



Green Building & Sustainable Construction (TCM 5330)

Indoor Environmental Quality



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How much time, on average, do we spend inside? What does it show?

- Americans spend approximately 90% of their time indoors, with a significant portion of that time being inside their homes.



- This statistic comes from the Environmental Protection Agency (EPA) and highlights the significance of indoor environmental quality.

The potential annual savings and productivity gains from improved indoor environmental quality in the United States are estimated as follows:

\$6 billion to \$14 billion from reduced respiratory disease;

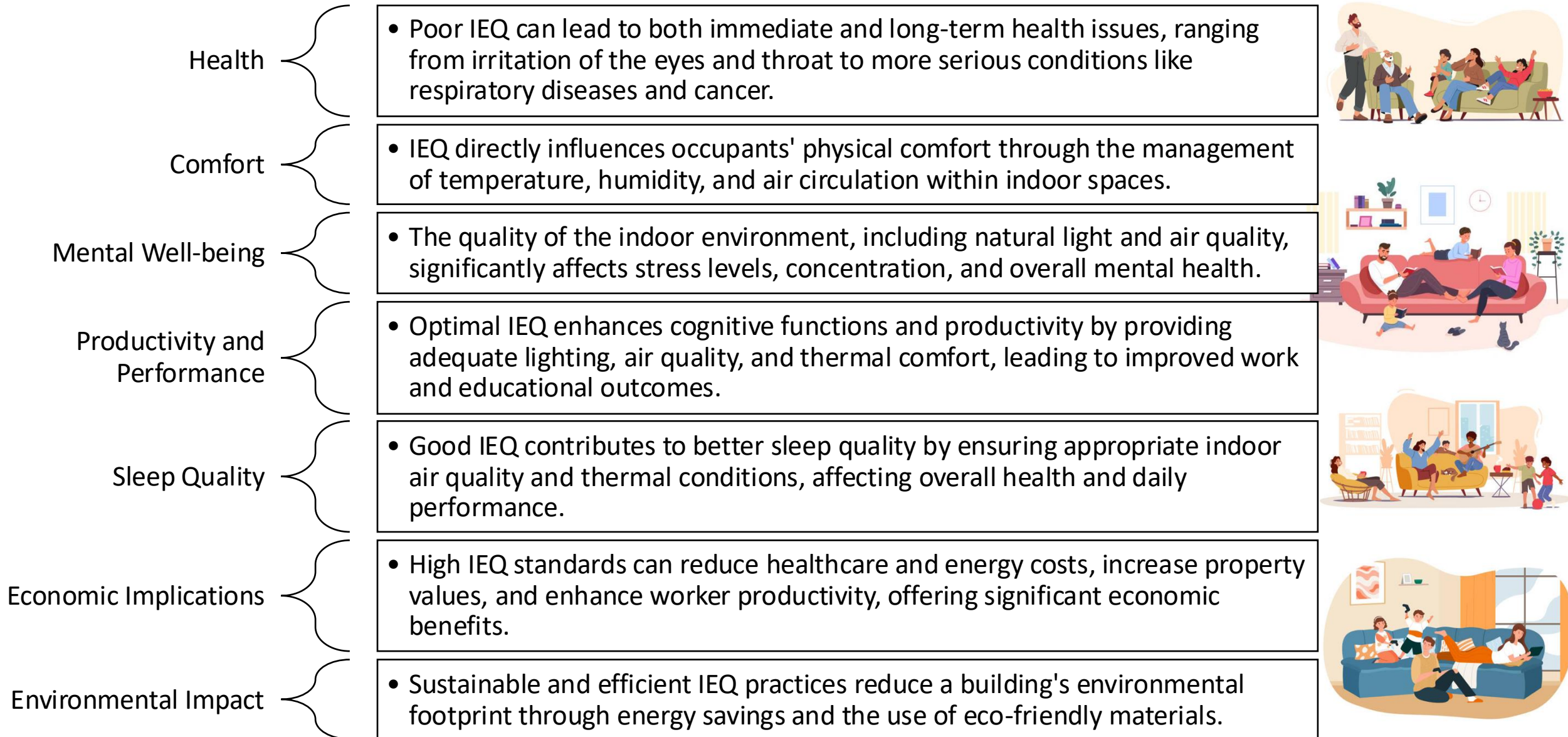
\$1 billion to \$4 billion from reduced allergies and asthma;

\$10 billion to \$30 billion from reduced sick-building–syndrome symptoms; and

\$20 billion to \$160 billion from direct improvements in worker performance unrelated to health.

This will not be included in the examination

What does indoor environmental quality impact?



Watch the video

LEED v4 Tutorial: Indoor Environmental Quality

- Link: <https://www.youtube.com/watch?v=sxgdgaQtZEE>

(you may also click on the YouTube Logo below)



What are the four critical factors of indoor environmental quality?

