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IMPACT OF DESIGN BRIEF:

CLIMATE IMPACTS ON BUILDING RESILIENCE & HUMAN HEALTH

EXTREME HEAT IMPACTS ON INTERIOR DESIGN MATERIALS

Building Better Human Health Outcomes for Occupants

CREATED IN PARTNERSHIP BY:

design RESEARCH by ASID

AMERICAN SOCIETY OF INTERIOR DESIGNERS

UL Research Institutes | Chemical Insights

OVERVIEW

Post-pandemic, health, wellness, and sustainability remain top priorities for clients looking for products and solutions that not only meet their needs but mitigate health risks. With this emphasis on health, clients are also concerned about the increase in extreme weather events—record-breaking heat waves, hurricanes, severe flooding, tornados, and wildfires, which have resulted in devastating destruction and prolonged power outages. When asked about their own experiences, two-thirds of Americans said that they've experienced an extreme weather event in just the past year.[1]

Instead of being reactive, we have an opportunity to be more proactive and design for the future.

Evolving environmental conditions, particularly those related to a changing climate, are impacting building materials and increasing risks to human health. Research recently conducted by the Chemical Insights Research Institute (CIRI) of UL Research Institutes demonstrates how new environmental conditions, specifically extreme heat, affect product emissions. When tested at higher temperatures, emissions from many common building materials are found to have higher total volatile organic compound and aldehyde concentrations, increasing occupants' exposure to poor indoor air quality.

The prolific use of synthetic products, coupled with the focus on airtight buildings to conserve energy and prolonged power outages from extreme weather events, has led to a rise in volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and chemical-related indoor air quality (IAQ) issues.[2] Unfortunately, poor IAQ puts nearly 40% of the U.S. population at risk for serious health problems.[3]

To reduce indoor air pollution and achieve better building resiliency, the interior design community has an opportunity to be more proactive. Designers can incorporate more comprehensive criteria into their design process, evaluate potential impacts resulting from extreme temperatures and prioritize the selection of materials, finishes, and furnishings that minimize the risks. This brief seeks to raise awareness and expand the vocabulary around these issues, **providing designers and industry leaders with a series of questions to consider when working on projects in areas at greater risk from extreme heat**. There is no perfect solution, as competing priorities must always be balanced. Thus, collaborating with a knowledgeable expert is essential for consumers and clients, given that no perfect solution exists.

As stewards of the interior environment, the interior design community has an opportunity to shift and expand its focus while minimizing some of the risks from climate-related impacts. Collectively, we can drive market transformation towards healthier spaces.

WEATHER EFFECTS ON THE BUILT ENVIRONMENT

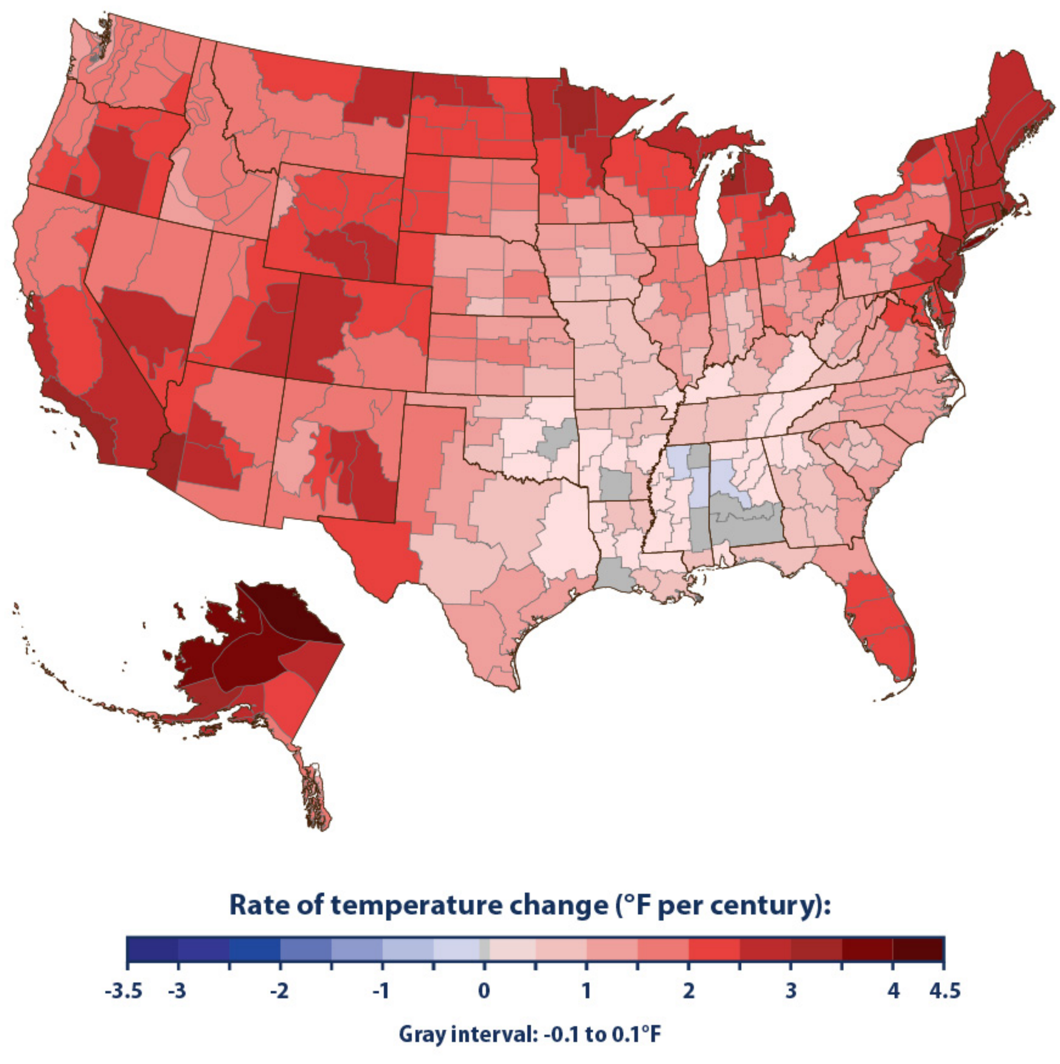
As discussed in the *Impact of Design Brief: Extreme Weather Impacts on Interior Design Materials*, the United States has witnessed an increased number of extreme weather events over the last century. In addition, we have witnessed changes in temperature, with most experiencing warmer temperatures, which has led to earlier springs, prolonged exposure to heat, increased ground ozone, increased mold, and the growth of pathogens. [4]

