ELECTRIC POWER RESEARCH INSTITUTE

Quick Insights

Research Pathways for Building Technologies that Enable Healthier Work and Living Spaces

RESEARCH QUESTION

The global pandemic shines a light on opportunities to combine energy efficiency with health and safety outcomes through disinfection, removal of pathogens from indoor air, and improving the quality of indoor spaces as people spend more time inside.[1]

To what extent can building equipment—lighting, heating, ventilation, and air conditioning (HVAC) systems, and the building envelope itself—aid in managing pathogens spread in the air and on surfaces, or contribute to enhanced health and comfort due to improved indoor air quality?

KEY OPPORTUNITIES TO ADVANCE UNDERSTANDING

- Conduct additional laboratory and field testing to broaden current understanding of the efficacy of:
  - A new class of LED lighting which may have disinfection capability for air and surfaces, and can be used in the presence of humans, and
  - Reactive oxygen species generated using prototype cold plasma technology in eliminating bacteria and viruses from a variety of hard surfaces.
- Explore advanced design and evaluation, measurement, and verification (EM&V) plans that could quantify the potential for management of pathogen spread in critical settings such as hospitals, and include approaches that combine increased filtration and UV lighting in commercial building high-efficiency dehumidification system (HEDS) technologies.
- Field test and verify potential health and comfort benefits of HEDS technologies and passive home (PH) design standards and include approaches that improve filtration and airflow management for enhanced air quality in indoor settings.
- Assess the air quality, health, and safety benefits of these technologies, singly or in combination, for better managing pathogen spread in the built environment.

1. *Quick Insights: Potential Health and Safety Benefits of Efficient Electrification*. EPRI, Palo Alto, CA: 2017. 3002011450. https://www.epri.com/#/pages/product/000000003002011450/?lang=en-US

MANAGING PATHOGENS IN THE BUILT ENVIRONMENT

A home or commercial building is an ecosystem of living organisms, invariably including microorganisms present on the surfaces we touch and in the air we breathe. While most microorganisms are benign, pathogens—including bacteria, fungi, and viruses—are ever-present and, given the right circumstances, pose health threats ranging from minor impacts to global pandemics. Current technologies for disinfecting and managing pathogen spread include high-efficiency particulate air (HEPA) filtration to capture airborne particles in sensitive environments; chemicals such as bleach for surface cleaning, and ultraviolet-C (UVC) lighting (200–280 nm) within HVAC ducts or above eye-level within spaces.

As the world confronts the operational and human challenges of the current coronavirus disease (COVID-19, caused by the novel coronavirus SARS-CoV-2), researchers are exploring the potential of existing and emerging technologies to help manage pathogen transmission through disinfection, filtration, and management of airflow. While indoor pathogen transmission is unavoidable, advancements in building technologies could reduce their transmission and enhance occupant comfort and health.[2]

This Quick Insights brief highlights four technologies, ranging from overhead lighting to building envelope standards, that could be deployed to improve health, safety, and/or comfort, alone or in combination with more traditional approaches. The potential of these technology applications gives rise to new research questions to illuminate a path forward and to evaluate specific benefits.

	Description	Possible Benefits	Possible Applications	Key Research Need
Human-Safe (405 nm) LED Lighting	Specialized LED fixtures; operate in disinfection-only or simultaneous illumination and disinfection modes	Air and surface disinfection; non-UV (405 nm) light source safe for humans	Commercial spaces with traditional overhead troffer,[3] can, and cove lighting	Determine efficacy in reducing pathogens
Cold Plasma	Deactivates and destroys some pathogens, including bacteria and viruses	Targeted air and surface disinfection	Medical, agricultural, and broader use in food industry	Evaluate prototype systems
High-Efficiency Dehumidification Systems (HEDS)	Combines a higher level of filtration and UV disinfection, and better control of humidity at lower energy cost	Airborne pathogen mitigation and destruction, and improved indoor air quality	Commercial HVAC systems with possibility for adaptation to homes	Determine efficacy in reducing pathogens
Passive House (PH) Design Standards	Designed to enhance living conditions by improving indoor air quality	Improved indoor air quality	Single- and multi-family home developments	Quantify health benefits compared to traditional home design

2. HEPA filters capture at least 99.97% of particles 0.3 µm in diameter, SARS-CoV-2 is smaller (60–140 nm).

3. An example are the common overhead linear fluorescent fixtures with 2–4 lamps in commercial spaces.

HUMAN-SAFE (405 NM) NON-UV LED DISINFECTION LIGHTING

An emerging LED lighting concept offers the potential for light-based disinfection at the longer, human-compatible-space wavelength in the range of 405 nm. Unlike ultraviolet-C (UVC) systems (200–280 nm), this emerging technology could safely disinfect air and surfaces in the presence of people and animals.