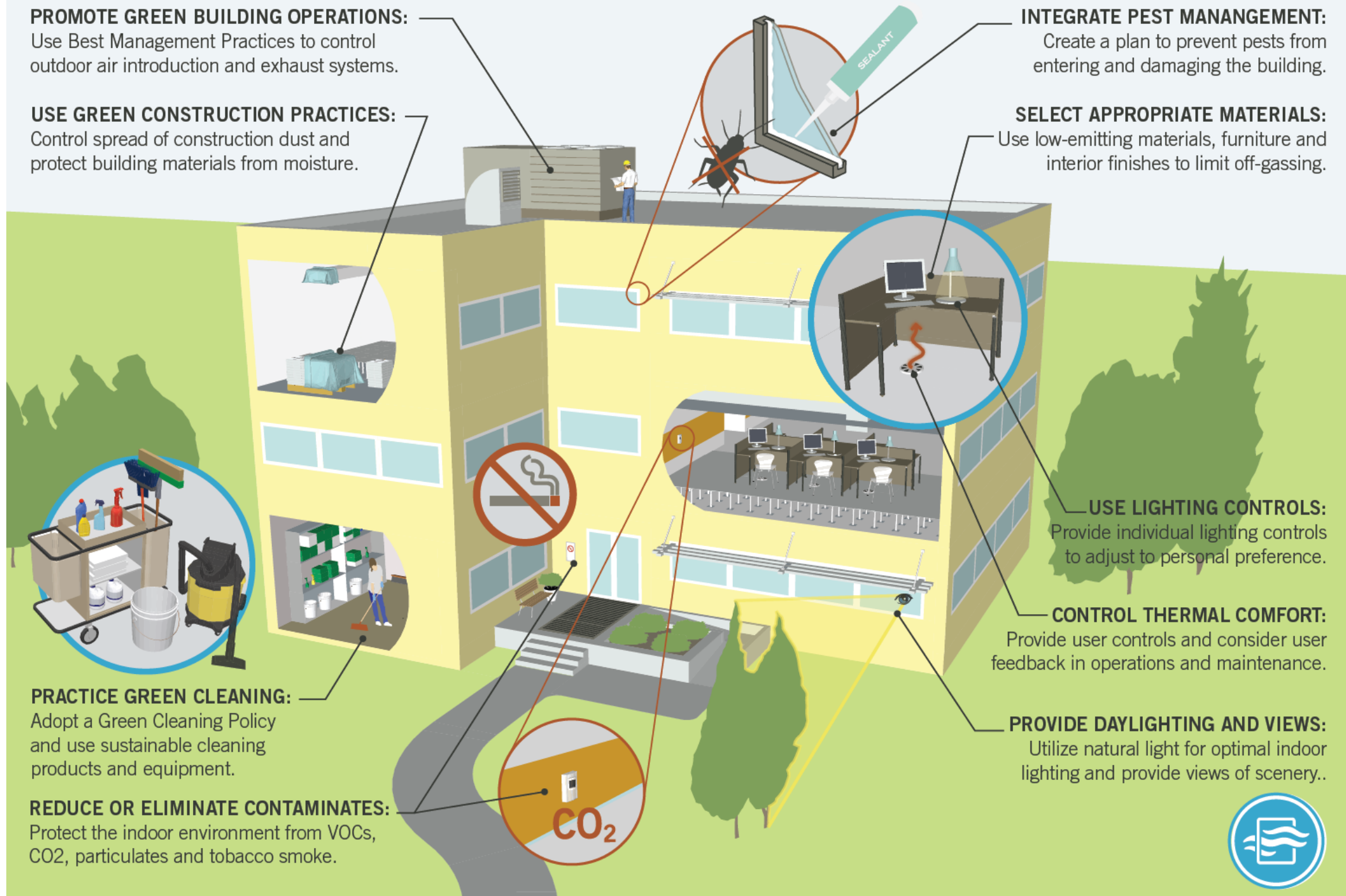
Indoor *air*
quality

Thermal
comfort

Lighting

Acoustics

Ways to improve indoor environmental quality



What are some key strategies for achieving high indoor environmental quality?

1. Ensure proper ventilation.
2. Prohibit smoking indoors.
3. Use high-quality air filters and monitor carbon dioxide
4. Use daylighting.
5. Reduce indoor pollutants and VOCs.
6. Incorporate natural lighting and operable windows for ventilation.
7. Use acoustic finishes and low-emitting materials.
8. Give occupants temperature, lighting, and ventilation control.



Factors to improve indoor environmental quality

Factor 1. *Indoor air quality*



Strategies to improve indoor air quality

1. Prohibit smoking.



Effective strategies to prohibit smoking indoors:

Implement Clear No-Smoking Policies: Establish and enforce a strict no-smoking policy within all indoor areas and near building entrances and air intakes, clearly stating that smoking is prohibited. This policy should be communicated through visible signage and included in any contracts or agreements for residents, employees, or guests.

Provide Designated Smoking Areas: Set up designated smoking areas outside the building, away from entrances, windows, and ventilation systems, to accommodate smokers without allowing smoke to enter indoor spaces.

Educate About the Risks of Secondhand Smoke: Offer education and resources about the health risks associated with secondhand smoke to encourage compliance with no-smoking policies and promote a healthier environment.

Strategies to improve indoor air quality

2. Ensure adequate ventilation.

Effective Strategies:

- Use exhaust fans in bathrooms and kitchens
- Install and maintain air purifiers
- Ensure proper HVAC system maintenance
- Utilize natural ventilation whenever possible
- Incorporate air-cleaning plants into indoor spaces
- Implement demand-controlled ventilation
- Use ceiling fans to improve air circulation



Strategies to improve indoor air quality

3. Monitor carbon dioxide.

- Monitoring carbon dioxide levels within spaces, especially spaces where the number of people changes, can allow for **demand-control ventilation strategies** in which the amount of air delivered to the space is controlled based on the needs of the users.



Strategies to improve indoor air quality

4. Install high-efficiency air filters.

- High-efficiency air filters are designed to capture and remove small particles from the air more effectively than standard filters. They can trap dust, pollen, mold spores, and other pollutants, improving indoor air quality.
- High-efficiency air filters continually remove contaminants from the air and contribute to cleaner, healthier indoor air.



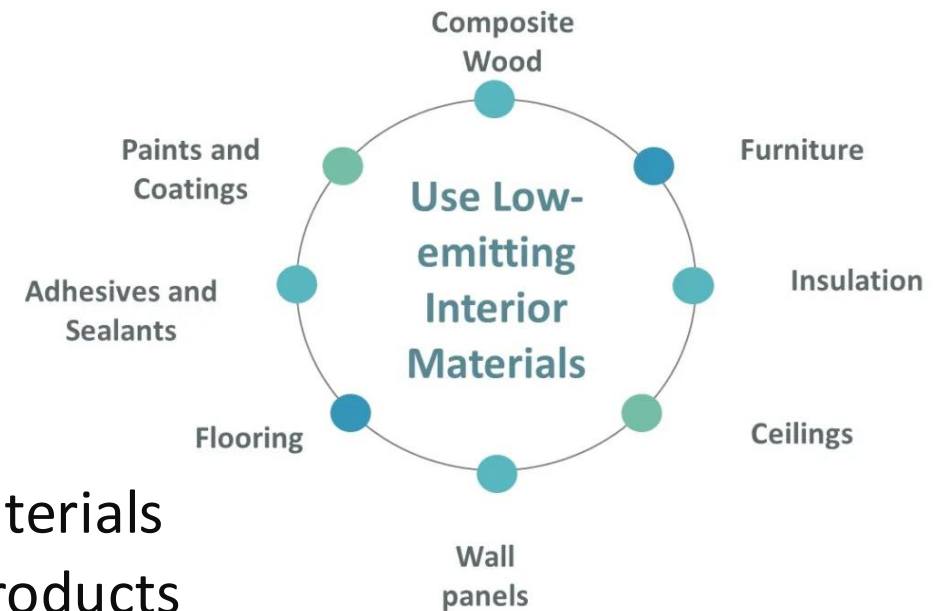
Strategies to improve indoor air quality

5. Specify low-emitting materials.

- Low-emitting materials are products used in building and construction that release minimal amounts of pollutants, such as volatile organic compounds (VOCs), into the indoor environment.
- These materials are designed to improve indoor air quality and reduce health risks associated with air pollution. Examples include paints, adhesives, flooring, and insulation that emit fewer chemicals.