Increases in extreme weather events and everyday temperatures have changed the way materials behave and created new challenges for designers.

Unfortunately, warmer temperatures are also associated with higher levels of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs). [5] [6] "VOCs are emitted as gases from certain solids or liquids and include a variety of chemicals, some of which may have short- and long-term adverse health effects." [7] Chemicals such as plasticizers, flame retardants, and pesticides, are SVOCs that can be particularly harmful as "cytotoxic, mutagenic, and carcinogenic," leading to an increased risk of cancer or cardiovascular disease for some with genetic differences [8] as well as pulmonary and respiratory symptoms. [9]

According to the U.S. Environmental Protection Agency (EPA), "the ability of organic chemicals to cause health effects varies greatly from those that are highly toxic, to those with no known health effect, and as with other pollutants, the extent and nature of the health effect will depend on many factors including level of exposure and length of time exposed." [10]

RATE OF TEMPERATURE CHANGE IN THE U.S., 1901-2021



Source: U.S. Environmental Protection Agency (EPA), Climate Change Indicators in the United States

INTERIOR DESIGN AND BUILDING RESILIENCE

Building resiliency should be considered holistically to safeguard human health from external and internal stressors affecting the built environment.

Weather and climate-related disasters impact the built environment, increasing chemical and particle exposure. [17] Beyond these extreme weather events, smaller, more daily occurrences are negatively affecting the built environment. For instance, warmer, longer summers increase chemical emissions from synthetic materials and prolong exposure. [18]

Buildings are being designed to mitigate the impact of external stressors, like high winds, storms, fire, and extreme heat, but there are also many internal stressors contributing to a building's resilience and affecting the health of the people in the building. These internal stressors include:

- Chemicals
- Molds
- Particles in the air
- Temperature
- Humidity
- Dust, allergens, and microbiologicals

IMPACT OF EXTREME HEAT ON MATERIAL EMISSIONS

Environmental conditions significantly influence material emissions, including those from natural materials, which reflect the conditions of their origin. This creates a complex issue, as not all materials behave the same way under varying environmental conditions, and even similar materials can exhibit different behaviors depending on their composition. Additionally, the emissions associated with processing and shipping can vary greatly, with some materials contributing more to emissions than others.

Recently, research conducted by CIRI, using their environmental chamber technology, demonstrated how these new environmental conditions, specifically extreme heat, affect product emissions, even those products already recognized for their sustainable and wellness features.[19] [20] Common building material products adversely affected by extreme heat include paints, coatings, adhesives, cabinetry, and flooring materials.

Increased temperatures can have a negative impact on the emissions of building materials. Understanding the factors that contribute to risks to human health is crucial for making informed decisions about material selection.

