ in military installations can compromise readiness by impacting the health and performance of military personnel, reducing operational effectiveness, and increasing biosecurity risk to our armed services and the general population from naturally occurring, accidental, and deliberate (weaponized) airborne biological threats (2023 Biodefense Posture Review). Critical infrastructure—including hospitals, transportation, and emergency services—depends on clean air to remain operational, especially during crises (Lagoudas et al, 2025).

GUIDING PRINCIPLES, PRIMARY GOAL, AND CURRENT STATE ASSESSMENT

Guiding Principles

Eight guiding principles frame our proposed approach to achieving health-based IAQ standards:

1. Health-centric: IAQ standards should incorporate "good health and well-being" as foundational priorities consistent with the UN Sustainable Development Goals
2. All buildings: health-based IAQ standards should eventually apply to all buildings – new and existing, while accounting for varying baseline levels of readiness, capabilities, and financial means and providing support mechanisms rather than exemptions
3. Mandatory: health-based IAQ standards should eventually become mandatory and backed by enforcement capabilities to ensure widespread, consistent adoption
4. Design and operations: health-based IAQ standards should address operations and maintenance in existing buildings in addition to design of new buildings
5. Comprehensive protection: health-based IAQ standards should address the three main categories of contaminants (particles, gases, and pathogens) in an integrated, coherent manner
6. Performance-based: health-based IAQ standards should enable performance-based approaches that empower buildings to make appropriate choices given unique differences
7. Resilient: health-based IAQ standards should address acute hazards such as wildfires and infectious disease outbreaks in addition to chronic hazards during normal operations
8. Practical: health-based IAQ standards must be simple to understand and implement, cost-effective, and manageable on an ongoing basis to the maximum extent possible

Primary Goal – Mandatory Minimum Requirements

Mandatory minimum requirements are the most powerful way to promote implementation of health-based IAQ standards consistent with our guiding principles. While voluntary approaches, including certification programs and organization-specific initiatives, are valuable for catalyzing early adopters and "raising the ceiling," most building owners and operators will do only what they are compelled to do by force of law and regulation. This consideration is especially relevant for buildings serving high-risk, vulnerable populations including the immunocompromised,

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elderly, and children. More ambitious mandatory minimum requirements, rather than perfunctory, check-the-box ones lacking grounding in health science and legitimate health benefits, offer the greatest opportunity to "raise the floor" for health-based IAQ across the built environment.

It seems self-evident that the standards of the future should, to the extent possible, evolve from the standards of the present. A key strength of this approach is that these consensus standards are already referenced in model building codes and are the basis of many state and local codes. To start from scratch to develop new standards that would then have to work their way into regulations would delay their implementation for many years. The normal development time for a new standard can easily be three to five years and adoption in code can also take three to six years.

Within the US, the only nationally recognized minimum standard for non-residential buildings is ASHRAE Standard 62.1. It has been criticized for setting expectations for IAQ too low, but there is no reason that its definition of acceptable IAQ cannot change to reflect higher aspirations for impact on health and wellness. For those who think the bar should be set at a higher level than "air in which there are no known contaminants at harmful concentrations as determined by cognizant authorities and with which a substantial majority do not express dissatisfaction," engagement in the development of the standard as members of the project committee or through change proposals is a well-defined, open process.

If, for the US, ASHRAE Standard 62.1 is the starting point, an important first step would be to support transition from the prescriptive Ventilation Rate Procedure that sets requirements for outdoor air flow based on space type to the Indoor Air Quality Procedure (IAQP) that sets maximum allowable levels for 15 important air contaminants and three mixtures – and requires verification that they are met post-construction. The further development of this approach is to 1) determine whether this relatively large list of contaminants can be reduced in a rational way to a more compact set for which continuous monitoring is feasible and 2) adjust the acceptable levels of key contaminants to conform to a more ambitious objective of promoting health and wellness. Additionally, ASHRAE Standard 241 could be required as an adjunct to Standard 62.1 to address risk of airborne infectious disease transmission. Some potential sources of new criteria for indoor contaminant exposures include:

- World Health Organization (WHO): The 2021 Air Quality Guidelines recommend levels and interim targets for particulate matter of 2.5 micrometers and 10 micrometers in diameter (PM2.5 and PM10, respectively), ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO), and sulfur dioxide (SO2).
- Morawska et al (2024): The article "Mandating IAQ for Public Buildings" proposes routine monitoring of PM2.5, carbon dioxide, carbon monoxide, and ventilation rate and proposes limits for each contaminant.
- Morantes et al (2024): The article "Harm from Residential Indoor Air Contaminants" reports that five out of 45 potential contaminants of concern (PM2.5- PM10, NO2, formaldehyde, radon, and O3) account for over 99% of total medium harm, quantified as disability adjusted life years (DALY's), in dwellings. ASHRAE Standard 62.2 is considering a proposed IAQP for residential buildings based on this work and ASHRAE Standard 62.1 is evaluating the applicability of this approach to non-residential buildings.