Examples of low-emitting materials include:

- Zero or low-VOC paints and coatings
- Non-toxic adhesives and sealants
- VOC-free carpets and flooring materials
- Formaldehyde-free wood products
- Greenguard-certified furniture and building materials
- Low-emission composite wood and laminate products



Strategies to improve indoor air quality

6. Use integrated pest management.



- Integrated Pest Management (IPM) is a strategy that combines different methods to control pests safely and effectively.
- It involves understanding the pest's behavior and environment to choose the best methods to reduce pest damage with the least harm to people, property, and the environment.
- This approach can include biological, physical, chemical, and cultural tactics to keep pest numbers low and prevent them from becoming a significant problem.
- Integrated pest management uses strategies that minimize or eliminate the potential for human exposure to pest-control chemicals by prioritizing nonchemical strategies, such as monitoring and baiting, rather than taking a “pesticide first” approach.

Strategies to improve indoor air quality

7. Protect air quality during construction.

- Project teams can implement an indoor air quality management plan during construction to improve the air quality for construction professionals as well as reduce the buildup of dust and other contaminants within the building's HVAC system.
- Additionally, projects that carefully protect absorptive materials from moisture damage reduce the potential for future mold growth.



Strategies to improve indoor air quality

8. Conduct a flush-out.

What do we mean by a flush-out?

Once construction is complete, before occupants move into the building, the space can be flushed with large quantities of outside air to remove residual contaminants from construction activities.



Strategies to improve indoor air quality

9. Employ a green cleaning program.

Green cleaning policies can greatly reduce the introduction of harmful chemicals during building operation and encourage best practices by custodial staff.



Watch the video

How To Improve Indoor Air Quality

- Link: <https://www.youtube.com/watch?v=djnie-h6Bn8>

(you may also click on the YouTube Logo below)



Factors to improve indoor environmental quality

Factors 2,3,& 4. Thermal comfort, Lighting, and Acoustics



Thermal Comfort



Lighting Comfort



Acoustic Comfort

Strategies to improve thermal comfort, lighting, and acoustics

1. Use daylighting.

- Projects should be designed to introduce ample natural light into the space while providing glare-control devices to minimize the unwanted effects of unfettered sunlight.
- Areas that are not regularly occupied should be designed in the core of the building, while spaces such as offices and classrooms should be located along the building perimeter to take advantage of greater access to windows.



What are some design strategies for using daylighting?

Orientation of Windows

- Placing windows on the south side (in the Northern Hemisphere) to capture maximum sunlight.

Use of Skylights

- Installing skylights to bring natural light into central areas of a building.

Light Shelves

- Implementing light shelves to bounce light deeper into the interior spaces.

Clerestory Windows

- Utilizing high windows to allow light into deeper parts of a room.

Reflective Surfaces

- Using light-colored and reflective interior finishes to distribute light more evenly.

Solar Tubes

- Incorporating solar tubes to channel sunlight through reflective tubes into lower floors or interior rooms.

Shading Devices

- Designing overhangs or using shading devices to control glare and reduce overheating.

Strategies to improve thermal comfort, lighting, and acoustics

2. Install operable windows.

- Operable windows can enhance indoor air quality by allowing fresh outdoor air to enter and circulate within the indoor space. This helps to dilute and remove stale air and pollutants from the inside, improving the overall air quality.



Strategies to improve thermal comfort, lighting, and acoustics

3. Give occupants temperature and ventilation control.

Giving occupants control over temperature and ventilation allows them to adjust settings according to their comfort and needs, leading to improved air circulation and reduced buildup of pollutants, thereby enhancing indoor air quality.



Strategies to improve thermal comfort, lighting, and acoustics

4. Give occupants lighting control.

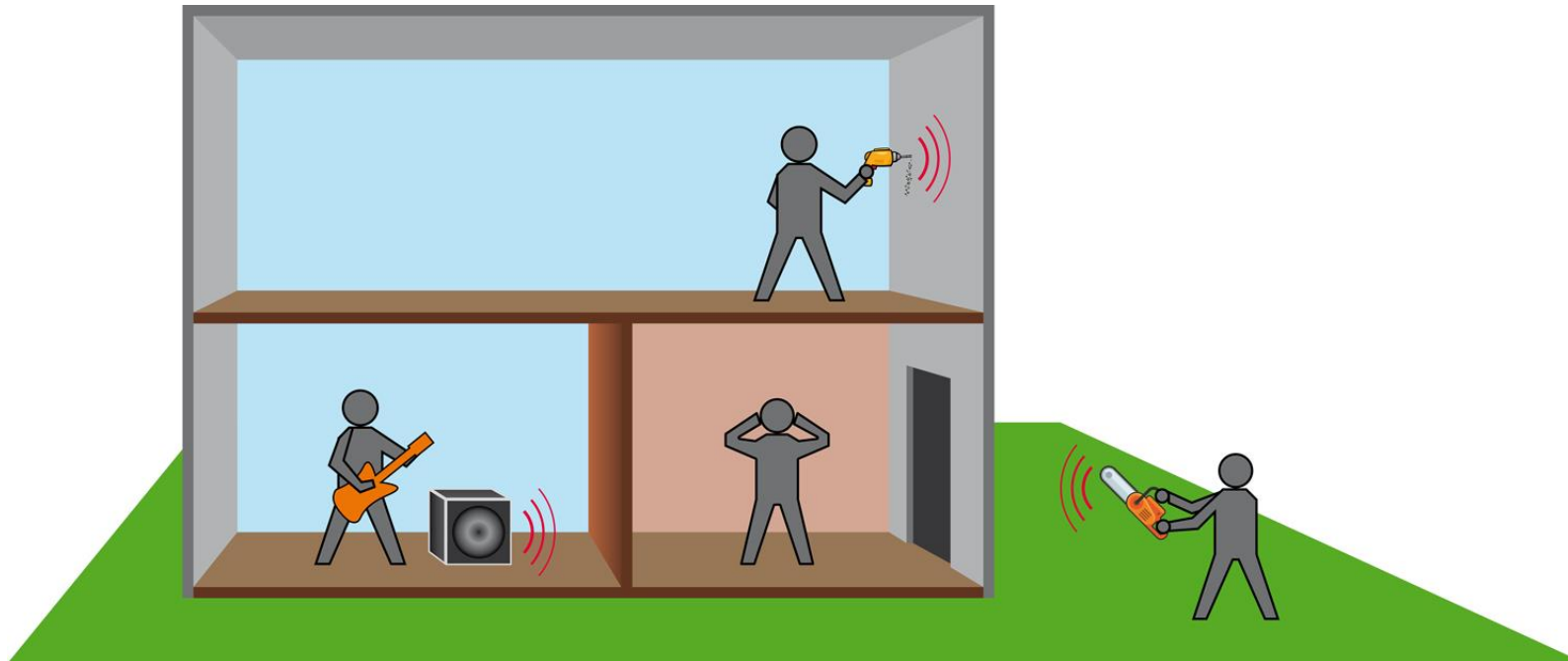
- Giving occupants lighting control contributes to a better indoor environment by allowing individuals to adjust the lighting to their comfort, which can indirectly support well-being and productivity.
- Task lighting at individual workstations and group lighting controls for shared spaces should be incorporated into the building to allow occupants to adjust the light levels to suit their needs and preferences.
- This also enables occupants to actively participate in energy savings by turning off lights when they're not needed.