> **“People spend more than 90 percent of their time indoors, and they expect the air quality to be safe and free of harm. We use many industrial chemicals without fully understanding their indoor air quality impact. This, along with rapidly changing chemistries used to manufacture products and materials and the use of extensive global supply changes, brings unknown risks.”**
> **– Dr. Marilyn Black [23]**

CIRI scientists examined various common building materials rated for both commercial and residential use to assess their emissions. The selected materials represent a range of products typically specified for surfaces such as ceilings, walls, and floors. It is important to note that while these materials are commonly used in interior design, the results can vary significantly due to differences in material composition—meaning not all products of a shared category or type, like nylon carpet, behave the same way. The list of materials CIRI tested is not exhaustive; rather, it aims to illustrate key considerations when designing spaces that may be exposed to higher temperatures. **Many factors influence emission results, including material composition, construction methods, and coatings.**

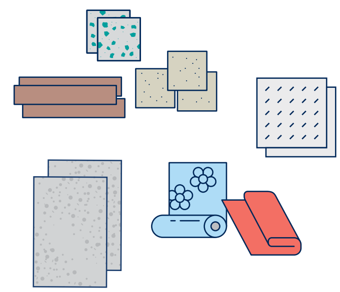
Emissions from various common building products were analyzed at two different temperatures: an average room temperature of 73° F (23° C), often used as a standard when testing materials for acceptable IAQ, and an elevated temperature of 95° F (35° C), often experienced by vulnerable populations in suboptimal conditions and/or those experiencing power outages in areas of extreme heat.

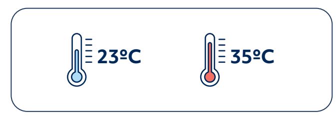
Each material was isolated and tested for its chemical emissions, independent of any adhesives, substrates, or materials required for installation. Standard testing and analysis methods were utilized to ensure accuracy and repeatability. The research aimed to provide a more comprehensive understanding of VOC and aldehyde emissions under emerging indoor environmental conditions facing extreme heat scenarios.

The total concentrations of chemical emissions released from each material were quantified. Effects, if any, resulting from increased temperature were analyzed to evaluate changes in the type and/or level of chemical emissions released. **All of the tested materials, natural and synthetic, emitted VOCs.**

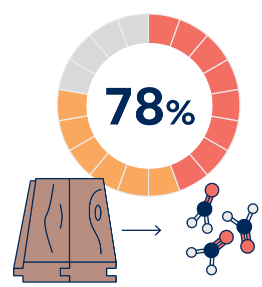
With few exceptions, total VOC and aldehyde concentrations were found to be **greater at the higher temperature**, with varying results.

MATERIALS





FINDINGS



KEY INSIGHTS

Results were not associated with the cost of the material. Inexpensive materials did not necessarily produce higher VOC emissions at room temperature or at elevated temperature.

Not all materials perform the same when exposed to higher temperatures. Materials with the highest rate of emissions at room temperature were not necessarily the materials with the highest rate of emissions at the elevated temperature. One way that designers could interpret this when selecting materials is to carefully consider the impact of heat on materials when making project selections.

Vague product claims, including "low-VOC," were not necessarily reflective of the overall VOC emissions. Thus, vague terms should not be the sole criteria for selecting building materials when trying to manage indoor air quality.

Many synthetic materials were found to have higher total VOC (TVOC) and total aldehyde (TALD) concentrations, increasing occupants' exposure to poor indoor air quality.

Certification systems, such as GREENGUARD and the Cradle to Cradle Certified® Products Program, have been established to help manage, independently measure and verify the levels of risk associated with building materials. These systems assess emissions and rate materials, providing specifiers and consumers the opportunity to limit their VOC exposures. Accredited professionals work to meet the criteria for project certifications, ensuring that selected products contribute to achieving suggested standards. However, this process involves a mix of competing priorities and complex trade-offs, as designers must balance sustainability and wellness targets with cost and durability requirements.

