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Improving Air Quality: A Guide for Property Owners

Rutgers Center for Green Building

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Improving Air Quality: A Guide for Property Owners

Ensuring good air quality is essential to creating living environments that support healthy, comfortable and productive building occupants. Improving air quality need not be a major financial burden for either property owners or tenants, and the benefits of ensuring good air quality outweigh costs. The success of air quality improvement initiatives, however, does sometimes require extensive coordination between property owners and tenants. This guide provides an overview of air improvement strategies that fall within the purview of property owners and managers. Moreover, the guide places greater emphasis on air quality improvement strategies that double as effective heatwave resiliency measures.

Source control and ventilation are the two major strategies for controlling indoor air quality. While both components are important for maintaining a high level of air quality, careful source control is 'doubly effective' because it reduces the need for frequent and potentially inconvenient ventilation strategies. Heatwave prevention and preparedness refers to strategies that help to minimize the urban heat island effect and that help to make buildings and occupants more resilient to the impacts of rising temperatures associated with climate change such as increased energy demands that result in higher air conditioning costs, increased greenhouse gas emissions and air pollution, more frequent power outages, and increased risk of heat-related illnesses.

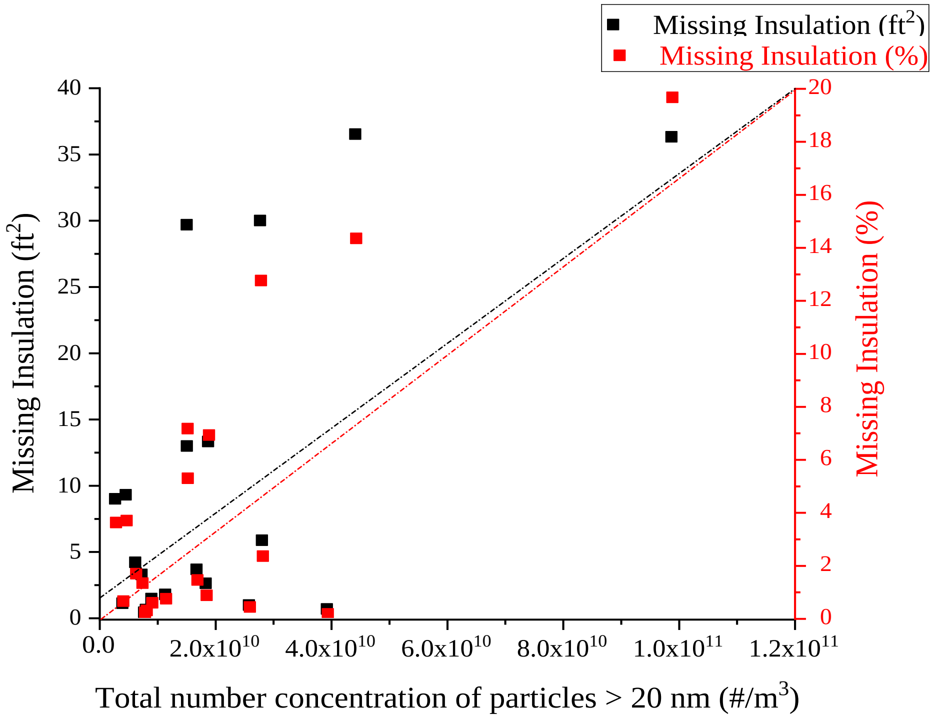
Source Control

Source control focuses on improving air quality through strategies to prevent, eliminate or reduce pollution at its source.[1]