Strategies to improve thermal comfort, lighting, and acoustics

5. Consider acoustics.

- Projects can make use of acoustical finishes, building geometry, duct insulation, and other strategies to facilitate this critical component of human interaction.



6. Conduct occupant surveys.

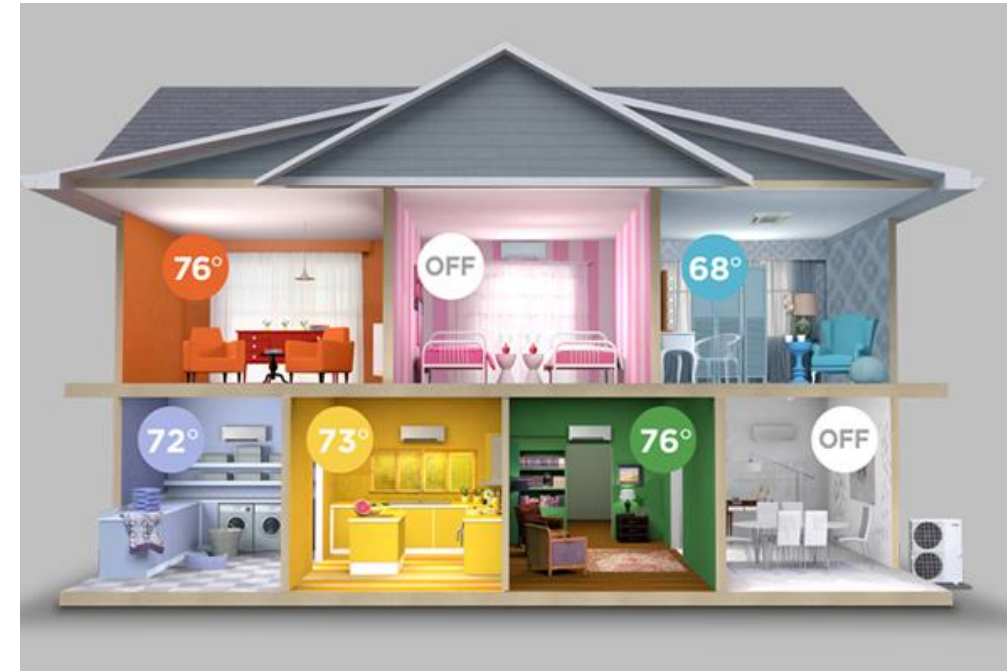
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What are some strategies to balance ventilation and comfort versus energy efficiency?

- **Smart Thermostat Use:** Implementing programmable or smart thermostats allows for the optimization of heating and cooling systems based on occupancy and usage patterns. Lowering the thermostat in winter months can save energy, and this can be done without significantly reducing comfort by setting it to lower temperatures during unoccupied times or when occupants are asleep.
- **Energy Recovery Ventilation (ERV):** ERV systems can help balance ventilation with energy efficiency by recovering heat (or coolness in summer) from outgoing air and transferring it to incoming fresh air. This reduces the energy needed to heat or cool the incoming air, maintaining comfort while enhancing ventilation.
- **High-Performance Building Envelope:** Investing in a high-performance building envelope, including effective insulation and high-quality windows, minimizes heat loss in winter (and heat gain in summer), allowing for lower thermostat settings without compromising comfort.
- **Zoned Heating and Cooling:** Creating zones within a building can help manage energy use more efficiently by allowing for different areas to be heated or cooled based on occupancy and specific needs, thus maintaining comfort while reducing overall energy consumption.
- **Use of Renewable Energy:** Incorporating renewable energy sources, such as solar panels, can offset energy use from heating and cooling systems, contributing to overall energy efficiency while maintaining indoor environmental quality.
- **Occupant Education and Engagement:** Educating building occupants about the importance of energy efficiency and how to use systems properly can lead to more conscious behavior, such as wearing warmer clothing indoors, that supports energy-saving measures without significantly impacting comfort.
- **Regular Maintenance and Monitoring:** Regular maintenance of HVAC systems ensures they operate efficiently, and monitoring energy use can identify opportunities for adjustments that balance comfort with energy efficiency.

What do we mean by zoned heating and cooling?