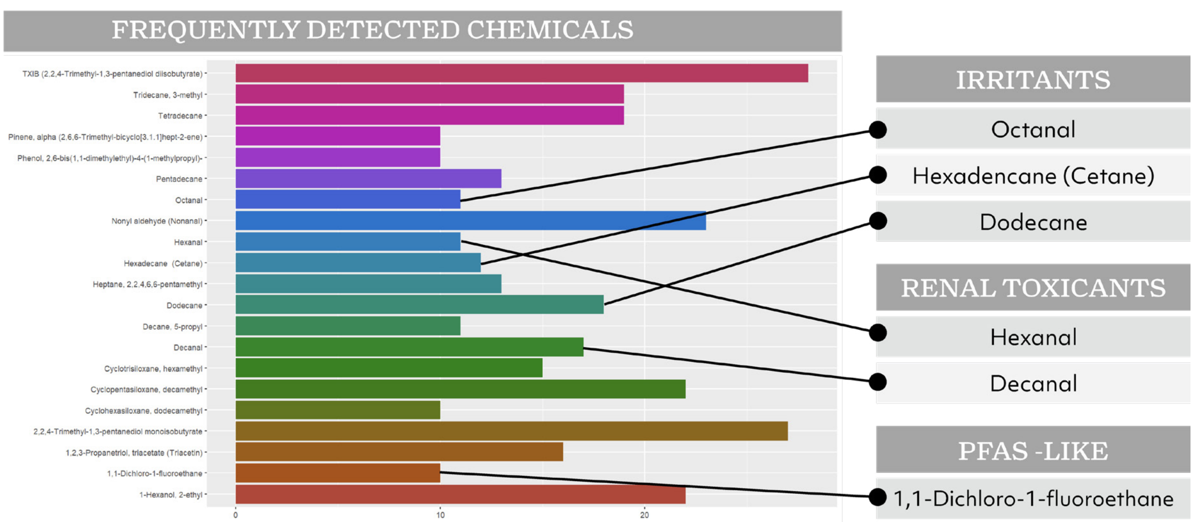
Now that we are aware of the potential effects of elevated temperatures on material emissions, it is crucial for the interior design community to advocate for third-party certifications that test materials at higher temperatures. By doing so, the industry can proactively minimize risks and make more informed decisions when mitigating these issues.

CHEMICALS OF CONCERN DETECTED AT HIGHER TEMPERATURES

In some cases, new chemicals of concern were detected only at the higher temperature. When tested, these building materials exhibited irritant chemicals that affect occupants who are more sensitive and affected by lower concentrations. Renal toxicants associated with kidney toxicity and per- and poly-fluoroalkyl substances (PFAS), which are not likely to be found naturally in the environment, were also identified.

DETECTED CHEMICALS IN BUILDING MATERIALS

EXPOSED TO INCREASED HEAT [i]



Occupants in the built environment face a very complex mixture of chemicals, particularly at increased indoor temperatures.

Specifically, benzophenone and neodecanoic acid were detected only at the higher temperature in one of the resilient flooring samples. Unfortunately, these chemicals can impact human health. Benzophenone is thought to be a carcinogen, an endocrine disruptor, and a neurotransmitter inhibitor. Neodecanoic acid is thought to induce pulmonary inflammation and cause skin and eye irritations, [21] [22] underscoring the need to expand the testing criteria for third-party certification.