Balancing comprehensiveness, practicality, and expediency, we recommend focusing on stronger integration of existing ASHRAE standards, including Standards 62.1 and 241 to create a holistic, coherent package of standards. Then, we advise an organized, resourced effort pushing for their adoption and enforcement, while further integrating and refining these standards in the future. Additionally, health-centric IAQ guidelines published by the American Industrial Hygiene Association (AIHA), the US Centers for Disease Control (CDC), and other government and non- governmental organizations with a health and safety mandate can reinforce existing ASHRAE standards and provide a strong health-focused basis for future improvements. We recommend that, rather than criticize the level of existing standards and proposing alternatives as if they are fundamentally different, that IAQ advocates engage in the consensus standards process and work towards the adoption of criteria that they believe are sufficient. Of critical importance, whatever the criteria embedded in standards are, is the enforced requirement that buildings continue to meet those requirements throughout their life cycle. The majority of harm caused by poor IAQ is in existing buildings that have

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degraded over time. Without requirements for the performance of existing buildings, improved requirements for new buildings will have limited effect. Ongoing compliance may be assessed by continuous monitoring, but periodic retro-commissioning is also an effective way to ensure that performance is being maintained over the life of a building.

Current State Assessment

Taking the US as an example, the status quo for regulation of IAQ is far from the ideal expressed above in the guiding principles. The existing criteria on design requirements are based on perceived air quality and limiting contaminant exposures to levels that limit health problems from chronic exposures, contrary to the WHO definition of health as "not merely the absence of disease."

There are no uniform national standards for indoor air, unlike the criteria for ambient air promulgated by the Environmental Protection Agency (EPA) under the Clean Air Act. The regulatory landscape is a patchwork of state and municipal codes that may or may not adhere to model codes. Model codes excerpt consensus standards such as ASHRAE Standard 62.1, but in a very limited way. Mandatory requirements are, in most cases, design requirements for outdoor air flow rates and do not extend to operation and maintenance.

In principle, codes and the standards that reference them address all major contaminant types, but only in a prescriptive way. Providing specified outdoor air flow rates and filter efficiencies is presumed to provide acceptable IAQ. For example, acceptable indoor air quality in ASHRAE Standard 62.1 in part is air "in which there are *not likely* to be contaminants at concentrations that are known to pose a health risk" (emphasis added). Only in optional performance-based compliance paths such as the IAQP of ASHRAE Standard 62.1 is verified compliance with exposure limits for specific contaminants required, and verification need only be done once at the completion of construction.

Sustainability, as currently applied to IAQ management, focuses on limiting the energy use associated with IAQ control, not with promoting "good health and well-being" as embodied in the UN Sustainable Development Goals. Energy standards and codes, on the other hand, require the use of energy efficient technologies including demand control ventilation, outdoor air economizer controls, and air-to-air energy recovery to mitigate the energy impact of ventilation.

Driven by increasingly frequent and widespread wildfire smoke events as well as the horrific consequences of the COVID-19 pandemic, resilience now has a high profile. However, requirements to harden buildings against extreme IAQ incidents are not yet included in design regulations. ASHRAE Standard 241 for control of infectious aerosols and ASHRAE Guideline 44 for mitigation of wildfire and controlled burn smoke promise to provide a basis for such requirements but are too recently published to have had a major impact. Existing standards and codes may be called "practical" but unfortunately are limited in their scope and adoption. In sum, although many resources provide a starting point for health-based IAQ minimum requirements, much work is required to refine and implement them.

CASE STUDIES FOR BUILDING AND PUBLIC HEALTH REGULATION REFORM

The process by which national energy and life safety codes developed suggest a possible path forward for achieving national IAQ standards. It is notable that in both cases, crises of different types – the energy crisis of the early 1970s and widely publicized, preventable fire disasters were instigating events. The COVID-19 pandemic should be the crisis that tips the balance for IAQ regulations, but that remains to be seen.