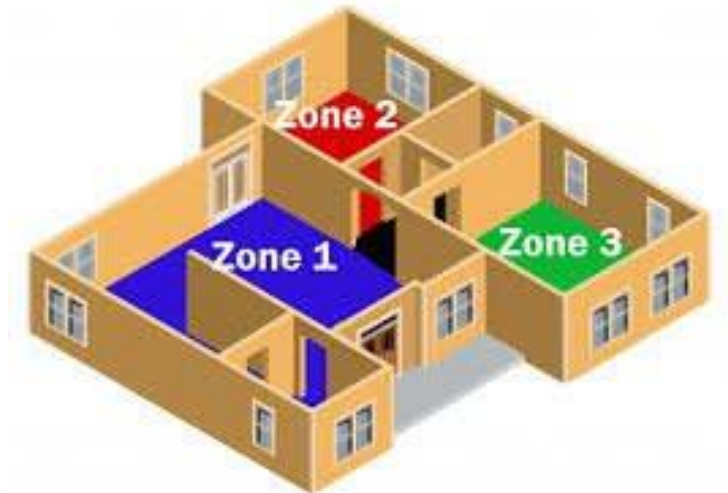
- Zoned heating and cooling refer to a system designed to heat or cool different areas of a building independently, allowing for customized temperature control in each zone.
- This approach uses multiple thermostats connected to a central control panel that manages dampers within the ductwork of a forced-air system.
- By opening or closing these dampers, the system can direct heating or cooling only to specified areas (zones) as needed.



Why is it important to provide lighting and thermal comfort controls to building occupants?

Providing lighting and thermal comfort controls to building occupants is crucial for several reasons, impacting well-being, productivity, and energy efficiency:

- Enhances Occupant Comfort and Well-being
- Increases Productivity
- Promotes Energy Efficiency
- Supports Sustainability Goals
- Improves Building Flexibility and Resilience



What do we mean by thermal comfort?

Thermal comfort refers to the temperature, humidity, and airflow ranges within which the majority of people are most comfortable, as determined by ASHRAE Standard 55–2004.

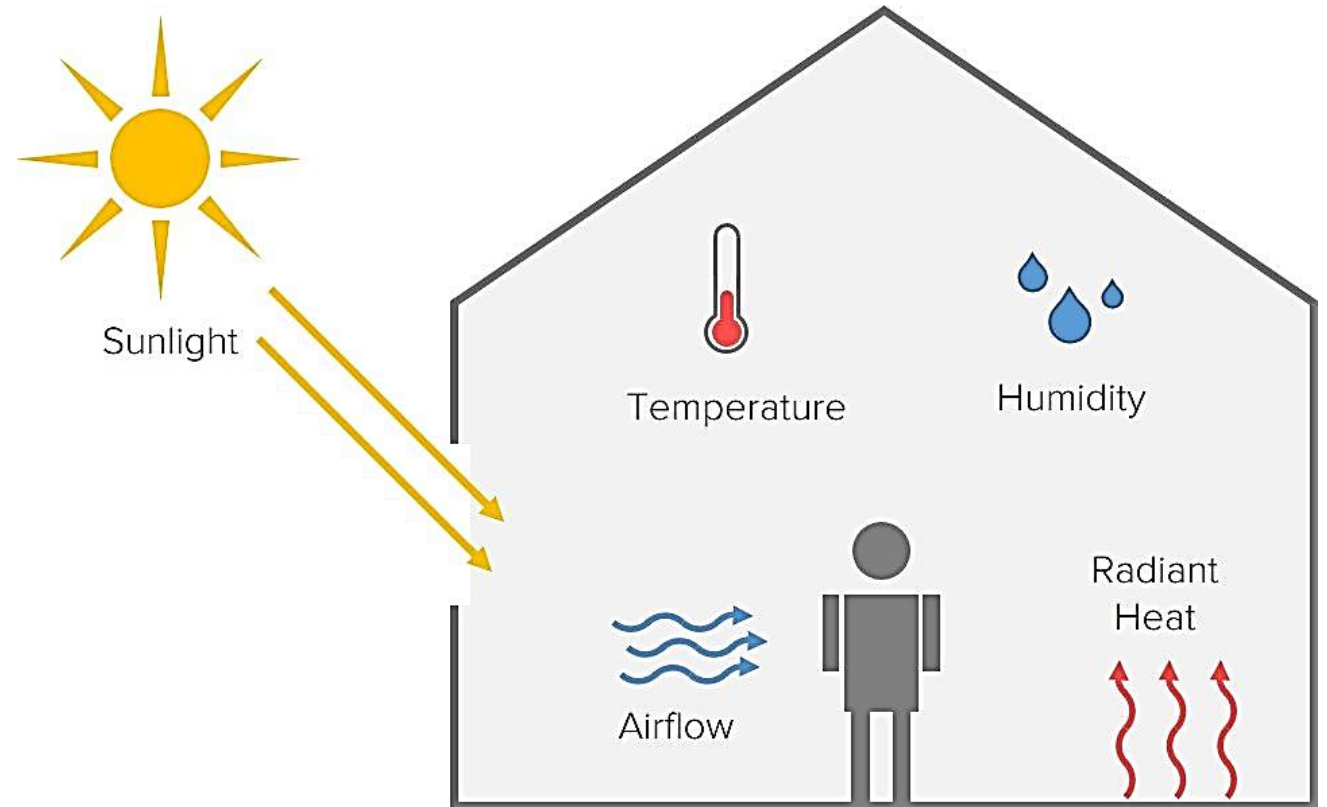
Because people dress differently depending on the season, thermal comfort levels vary with the season.

Control setpoints for HVAC systems should vary accordingly, to ensure that occupants are comfortable and energy is conserved.

Why is achieving thermal comfort essential in a building?

Achieving thermal comfort is essential for maintaining both physical well-being and productivity in living and working environments, as it significantly affects how satisfied and comfortable individuals feel in a particular space.

Thermal comfort is a key consideration in building design and environmental control to ensure that indoor environments can adapt to the preferences and needs of their occupants.



What does ASHRAE stand for and what is its mission?



- ASHRAE stands for the American Society of Heating, Refrigerating and Air-Conditioning Engineers.
- Its mission is to advance the arts and sciences of heating, ventilation, air conditioning, refrigeration, and related fields to serve humanity and promote a sustainable world.
- ASHRAE focuses on research, standards writing, continuing education, and advocacy to ensure energy efficiency, indoor air quality, and sustainable practices within the industry.

What do we mean by the “bake-out” process?

- Bake-out is a process used to remove volatile organic compounds (VOCs) from a building by elevating the temperature in the fully furnished and ventilated building prior to human occupancy.