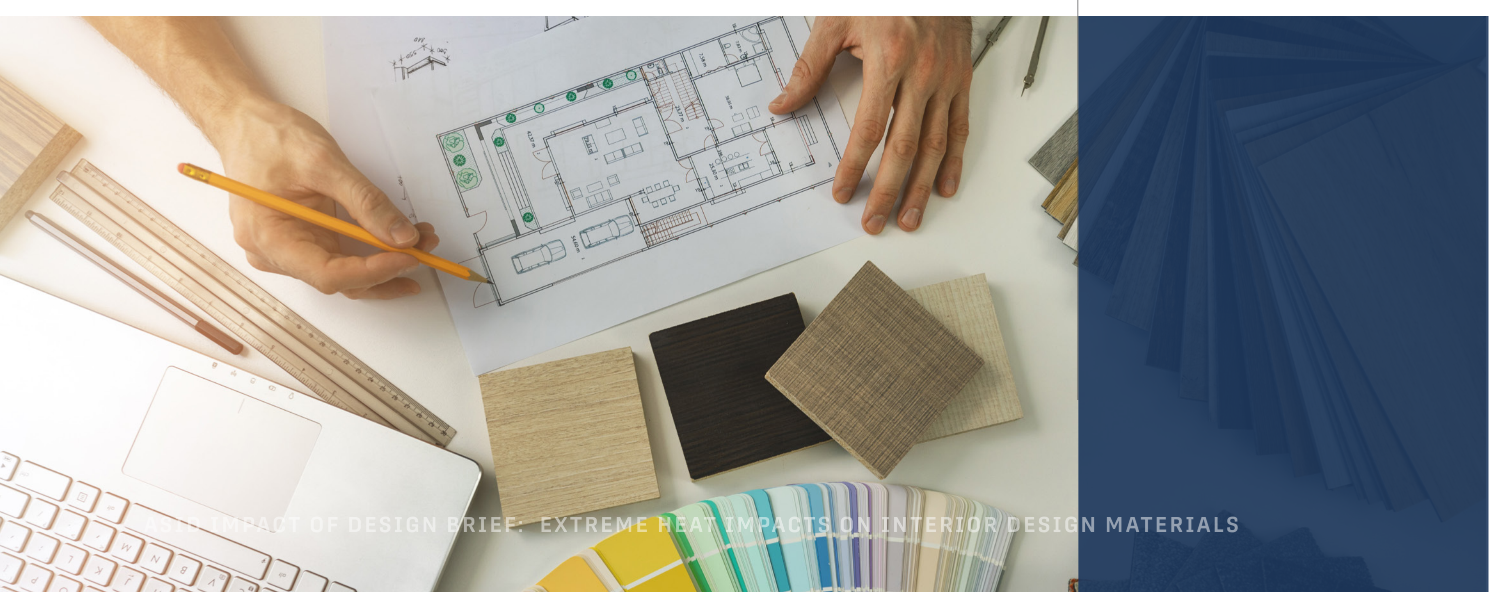
CUMULATIVE EFFECTS

Interior designers select not just one material but many. To consider the cumulative effects, researchers at CIRI used exposure modeling to assess the total chemical exposure, which sums the concentration levels of each material in a space. [24] Several factors affect the cumulative effects.

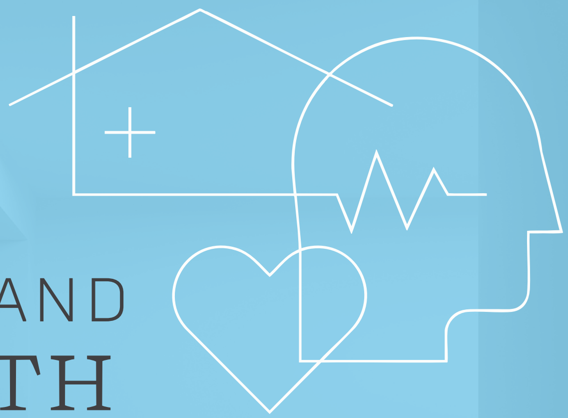
- Material Selection: As illustrated by the research, some materials emit more TVOCs and TALDs than others. Specifying a material that emits higher concentrations will increase the cumulative effect.
- Exposure to Extreme Heat: Almost all of the materials tested demonstrated higher quantities of TVOCs at the higher temperature, significantly increasing total exposure.
- Quantity of the Material Installed: Some materials, like flooring, are installed in larger quantities than others, like millwork. The larger the quantity, the greater the impact on the cumulative effect.

Simple changes can make a significant difference when selecting materials, developing designs, and considering solutions to mitigate occupant risk.

"The U.S. EPA reports that pollutant levels of indoor environments may run two to five times – and occasionally more than 100 times – higher than outdoor levels." [23]



INTERIOR DESIGN AND HUMAN HEALTH



Incidents of heat-related illness and death, cardiovascular illness, asthma and allergen illnesses, and stress-related disorders are on the rise, [11] and they have a greater impact on our most vulnerable populations, including those with existing health disparities and those with less access to resources.

- Older adults and people who have preexisting conditions are at greater risk. [12]
- Children are more vulnerable because they have developing organs, immature immune responses, and inhale more air per pound of body weight. [13]
- During pregnancy, physiological changes increase a person's vulnerability to environmental exposures, and exposure to air pollution may harm the developing fetus during critical windows of human development. [14]

Depending on specific chemicals and their exposure levels, studies show that chronic exposure may lead to cognitive, reproductive, and carcinogenic effects. [15] Of note, exposure to pollutants occurs not only through inhalation—breathing hazardous substances—but also through ingestion—swallowing contaminated settled dust or potable water, and dermal transfer—coming in contact with pollutants or contaminated settled dust particles. [16]

PROACTIVE DESIGN MEASURES TO IMPROVE OUTCOMES

DESIGNING FOR THE FUTURE

The interior design community has an opportunity to reduce indoor pollution and achieve better building resiliency.

1

Use an integrative design process.

Early in the design process, bring the owner, design team, subject matter experts (SMEs), contractors, and other key stakeholders together to establish goals, set priorities, and identify occupant risks.

- **BUILD CONSENSUS**
- **IDENTIFY COMPEXITIES**
- **DETERMINE RISK**

2

Proactively evaluate potential impacts.

Prioritize the materials, finishes and furnishings that minimize risks to human health to reduce indoor pollution and achieve better building resiliency.

- **INVESTIGATE OPTIONS**
- **MITIGATE RISK OF MATERIAL EMISSIONS**
- **LIMIT RISKS TO INDOOR AIR QUALITY**

3

Convey strategies and assess outcomes.

Communicate to ensure alignment, engage stakeholders and demonstrate results for greater transparency and trust.

- **COMMUNICATE DECISIONS**
- **MONITOR OUTCOMES**

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BUILD CONSENSUS

Use an Integrative Design Process [25] to bring stakeholders together to identify occupant risks, set priorities, align values, and establish goals.