National Energy Code: While the US does not have a single, uniform federal energy code that covers all buildings, US law requires states to have energy codes for non-residential buildings that are at least as stringent as ASHRAE Standard 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings (originally, Standard 90). In a favorable federal regulatory environment, the path to such requirements could be emulated for IAQ. In July 1973, the year of the "oil crisis" caused by the Organization of Petroleum Exporting States (OPEC) oil embargo, the National Bureau of Standards (NBS, now the National Institute of Standards and Technology, NIST) was requested to develop criteria for a national building energy efficiency standard by the National Council of States for Building Codes and Standards (NCSBCS). The criteria document developed by NBS was delivered to NCBCS in February 1974 after which it was given to ASHRAE to develop into a consensus standard. The first public review draft of ASHRAE Standard 90P was issued in June 1974 and the first

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version of the standard, ASHRAE Standard 90-1975, was published in January 1975. The Energy Conservation Standards for New Buildings Act of 1976 (now called the Energy Conservation and Production Act, ECPA) called for "the development and implementation, as soon as practicable, of performance standards for new residential and commercial buildings." This statute, developed at the same time as the first ASHRAE Standard 90, did not initially make explicit reference to it, but subsequently was amended to require that state code provisions meet or exceed the current version beginning with 90-1989. Although achieved in a short period of time by what looks in retrospect to be a straightforward process, this significant achievement required great commitment and effort. Nevertheless, this successful effort to establish a national energy standard 50 years ago creates hope that the same outcome can be achieved for IAQ standards. The adoption of this national standard did not establish operation and maintenance (O&M) requirements for all regulated buildings. The development of energy benchmarking programs, mainly on the municipal level, has led to progress in O&M. Perhaps this, too, is an approach that will work again for IAQ.

Life Safety Code: The Life Safety Code was established in 1913 by the National Fire Protection Association and created a framework for inspection of buildings to ensure they meet specific codes that protect the health, safety, and lives of occupants, especially in emergencies like fires. A major catalyst was the 1911 Triangle Shirtwaist Factory fire in New York City, which claimed the lives of 146 workers, primarily young immigrant women. The disaster laid bare important deficiencies in building safety, such as locked exits and inadequate fire escapes. The Life Safety Code requires regular (typically annual) building inspections to assess fire alarms, sprinklers, egresses, and fire extinguishers, often conducted by the local fire department or building authorities. In hospitals and healthcare centers, inspections may be conducted by the state health departments and/or the Centers for Medicare and Medicaid Services (CMS). The Life Safety Code is an important component of building safety and has also served as a basis for determining liability in accidents, including by insurance companies. The code is an example of the necessity of requiring ongoing O&M, along with requiring design standards, to protect the health of building occupants. IAQ standards would also protect the health of building occupants and could be incorporated into regular inspections, similar to the Life Safety Code.

CRITICAL PATH TO ACHIEVING HEALTH-BASED IAQ STANDARDS

We propose the following milestone-based critical path (see fig. 1) to achieve health-based IAQ standards at national scale in the US over the next decade:

Phase 1: the focus will be to clearly define minimum requirements for health-based IAQ during building design and operations phases via integration of existing ASHRAE IAQ standards (creating flexibility for future improvements), educate the market, and recruit early adopters. We propose that an inter-organizational IAQ Task Force co-led by ASHRAE and the AIHA assume primary responsibility for Phase 1 activities. These two associations have expertise in the building and health sciences, large membership bases with chapters and representation across the US, and capabilities well-suited to Phase 1 activities. Importantly, ASHRAE and AIHA can bridge between public health and building experts to develop practical, health-based IAQ requirements. Market education will require providing a clear cost-benefit analysis for building owners and making the case to building occupants to drive demand. **Phase 2:** the focus will be to conduct pilot implementation of minimum requirements in early adopter localities (city and county level). We propose that an organization(s) with operational field-level capabilities to provide hands-on and ongoing support to early adopters assume primary responsibility for Phase 2 activities under the ongoing supervision of ASHRAE and AIHA. One potential option is to work via ASHRAE and AIHA field chapters and their affiliates. A key consideration will be whether participating organizations will provide pro bono services and/or be compensated for their efforts, and if the latter, what level of financial resourcing will be required and from where these
resources will be raised.