Watch the video VOCs & Indoor Air Quality

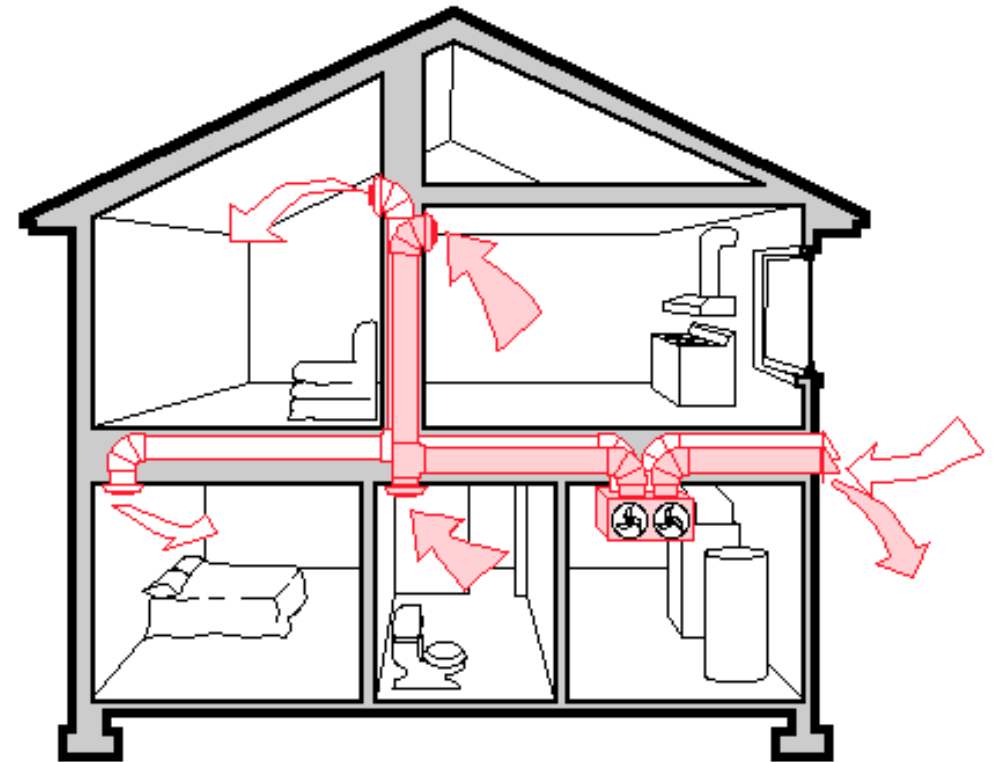
- Link: <https://www.youtube.com/watch?v=DlbDI1ZfdTg>

(you may also click on the YouTube Logo below)



What do we mean by “Ventilation Rate”?

- Ventilation Rate is the amount of air circulated through a space, measured in air changes per hour (the quantity of infiltration air in cubic feet per minute divided by the volume of the room).
- Proper ventilation rates, as prescribed by ASHRAE Standard 62, ensure that enough air is supplied for the number of occupants to prevent the accumulation of carbon dioxide and other pollutants in the space.



What is CO₂ concentration and why is it an indicator of ventilation effectiveness

- Carbon Dioxide Concentration is an indicator of ventilation effectiveness inside buildings.
- CO₂ concentrations greater than 530 parts per million (ppm) above outdoor conditions generally indicate inadequate ventilation.
- Absolute concentrations of greater than 800 to 1,000 ppm generally indicate poor air quality for breathing.
- CO₂ builds up in a space when there is not enough ventilation.



What do we mean by Commissioning (Cx)?

- Commissioning is the process of verifying and documenting that a building and all of its systems and assemblies are planned, designed, installed, tested, operated, and maintained to meet the owner's project requirements.



What is a “Commissioning Plan”?

- Commissioning Plan is a document that outlines the organization, schedule, allocation of resources, and documentation requirements of the commissioning process.



What is “Commissioning Report”?

- The Commissioning Report is a document that details the commissioning process, including a commissioning program overview, identification of the commissioning team, and description of the commissioning process activities.

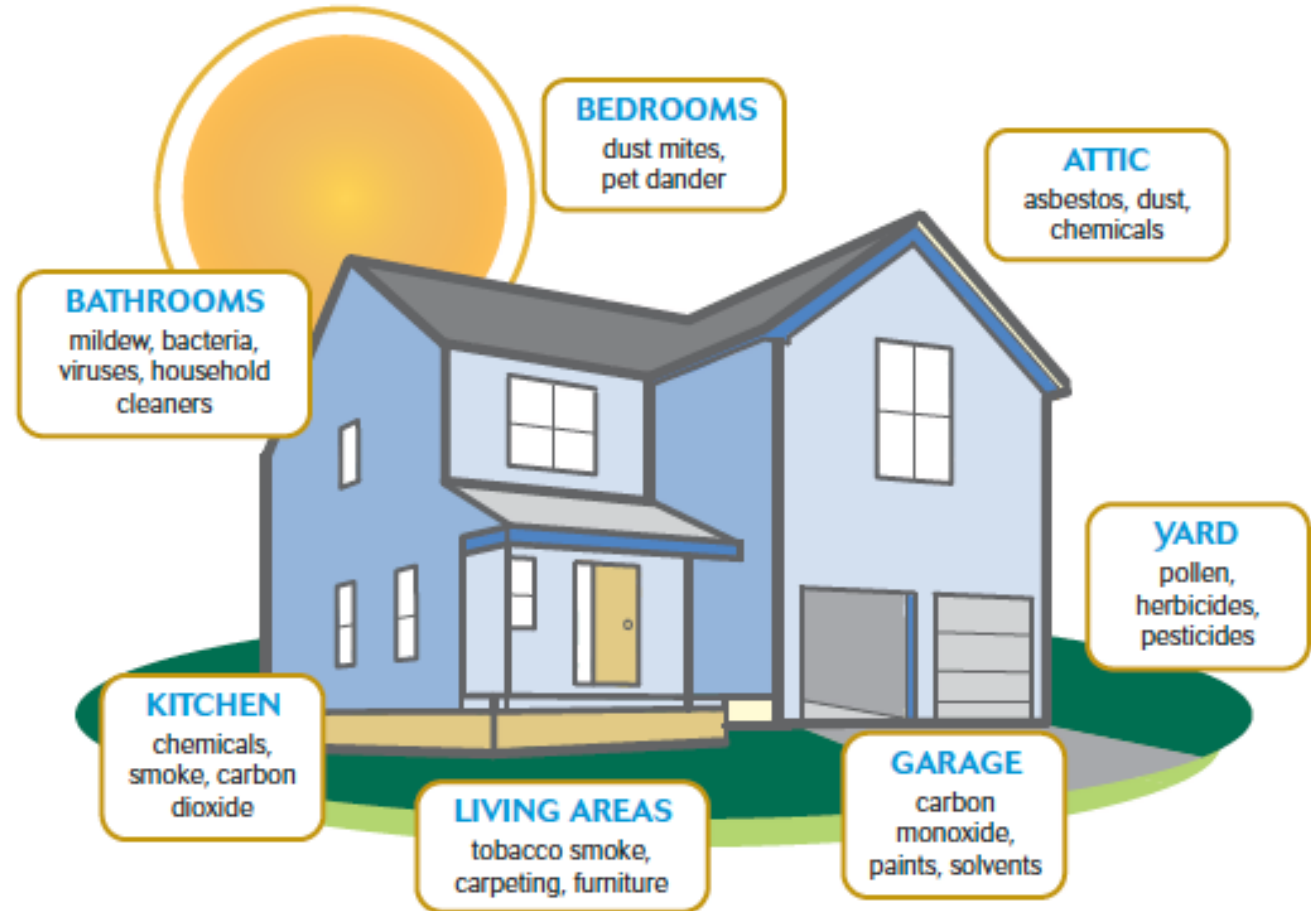
Figure 1: Commissioning Phases and Key Activities