These light-based disinfection products and can be combined with high-efficiency particulate air (HEPA) filtration systems and chemical cleaning solutions to destroy specific pathogens.

Key research opportunities

- Conduct additional laboratory and field research, including the development of monitoring and data collection systems
- Explore efficacy in various residential, commercial, and industrial environments to identify high-value applications

Irradiation breaks molecular bonds in pathogen DNA or RNA. Required dosages of irradiation depend on specific pathogens. Airborne pathogens typically are resident in droplets, the size and nature of which also affect required irradiation.

COLD PLASMA

Cold plasma may generate reactive chemical species to treat biological contaminants. These reactive chemical species are produced by electrifying a source gas (as simple as air), creating a gas flow of new chemical agents that differ from the original gas.[4] Research activities continue to focus on a range of applications, including the food industry, medicine, agriculture, and disinfection.

Key research opportunities

- Evaluate the ability of prototype cold plasma technologies to destroy microbial contaminants on hard surfaces through laboratory and field trials
- Characterize the potential health impacts of exposure to the reactive species produced
- Assess the technical and economic viability of prototype technologies to identify beneficial technology development pathways

HIGH-EFFICIENCY DEHUMIDIFICATION SYSTEMS

Controlling relative humidity helps mitigate mold and corrosion for some process loads (such as equipment used in industrial facilities) and maintains occupant comfort. In many large commercial HVAC systems, a heating system such as a natural gas boiler may support dehumidification within the chiller system. The air is cooled to enable moisture removal, with lower temperatures providing greater dehumidification, and the air is reheated using the boiler before being recirculated.

A high-efficiency dehumidification system (HEDS) can minimize the energy required for reheating after cooling air as it circulates, providing energy savings. Avoiding direct combustion may also provide indoor air quality benefits. HEDS solutions that include multiple filter layers and UV lighting slow airflow through the air handler, allowing exposure to the UV light sufficient for destroying pathogens.

4. The oxidative species created may include O, O_3 (ozone), OH, H_2O_2, HO_2, NO, and ONOOH.

Key research opportunities

- Evaluate the relative humidity range for a commercial building for optimal air quality conditions
- Quantify the air quality impacts of HEDS
- Explore the design of EM&V plans that could quantify the potential for management of pathogen spread in critical settings such as hospitals

PASSIVE HOUSE DESIGN STANDARDS

One of several goals of passive house (PH) standards[5] is to improve indoor air quality while maintaining or increasing occupant comfort. PH design includes filtration of air coming into homes and venting indoor air instead of recirculating it. This may reduce the spread of disease throughout structures occupied by infected individuals. For those dealing with health issues at home—whether existing or pandemic-related—such highly filtered air could improve their health, comfort, and endurance contributing to overall wellbeing. Understanding the benefits of PH design could lead to future home design standards that include aspects of health.

Key research opportunities

- Explore the design of EM&V plans that could quantify the potential determine the pathogen transmission impacts of PH design compared to standard building codes
- Quantify the air quality, health, and comfort impacts of PH design on occupants

FOUNDATION FOR MOVING FORWARD

The research opportunities highlighted here begin to frame pathways forward for technologies that may improve health, safety, and comfort in our living and working spaces. Collaboration among research organizations, technology providers, and end users can help guide technology development and accelerate adoption of promising solutions. Today's pandemic brings heightened urgency for a fresh approach to considering these technologies.

EPRI is driving global collaboration and helping find solutions by analyzing the pandemic's near-term energy impacts, gathering insights on industry mitigation efforts, and applying a forward-looking lens to identify and close research and development (R&D) gaps for the future. We are bringing together leaders from industry, government, and academia to address the longer-term implications of the pandemic—from broad-reaching economic and population impacts to potential changes in energy consumption and CO_2 reduction—to better inform strategic planning and operational decisions that will shape the future of energy.

5. Passive House Institute US, Passive House Principles: https://www.phius.org/what-is-passive-building/passive-house-principles

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