Source Control: Building Envelope

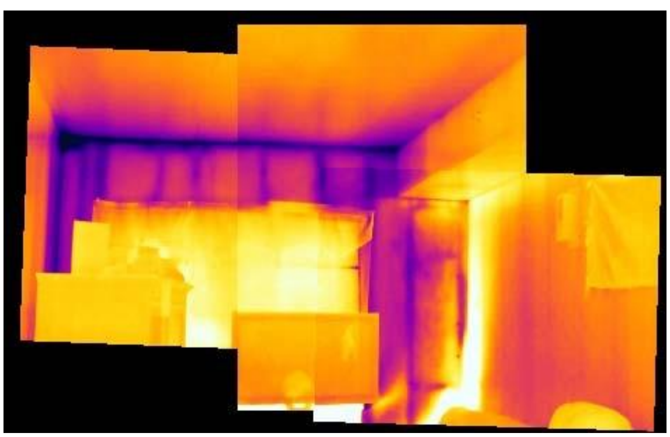
Air infiltration refers to the uncontrolled and unintentional entry of outside air through leaks in the building envelope. The building envelope is the physical barrier between indoors and outdoors that encloses the structure, including the foundation, roof, floor, ceiling and walls.[2] Minimizing air infiltration starts with the consideration of the building envelope, including insulation, moisture control, ventilation and air sealing. A Rutgers University study found a clear and significant correlation between the concentration of ultrafine particles (<300 nm) inside apartments and missing building insulation.[3] Additionally, residents reported mold at higher rates in apartments with missing insulation. This is important because the particles and mold worsened residents' experience with asthma; building defects such as missing insulation have a direct and negative effect on the residents' well-being.[4] In multifamily buildings, air sealing gaps and openings in walls, ceilings, and floors between individual dwelling units can minimize the transfer of common indoor air pollutants such as secondhand smoke.[5]

Low-cost detection methods in combination with cost-effective thermal imaging can give property owners a complete assessment of housing-related health and safety hazards. While property owners can pursue lower costs methods using consumer-grade technologies (e.g. 'Foobot' and 'Air Visual' products), they might want to work with a research center like the Center for Green Building (at Rutgers University) to utilize thermal imaging technologies.[6] The cost of such technologies is decreasing, but data processing requires computing power and specialized software that is typically beyond the access and affordability of building managers. Such technologies will enable owners to quickly identify and rectify problem spots in the building envelope and avoid the costs of more common but invasive and destructive trial-and-error processes.



Source: Thomas et al. 2018[7]

Reducing air infiltration improves building resiliency overall. Reducing leaks and drafts will help maintain thermal comfort and protects building occupants during power outages and from air-borne security threats. Controlling air infiltration also reduces the building's peak heating and cooling demand, saving money and reducing stress on the grid.



Moisture	Moisture areas usually appear as dark/cool areas without distinct edges.
Air leakage / Air infiltration	Air leakage usually appears as light/dark areas in building corners or near structural joints.

This panoramic infrared image of an apartment interior helps to isolate areas with missing insulation. Source: Rutgers Center for Green Building

Source Control: Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are found in many everyday products and building materials. They slowly 'off-gas' (vaporize from material surfaces into the air) at normal room temperatures and can adversely impact building occupants' health.[8] Children, aging adults and people with respiratory problems are at increased risk of negative health impacts (e.g. bodily irritation, headaches, loss of coordination) from VOC exposure.[9] Concentrations of many VOCs are consistently higher indoors than outdoors.

Paints, sealants, manufactured wood products and adhesives, as well as some furnishings and carpet systems, all release VOCs. Property owners can improve air quality and protect tenant health during interior fit-out by using furnishings and products that do not off-gas. While the standard of 'low emissions' varies by product type, several certification and labeling programs (e.g. GREENGUARD indoor air quality certification, Green Label Plus for carpets and rugs, Green Seal and Scientific Certification Systems) help identify products that meet sustainability and emissions standards.[10]

Formaldehyde, a known carcinogen, can be found in many building materials and products and can negatively impact occupant health. It is important to reduce the amount of products with formaldehyde inside the facility and share information with building occupants about how to protect themselves from exposure to formaldehyde through resources such as the US EPA website. [11]

Source Control: Entryway Systems

As much as 80 percent of the soil, dust and other contaminants found inside a home are tracked in on the shoes of occupants. These substances degrade indoor air quality by exposing building occupants to various irritants.[12] Entryway systems, such as mats, improve IAQ by catching and holding dirt particles and thereby reduce the amount of dirt that enters a dwelling.[13]

Door mat (Source: Flickr Adam Mulligan)
http://www.flickr.com/photos/amulligan/175739762/