Commissioning Phases and Key Activities

Commissioning Phase	Project Milestone(s)	Commissioning Activities
1. Pre-Design Phase (Project Planning Phase)	• Design team chosen	• Owner generates Request For Qualifications (RFQ) and Request For Proposal (RFP) • Cx agent selected • Cx agent helps develop the Owners Project Requirements (OPR) • Design Intent Document (DID) created • Define Cx roles and responsibilities • Begin developing the Commissioning Plan
2. Design Phase	• Building designed (schematic design) • Bid documents prepared • Job awarded to general contractor	• Plan developed • Cx agent verifies design documents accurately reflect owner's OPR • Cx agent reviews and comments on Basis of Design and Design Narrative • Format of Issues Log determined • Update Commissioning Plan • Commissioning specification are created • Cx agent performs design review
3. Construction Phase	• Construction of facility • Start-up of equipment	• Commissioning Plan is implemented • Cx agent reviews submittals • Test and Balance (TAB) procedures reviewed by design & Cx team • Cx agent observes and evaluates equipment installation • Commissioning agent maintains the Issues Log • Regular Commissioning meetings are held • Controls point to point checks (pre functional checklists) • HVAC start ups (correct problems and retest) • Test and Balance (TAB) agency performs their work • Operations & Maintenance (O&M) documentation and training
4. Acceptance Phase	• Training completed • Documentation completed • Building accepted by owner	• Cx agent conducts functional performance testing (FPT) • HVAC controls documented • TAB report submitted to design team and Cx agent verifies • Problems found are corrected and retested • O&M Documentation & Training
5. Post-Acceptance Phase (Project Occupancy Phase)	• Owner occupies building and assumes responsibility for ongoing operations and maintenance	• “Off season” FPTs • Problems are corrected and retested • Final Commissioning Report is issued

What is called a “Contaminant”?

- Contaminant is an unwanted airborne element that may reduce indoor air quality (ASHRAE Standard 62.1–2007).



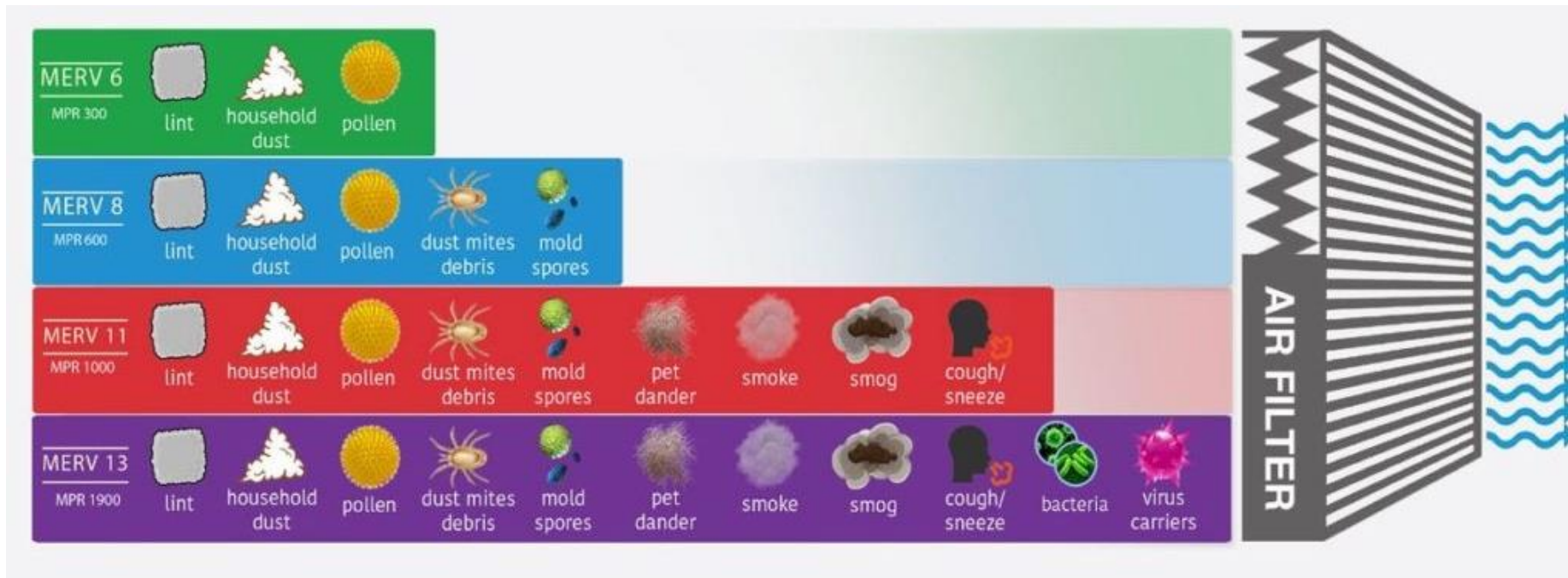
What does a flush-out require?

- Flash-out requires the operation of mechanical systems for a minimum of two weeks using 100 percent outside air at the end of construction and prior to building occupancy to ensure safe indoor air quality.