Phase 3: the focus will be expanding pilot implementation of minimum requirements, conduct lobbying and advocacy beginning in early adopter cities and counties before extending to state and federal-levels, and introduce minimum requirements for adoption into health and building code while supporting legislators to introduce tax incentives, grant funding, and technical assistance. We propose that a nonprofit organization assumes primary responsibility for Phase 3 activities and beyond. A key question is whether ASHRAE, AIHA, or another existing organization is positioned to assume

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this responsibility, or rather a new organization primarily focused on achieving health-based IAQ standards will be required. Advocacy should occur on all levels to some extent, but at any particular time should focus wherever political conditions indicate the greatest opportunity for progress.

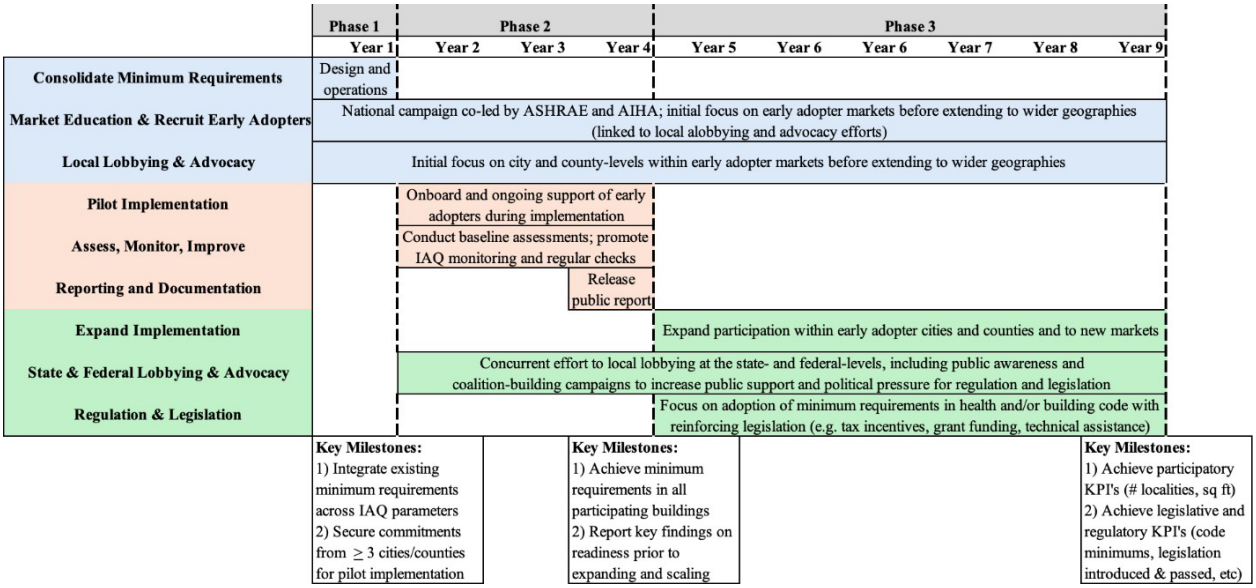

Figure 1: Critical Path Process, Timeline, and Key Milestones to Achieving Health-Based IAQ Standards. This Gantt chart establishes major workstreams set against key milestones in order to organize, coordinate, and resource efforts.

Key Stakeholders

A diverse coalition of stakeholders, with distributed roles and responsibilities within an overarching leadership structure, will be critical to advance health-based IAQ standards (see fig. 2). As referenced, this effort should be co-led by ASHRAE and AIHA to provide joint leadership and representation within the buildings and occupational health professional domains. Within this leadership structure, key stakeholders include those focused on:
1) standards development, integration, and advancement; 2) lobbying, advocacy, and external communications; 3) federal government agencies; and 4) local and state government agencies. The balance of effort vis-a-vis federal vs state and loca and statel government engagement will be heavily dependent on the political realities and dynamics at any given time. Nevertheless, a multi-level engagement strategy sustained over the long-term will be required to achieve progress and ultimately successful outcomes.

Standards Development, Integration, and Advancement: As mentioned in previous sections, ASHRAE and AIHA are the two key stakeholders within this area - ASHRAE by virtue of being the lead standards development organization for IAQ and AIHA by infusing a greater occupational health and safety focus into building standards specifically with respect to IAQ. Furthermore, they are already connected by a memorandum of understanding that commits them to strong ongoing collaborative efforts. Technical and industry experts will also play a critical role via advising and direct participation in relevant ASHRAE and AIHA committees.