IDENTIFY COMPLEXITIES

Identify potential competing priorities when selecting materials, finishes and furnishings. Some common priorities include:

- Time
- Cost
- Quality
- Aesthetics
- Function
- Sustainability
- Health & Well-Being
- Sourcing
- Comfort
- Durability
- Flexibility
- Adaptability
- Regional Risk
- Maintenance

DETERMINE RISK

Define the criteria for negotiating competing priorities and making a decision when selecting materials, finishes, and furnishings.

Occupant Demographics

Are there any sensitive populations (e.g., age, potential health concerns)?

Exposure to Heat

What is the regional risk for extreme heat around the project site?

Utilize the U.S. EPA Climate Indicator Map Viewer Tool

Length of Exposure

What is the expected amount of time the occupant will be in the space (e.g., bedroom or office vs. ancillary space)?

Criteria for Decision-Making

How will feasibility, trade-offs, and potential impacts be evaluated and determined?

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INVESTIGATE OPTIONS

Consider each material's appropriateness for both the concept and application, given existing project constraints. As proposed by Nadav Malin, CEO of BuidlingGreen®, ask more questions.[26] When looking at material options, consider the following:

- What are the options?
- Where did it come from, and what is it made of?
- How much of it is being used?
- What chemicals may be released?
- How might these chemicals affect occupants?
- What will be required to clean and/or maintain it daily?

Reference Building Codes for mandatory requirements and Standards and Guidelines for suggested performance requirements and best practices.

- Utilize existing Sustainability Guidelines, including U.S. Green Building Council LEED, Green Building Initiative (GBI), Energy Star Rating, Living Building Challenge, AIA Framework for Design Excellence, and ASID Design Principles for Sustainability.
- Utilize existing Wellness Guidelines, including WELL Building Standards and Fitwel Standard.
- Utilize other existing resources and recommended guidelines specific to chemicals in the building industry, like the Living Building Challenge Red List.
- Watch for regrettable substitutions, a term used to reference chemicals or products with an unknown or unforeseen hazard that are used to replace chemicals or products with identified risks.[27]

Reference existing resources that offer sustainability and wellness guidelines for materials and finishes. Look for neutral third-party certifications that offer specific performance metrics focused on improving air quality and reducing product toxicity.[28]

Review each material's Material Safety Data Sheet (MSDS), Environmental Product Declaration (EPD), Health Product Declaration (HPD), and/or Declare Label. Ask:

- Does the material contain fewer pollutants and toxins?[29]
- Has the material been tested at these higher temperatures?
- How is this material or product maintained without hazardous cleaning chemicals?[30]

2

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- MITIGATE RISK OF MATERIAL EMISSIONS
- LIMIT RISKS TO INDOOR AIR QUALITY

MITIGATE RISK OF MATERIAL EMISSIONS

Limit the use and/or quantity of materials known to produce higher emissions. Materials with greater surface area, as well as those located in living or sleeping areas and those with high chemical and solvent content requiring frequent chemical cleaning, pose greater risk.

Reconsider finishes and coatings that may increase risk.

- Strive for water-based sealers and pigments free of heavy metals.
- Strive for non-toxic additives in the processing.
- Reconsider solvents and other emitting chemicals during the drying process.

Complete a final clean prior to occupancy, using low-emitting cleaning equipment and products, such as those recommended by the EPA Safer Choice Cleaning Products and certified by Green Seal.

When possible, **reduce the quantity of synthetic materials in the space to reduce emmissions**. In this example of a hospitality space, engineered hardwood flooring is installed throughout with an area rug layered on top. Interior designers can reduce the **cumulative effect** of the combined flooring materials and still achieve the same effect aesthetically with a carpet inset, thus reducing the quantity of engineered hardwood flooring and ultimately reducing the total emissions within the space.

2

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LIMIT RISKS TO INDOOR AIR QUALITY

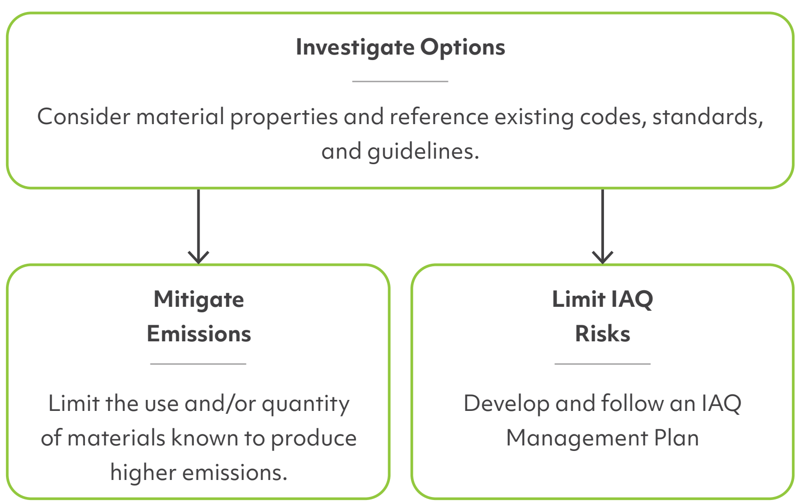
Develop and follow an IAQ Management Plan, identifying all potential contaminants and pollutants and developing methods of protection.