Property owners and managers may install door mats at building entry points and might also consider providing tenants with shoe racks to place by apartment doors as well as roll-out mats and information about the importance of walking the entire length of the mat to remove as much dirt as possible. In addition to improving indoor air quality through source control, entryway systems also reduce cleaning and maintenance costs per unit. An entrance mat may cost as little as $4.00 - $6.00 per sf.[14]

Source Control: Moisture Management

Excess moisture is central to many aspects of managing IAQ and the following strategies can help control moisture and improve IAQ:[15]

- Incorporate interior and exterior materials that are durable and resistant to moisture and excessive humidity.
- Install water-resistant, hard-surface flooring in kitchens, baths, entry, laundry and utility rooms to prevent mold and moisture issues.

- Insulate piping in exterior walls with pipe wrap to avoid condensation and cracking pipes during cold weather.
- Properly seal and flash windows to prevent problems caused by water intrusion, including mold, warping, and structural damage.[16]
- Incorporate covered entryways when possible to reduce water entry during wet weather.
- Utilize floodproofing including dry and wet floodproofing up to the design flood elevation.[17]
- Raise mechanicals and electrical equipment in flood prone zones.
- Manage stormwater runoff to prevent localized flooding issues by reusing stormwater onsite (e.g., cisterns for irrigation, rain gardens, and vegetated roofs).
- Use smart water metering and irrigation and moisture sensors to monitor water use, detect leaks, and prevent irrigation systems from running when it is raining or when unnecessary.

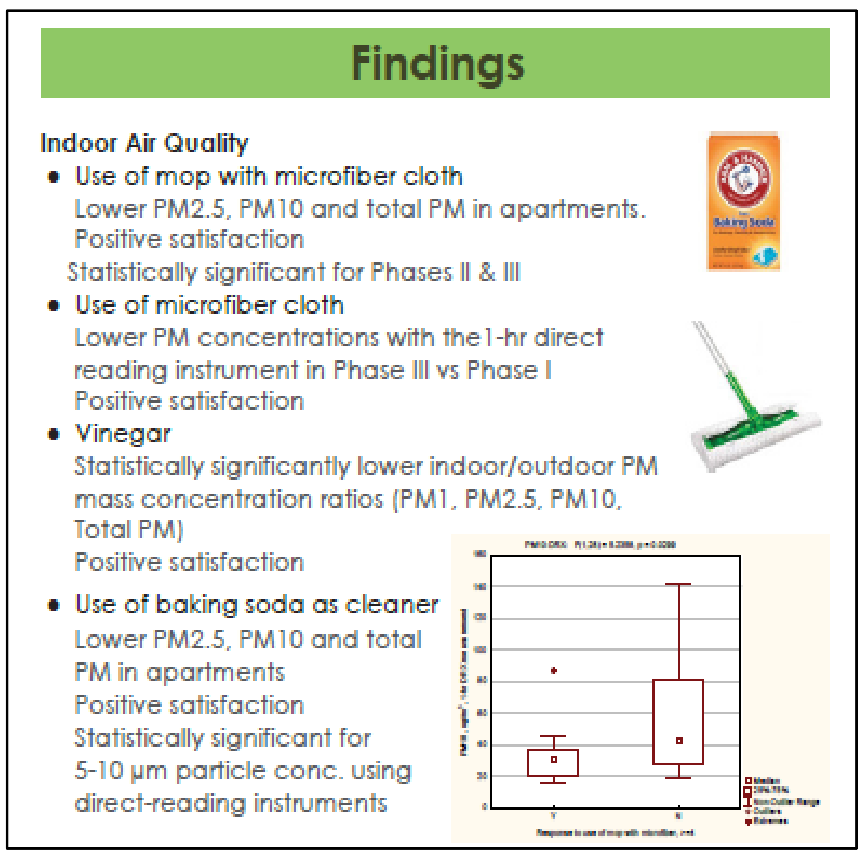
Source Control: Integrated Pest Management (IPM)