Lobbying, Advocacy, and External Communications: A strong community of non-governmental organizations is needed to make a clear, compelling case for action and then to drive towards defined goals and

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outcomes. In recent years, this community has been engaged, but fragmented in a way that has diluted efforts and failed to create sufficient, sustained political will and pressure on this issue. Members of this coalition will include nonprofits and advocacy entities across biosecurity, public health, medical, and sustainability fields; patient advocacy and workplace safety organizations; standards development organizations (like ASHRAE); building certification programs; industry representatives; academic experts; and other community leaders. Similar to public health campaigns calling for seatbelt requirements or ending smoking indoors, momentum around a public health effort on clean indoor air can generate demand for health-based IAQ standards and ongoing performance requirements. As previously mentioned, a key question is which organization is best-positioned to lead this coalition and effort, whether ASHRAE and/or AIHA, or rather a different organization geared specifically towards to this work stream and importantly able to garner resources - financial, human capital, and otherwise - to support it.

Figure 2: Key Stakeholder Map. This key stakeholder map is an initial but not exhaustive list of organizations that will be critical to advancing health-based IAQ standards, structured into key sub-categories within the overall effort.

Federal Government Agencies: Several agencies at the federal agency have authorities and resources related to IAQ. Given our health-centric definition of IAQ, a health-focused agency should assume leadership for advancing health-based IAQ standards at an inter-agency level, as well as with external stakeholders, with support and coordination from the White House. The Environmental Protection Agency (EPA), via its Indoor Environments Division if given a more robust authority in the future, and/or the Department of Health and Human Services (HHS) via the National Institute of Occupational Safety and Health (NIOSH) and the Centers for Disease Control and Prevention (CDC) are leading candidates to play this role. Additionally, the Department of Energy (DOE), although its primary mission is energy, plays a key role in building codes that can support further adoption or incentivize health- based IAQ standards. As outlined above, DOE previously supported the development of a national model building energy code and could do the same for a health-based ventilation and IAQ model code, potentially in partnership with NIST (Lagoudas et al, 2025). Other important federal government entities include the Occupational Safety and Health Administration (OSHA) in the Department of Labor, which can promulgate workplace safety standards that incorporate IAQ. The General Services Administration (GSA), which oversees 360 million square feet of workspace for federal employees, can set a precedent for state and local governments to follow by adopting health-based IAQ standards to support health and productivity of federal workers. Additionally, targeted and sustained engagement with Congressional member offices serving in key committees with relevant authorities over IAQ will be critically important. At the time of writing this paper, significant budgetary cuts, reductions in force, and policy rollbacks in the

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agencies referenced above have challenged advancement of health-based IAQ standards at the federal level, impressing the importance of local and state-level action in the current Congress and presidential administration while promoting and preparing for more favorable political environments in the future.

State and Local Government Agencies: Building and health-code setting bodies at the local and state levels are critical to advancing health-based IAQ standards. US HHS, EPA, and GSA-equivalents at the local and state levels can play key roles by adopting IAQ guidelines or requirements to promote healthy buildings. States can establish regulatory frameworks to support the monitoring of building air quality and ventilation levels (such as through CO2 and PM2.5 sensors), as well as inspection and compliance regimes as outlined in the Model Clean Indoor Air Act. Regulatory frameworks can follow a similar model to the National Fire Protection Association Life Safety Code (NFPA 101), which mandates annual inspections and testing of commercial buildings to ensure they meet minimum life safety standards. Additionally, building certification programs like LEED (through the US Green Building Council) provide a template for a monitoring and inspection protocol. OSHA and state-level occupational safety departments have inspection and monitoring procedures in place for restaurant food safety, among other requirements, and can be a framework to build upon. Like federal engagement, direct engagement with the offices of elected officials, including mayors, city councils, boards of education, governors, and state legislators, will also be critical to educating lawmakers and regulators and building political will.

CONCLUSION – A CALL TO ACTION

The purpose of this paper was to propose a practical, feasible, and actionable policy and regulatory roadmap to achieve health-based IAQ standards across the built environment. The first key step is to stand up an IAQ Task Force to define minimum requirements for health-based IAQ standards. We strongly urge ASHRAE in partnership with the AIHA to take the lead on this process, while beginning discussions on each organization's capacity to resource other Phase 1 activities, discussing additional fundraising, and engaging member organizations on their interest to participate in Phase 2 activities. In tandem, we call additional organizations to form a coalition to make the case for health-based IAQ standards and build a national campaign

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