- To capture small particles, use the highest MERV filter allowed in the HVAC system, preferably a MERV-13 or greater. Change filters per manufacturer recommendations and/or as required to decrease risk. When appropriate, increase ventilation with outdoor air through the ventilation system or or open doors and windows to allow for natural ventilation.

- For spaces unable to meet this criterion, consider using a portable air cleaner with a HEPA filter, preferably HEPA-16 or greater., or use a DIY air cleaner, particularly during periods of extreme heat.

Clean the site regularly, removing construction debris. Protect any existing HVAC system during construction and limit dust particles' ability to enter ductwork.

During installation, remove all packaging in a well-ventilated space, preferably outside, and allow items to off-gas for 72 hours prior to installation.



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- COMMUNICATE DECISIONS
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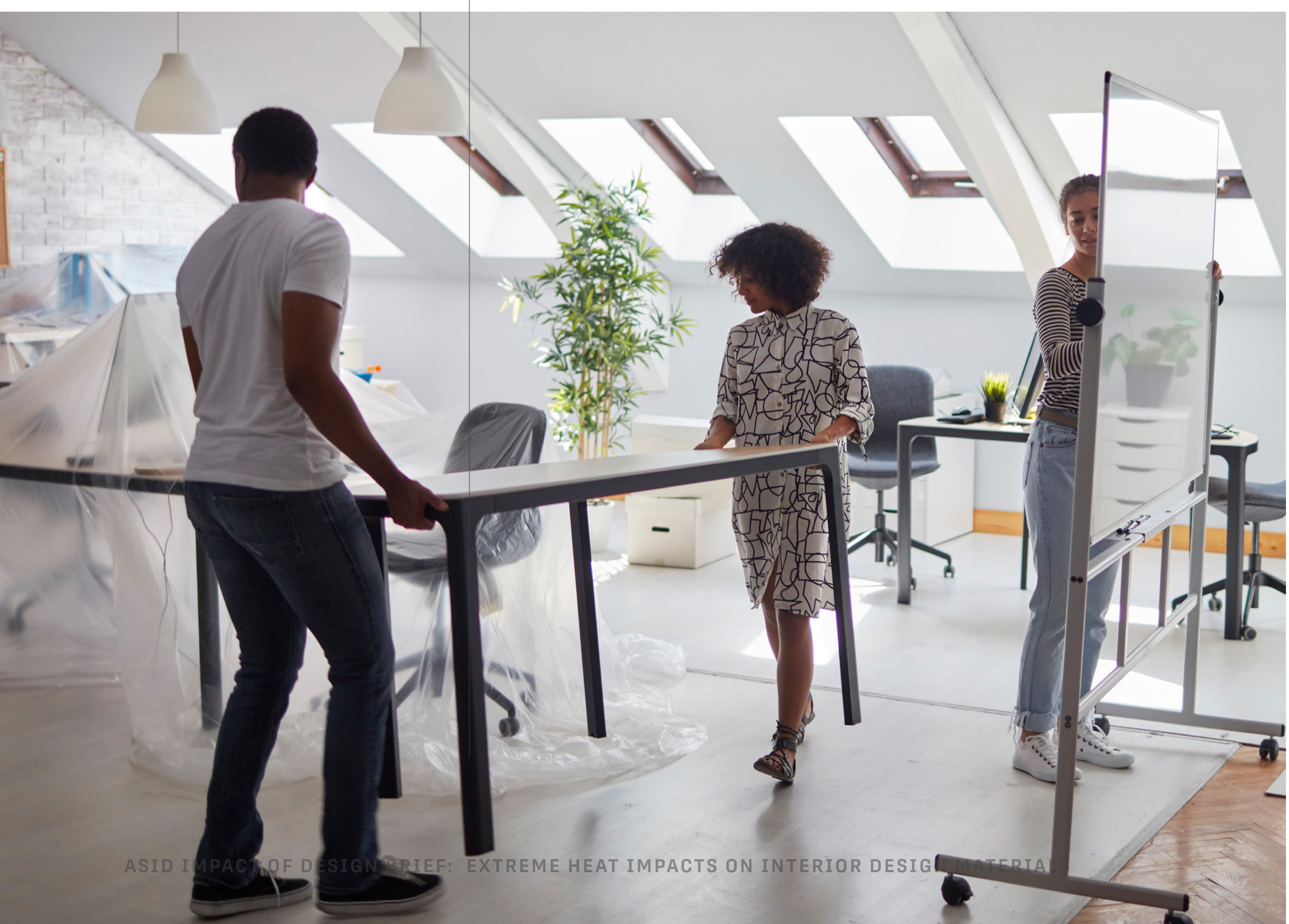
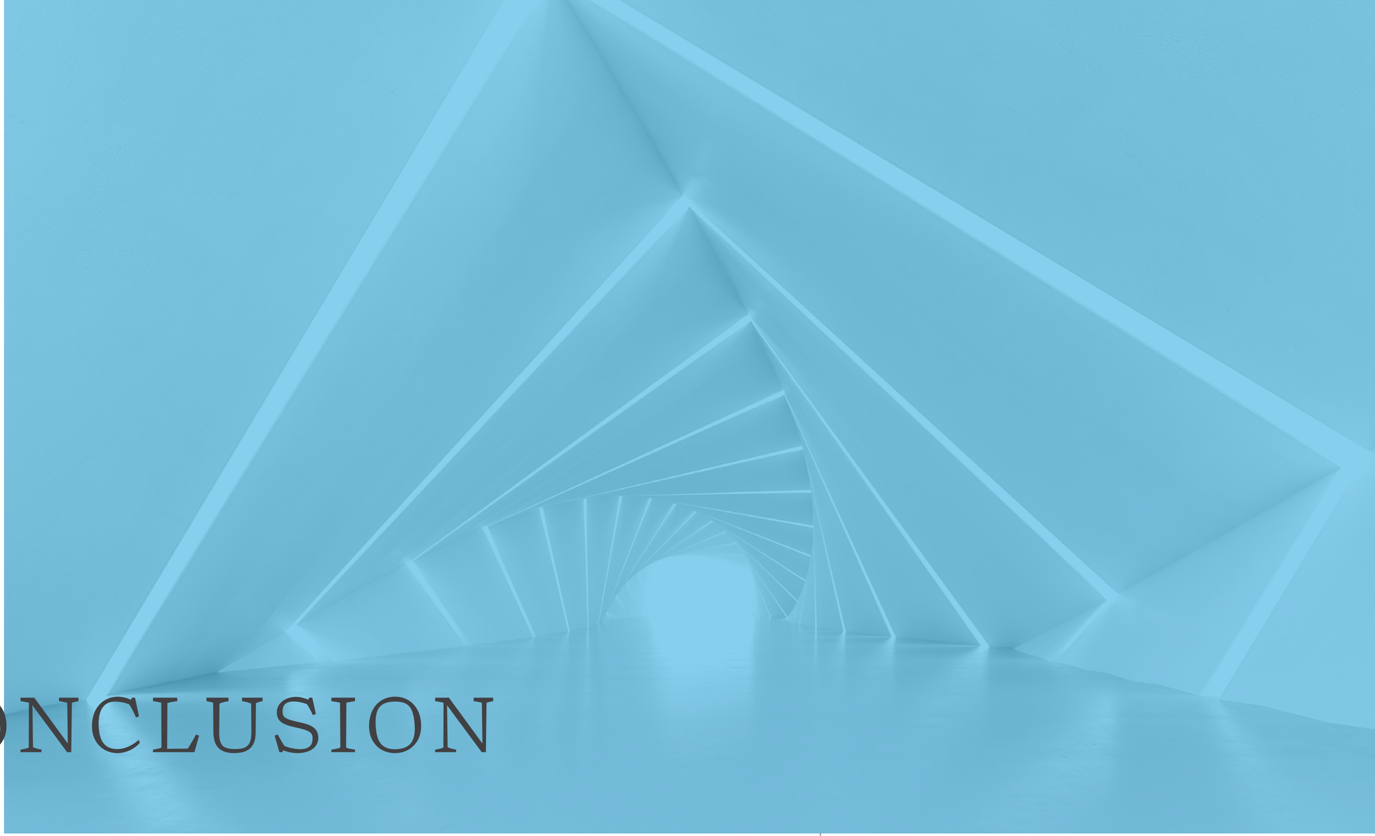
COMMUNICATE DECISIONS

Connect with stakeholders, partners and occupants.

MONITOR OUTCOMES

Consider engaging an air quality specialist and utilizing sensors to test and monitor $PM_{2.5}$ and VOC levels in the space.





CONCLUSION

Meeting the many expectations of a design project and adding resiliency can seem like a daunting equation but changing climate conditions have created a need for a new normal. As the design ethos shifts toward greater resiliency and sustainability, with a strong emphasis on human health, regional concerns, material sciences, and building practices will gain even greater importance.

Interior designers can mitigate some of these climate-related impacts and achieve better building resiliency.

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