IPM is a system of pest management that uses monitoring, prevention and control techniques with a focus on minimizing synthetic chemical use and prioritizing a holistic, whole-building approach. Key IPM components include regular monitoring, repairing structural damage, good sanitation and waste management, and a combination of low impact pesticides when necessary.[18]

Source Control: Green Cleaning

Green cleaning refers to using cleaning products and procedures that minimize potential negative impacts to human health and the environment.[19] Cleaning with green or natural products can lower airborne particulate matter concentration and improve IAQ. In addition to implementing a comprehensive green cleaning program throughout the facility, building owners/managers might consider providing green cleaning starter kits for tenants. These kits can include basic green cleaning items such as microfiber mop cloths, baking soda and vinegar. The Healthy Children and Family Study, conducted by Rutgers University, found that the use of a mop with microfiber cloth, microfiber cloth and the use of vinegar and baking soda as cleaners lowered airborne particulate matter concentration.

Natural Cleaning Products. Source: Rutgers Center for Green Building



Source: Rutgers University Healthy Children and Family Summary Report

Ventilation

Passive and active ventilation strategies help manage IAQ by maintaining the proper mix of gases in the air, controlling odors, and exhausting or diluting contaminants from occupied spaces. Natural ventilation strategies represent a passive approach to IAQ management. Many buildings rely predominantly on HVAC systems and some buildings utilize a combination of mechanical and natural ventilation strategies, referred to as mixed-mode systems. Smart building technologies applied to ventilation strategies, such as smart sensors and controls, continuously monitor and adjust conditions of the physical environment to optimize thermal comfort, energy efficiency and IAQ.

Ventilation: Natural Ventilation

Natural ventilation systems rely on natural forces, such as wind and temperature variation, to introduce fresh air to airtight buildings and homes.[20] Early in the design stage, building architects may use simulation tools (e.g. CoolVent) to evaluate the effects of different natural ventilation strategies (e.g. operable windows, fans and corridors help direct airflow).[21] Ceiling fans, for example, create a wind chill that can make a room 4 to 6 degrees cooler.[22] A whole house fan can swap warm indoor air with cooler nighttime air.

Natural ventilation strategies can reduce energy use, lower energy bills and reduce installation and maintenance costs by allowing for smaller mechanical systems and by extending the life of HVAC equipment. Property management staff can supplement natural ventilation by installing ceiling fans to support natural ventilation without the need to contract outside professionals, providing additional cost savings.

Other benefits include comfortable, year-round indoor temperatures and improved indoor air quality. If property owners consider natural ventilation strategies early in an integrated design process, they can realize upfront cost-savings from installing right-sized or downsized mechanical equipment as well as cost-savings associated with increased energy efficiency.[23] Installing ENERGY STAR certified ceiling fans saves 40% more energy compared to conventional fans.[24] Natural ventilation can promote heatwave resiliency by maintaining thermal comfort for building occupants, especially in the event of power outages or loss of air conditioning.

Mixed-mode systems add redundancy and flexibility to the building's ventilation and HVAC systems, providing back-up during outages, mechanical failures, security threats or the release of air-borne contaminants.

Ventilation: Demand Control Ventilation (DCV)

Mechanical ventilation systems typically provide a constant flow of fresh air to occupants based on maximum building occupancy or full ventilation rates in contrast to a minimum or area ventilation rate based on reduced occupancy levels. Demand control ventilation (DCV) modulates between full and area ventilation rates based on actual or estimated occupancy levels, saving energy and improving indoor air quality. Property owners and managers may consider using DCV with CO^2 and occupancy sensors, especially in common spaces, to adjust airflow based on CO^2 levels or the number of occupants in a space, saving energy by reducing ventilation during times of vacancy and reduced occupancy and by minimizing the energy required to heat or cool outside air, and improving indoor air quality.[25] DCV provides heatwave resiliency benefits by reducing heating and cooling loads, thereby reducing stress on the grid, and the likelihood of brownouts during peak demand and extreme heat events.

Ventilation: Smart Sensors and Controls

Smart sensors and controls, an integrated system of devices that help building owners and managers monitor and operate the building, can alert managers to leaks (preventing moisture issues), equipment failures (that can lead to indoor air pollution), and support more efficient operations.