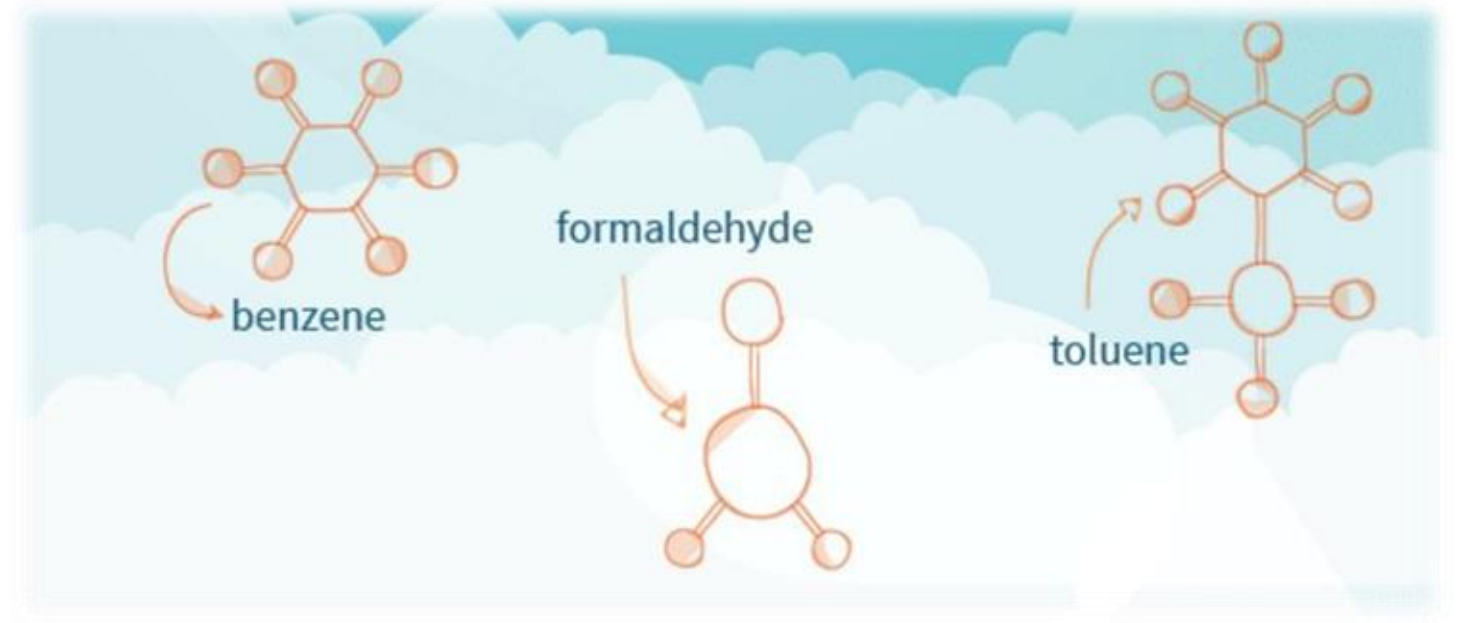
What is “Minimum Efficiency Reporting Value (MERV)”?

- MERV is a rating that indicates the efficiency of air filters in the mechanical system.
- MERV ratings range from 1 (very low efficiency) to 16 (very high efficiency).



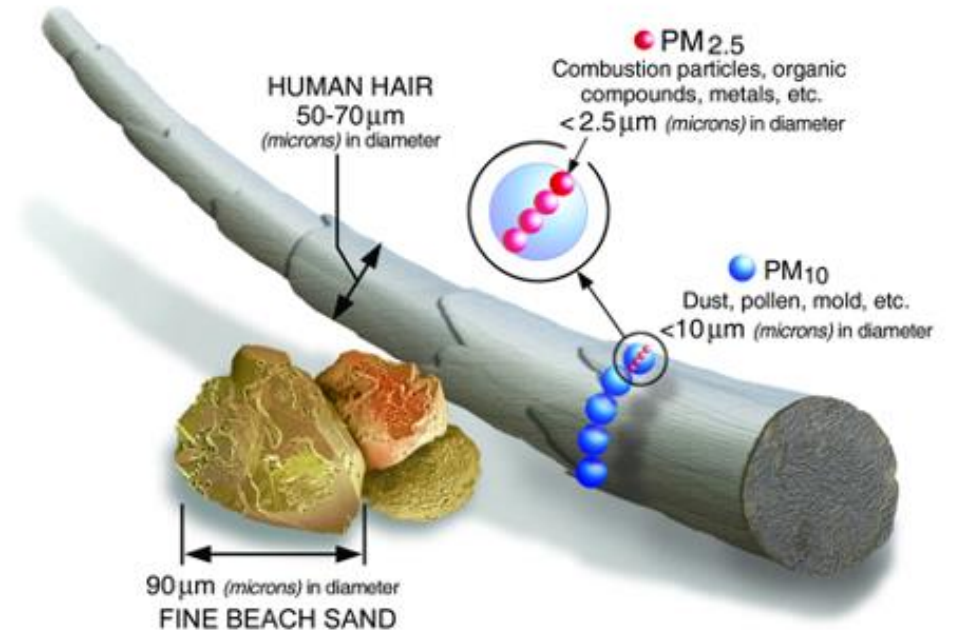
What is “Off-Gassing”?

- Off-Gassing is the emission of volatile organic compounds from synthetic and natural products.



What do we mean by “Particulates”?

- Particulates are solid particles or liquid droplets in the atmosphere.
- The chemical composition of particulates varies, depending on location and time of year.
- Sources include dust, emissions from industrial processes, combustion products from the burning of wood and coal, combustion products associated with motor vehicle or nonroad engine exhausts, and reactions to gases in the atmosphere. (EPA)



What do we mean by “Pollutant”?

- Pollutants are any substances introduced into the environment that harm the usefulness of a resource or the health of humans, animals, or ecosystems.
- (EPA) Air pollutants include emissions of carbon dioxide (CO₂), sulfur dioxide (SO₂), nitrogen oxides (NO_x), mercury (Hg), small particulates (PM_{2.5}), and large particulates (PM₁₀).



What is “Sick Building Syndrome (SBS)”?

- Sick Building Syndrome (SBS) is a combination of symptoms, experienced by occupants of a building, that appears to be linked to time spent in the building but cannot be traced to a specific cause.
- Complaints may be localized in a particular room or zone or be spread throughout the building. (EPA)