Electric Smart Meter
Source: RU Facilities

Smart sensors are devices that monitor conditions of the physical environment and building equipment such as temperature, air flow, moisture, humidity, and CO^2 levels, offer smoke and CO detection, and collect data about real-time building occupancy, and energy and water use. Smart controls utilize the data to adjust building conditions and optimize building performance in such areas as HVAC systems, security, fire suppression, and landscape irrigation. Property owners and managers may consider implementing the following smart devices:

- Smart thermostats and HVAC controls to manage proper humidity levels and temperature settings, control energy consumption in unoccupied areas and detect and diagnose issues.
- Smoke detectors linked to automated sprinkler systems.
- CO sensors that trigger alarms to protect building occupants before exposure to dangerous CO levels.
- Demand control ventilation (DCV) with carbon dioxide (CO^2) sensors or occupancy sensors that monitor indoor air quality based on actual occupancy levels.
- Operable windows that use auto-controlled devices to open and close at specific times of the day to manage ventilation levels and control indoor temperatures.[26]
- PM sensors that indicate when it is advisable to bring outside air either by opening windows or via HVAC if fresh air intake is an option.

Smart sensors and controls provide heatwave resiliency benefits by: providing real-time feedback on the status of critical building systems, notifying building operators when and where a problem exists, and providing remote access for turning systems on or off during potential power outages or other disruptive events.

Heatwave Prevention and Preparation

The health and comfort challenges presented by poor air quality are especially exacerbated by heatwaves, which are increasing in severity and duration because of climate change.[27] While it is difficult to control the quality of outdoor air, property owners and managers can still pursue strategies to improve outdoor air quality in the immediate vicinity of the property and encourage tenant use of outdoor amenities. Depending on location, outdoor air is generally better than indoor air for tenant health and comfort; as such property owners may want to implement changes that encourage tenants to leave the building.

Heatwave Prevention and Preparation: Outdoor Shaded Spaces

Aging adults and people with chronic illness are at particular risk of heat stroke, dehydration and dangerous fainting spells. This is exacerbated by the fact that some people living in public housing do not have access to central air conditioning (AC) or cannot afford to run window AC units. Property owners can encourage these populations to walk the outdoor premises by providing sufficient amenities that accommodate such activity.

While the grounds of apartment complexes often include outdoor common spaces, they do not always have shaded areas and aging adults, who are susceptible to heatstroke, may not be able to take advantage of unshaded outdoor spaces. Owners may consider planting trees on property grounds as the presence of trees will contribute to improved air quality. Trees absorb pollutants and also help reduce the urban heat island effect by cooling the immediate environment through evapotranspiration and can reduce the need the demand for air conditioning in nearby buildings.[28] Heat island effect takes place when built up or densely developed areas experience an increase in temperature due to large areas of dark surfaces (i.e., pavement, roofs, etc.) that absorb heat from the sun. Rising temperatures result in increased energy demands, which can lead to higher air conditioning costs, increased greenhouse gas emissions, pollution, and increased risk of heat-related illnesses.[29] If planting trees is not feasible, owners can still incorporate planted areas, install canopies or umbrellas and provide seating to accommodate outdoor activities. Consider multipurpose components such as photovoltaic panels or vegetated roofs on structural canopies. High reflectance or "cool" paving stays cooler in the sun than darker paving. Consider using light-colored and reflective-colored pavers an alternative to asphalt and other dark materials for outdoor spaces.[30] Water features can also help cool the microclimate of an outdoor space.[31]

Study site and its surroundings (NJGIN), 2016; Maps, 2017
Source: Rutgers Center for Green Buildings

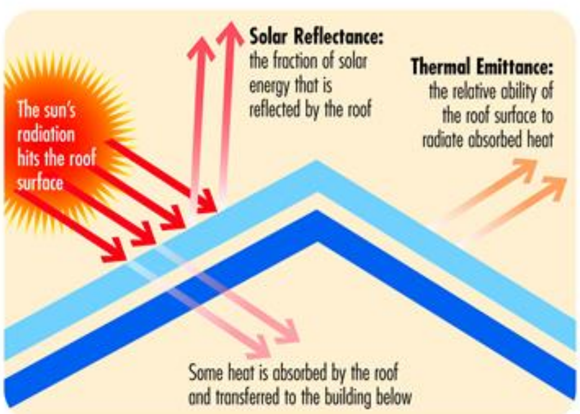
Heatwave Prevention and Preparation: Vegetated Roofs

A vegetated roof, or green roof, is a system of lightweight growing media and plants that can be installed on most new or existing roofs with the input of a structural engineer. Vegetated roofs can improve air quality, reduce the urban heat island effect, manage stormwater and reduce the need for heating and cooling within the building. Accessible green roofs can also provide opportunities for producing food as well as providing additional outdoor space and wildlife habitat.[32]

The Geraldine R. Dodge Foundation headquarters green roof in Morristown, NJ Source: Wild New Jersey

For example, vegetated roofs serve as a carbon sink, helping to offset carbon emissions. Vegetation traps dust and particulate matter as well as other contaminants such as nitrogen oxides.[33] The multiple layers of a vegetated roof provide insulation. By increasing a building's thermal mass, vegetated roofs can help keep temperatures cool in hot weather and warmer during the heating season translating into less energy spent on climate control for the building.[34] In the event of a power outage, common during heatwaves, vegetated roofs can help keep temperatures cool in the hot weather.

Heatwave Prevention and Preparation: Cool Roofs



Reflectance and Emittance of Roofs Source: Cool Roof Rating Council

Cool roofs, typically white, light-colored or reflective-colored roofs, reflect and radiate heat away from the building and are “cooler,” or have higher levels of reflectance and emissivity, than dark roofs. Many building codes and green building programs have a cool roof and urban heat island mitigation requirements that refer to ENERGY STAR and the Cool Roof Rating Council (CRRC) voluntary labeling programs. Cool roofs and proper insulation levels can reduce heating and cooling loads, reducing stress on the grid, and help to regulate thermal comfort during a power outage. [35]

Heatwave Prevention and Preparation: Energy-Efficient Landscaping

The careful selection and placement of trees, shrubs and other vegetation can help reduce a building’s cooling needs. For example, planting trees on the soutside of the building can minimize summer solar heat gain. During a heat wave, shade-providing trees help mitigate the urban heat island effect, reduce indoor cooling loads, and reduce stress on the power grid. Properly sited and maintained trees can block buildings from severe winds and offer protection from extreme cold.[36]

Heatwave Prevention and Preparation: Socializing Activities

A Rutgers University survey of public housing residents found that although all residents sought to adapt to heatwaves, their options were often limited by mobility and financial constraints. The study also found that residents' capacity to adapt or leave their building systems was bolstered by their ability to tap into strong social networks for assistance.[37]

Public housing authorities may want to consider partnerships with nonprofits or community associations to provide transportation services for aging residents. While seniors may want to enjoy the healthier and more resilient accommodations of local community centers, libraries and other amenities, they often are unable to transport themselves to the desired location. For seniors, walking to these locations is a not always feasible.

Property owners also can work more closely with city officials to improve the overall safety of the area surrounding the building complex, especially in and around nearby walkable parks and playgrounds. While aging adults would prefer to take advantage of shaded paths and green spaces, they are often dissuaded by news or perception of unsafe circumstances.

How far are you willing to walk from your home to a park or other destination?

Answer	Response	%
About a block	77	17%
2-3 blocks	119	27%
5-10 minute walk	102	23%
10-20 minute walk	89	20%
More than a 20 minute walk	62	14%
Total	449	100%

Survey fielded April-June 2016, based on AARP Age-Friendly Communities survey. n=532;
Courtesy Dr. Karen Lowrie, Rutgers University

Heatwave Prevention and Preparation: Air Quality Indicators and Warning

Property owners can implement a visual outdoor air quality monitoring and warning system. The US EPA has an 'Air Now' online tool (airnow.gov) that lists air quality conditions by zip code[38]; property managers can install a highly visible flag system whereby they raise flags whose color corresponds a scale of air quality.

Air Quality Index	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy	Very Unhealthy
Color					

Image source: US EPA

Heatwave Prevention and Preparation: Smart Metering

Smart meters or advanced meters, a component of the broader smart grid,[39] use digital meters to record and transmit energy consumption and generation data, namely electricity, but also natural gas or water usage in intervals of an hour or less through a secure wireless network back to the utility and consumer at least daily.[40] As opposed to traditional analog or automated meter readers, smart meter technology includes remote reading, two-way communication, support for dynamic pricing,[41] and remote disablement and enablement of supply.[42] Smart meters provide documentation for participation in utility-sponsored demand response programs, which incentivize property owners and managers to interrupt or adjust energy use by reducing or shifting loads or storing energy during peak demand and periods of higher energy costs or enable utilities to remotely switch electricity services on or off based on the cost or availability of energy.[43] For example, consumption data from smart meters can signal a utility or consumer to remotely turn off air-conditioning units to avoid peak load issues or to run appliances during lower demand, lower-cost times of the day. Smart metered buildings with on-site renewable energy generation (e.g., photovoltaic systems) and energy storage (e.g., thermal storage, battery storage, fuel cells) can signal consumers to use renewable electricity when available, store excess when not needed or sell excess electricity to the grid. Smart metering and participating in demand response programs can help reduce water and energy costs and prevent peak demand-related grid-outages.

Electric Smart Meter.
Source: RU Facilities

Smart meters increase heatwave resiliency by supporting the smart grid, which aims to diversify and strengthen the electric grid through better energy management and the integration of cleaner energy sources such as wind and solar as well as electric vehicle charging. During heatwaves or power outages, smart meters help accelerate service restoration by identifying problem areas and efficiently sending work crews, thereby reducing repair costs and total outage times and limiting business closures, health and safety hazards, food spoilage, and inconvenience from schedule disruptions. [44]

Heatwave Prevention and Preparation: Energy Storage and Back-up Power

In the last 20 years, an increase in the frequency and the intensity of extreme weather events, such as major hurricanes, heatwaves, thunderstorms, and ice storms in New Jersey and the associated costs of storm-related power outages, highlights the need for resilient energy systems that provide backup power in the event of a grid failure.[45]

Historically, generators fueled by fossil fuels, such as diesel or natural gas, provide backup power in the event of a power outage or natural disaster. In New Jersey, Hurricane Sandy exposed the vulnerability of generators, as the storm disrupted access to fuel and competing fuel demands from the transportation sector quickly depleted local fuel reserves.[46]

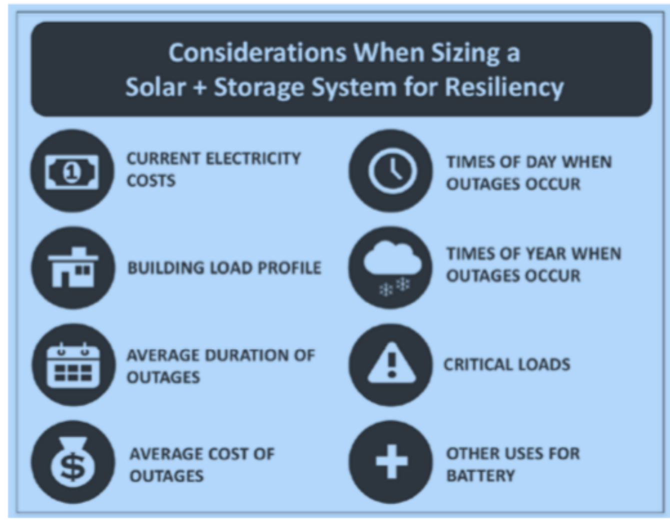
Energy storage refers to storing energy (e.g., batteries, thermal storage) for later use when it is needed, such as during a heatwave and power outage, or storing low priced energy and using that energy during peak demand, such as increased air conditioning usage during a heatwave, when prices climb.[47]

Backup power refers to supporting critical building functions by utilizing stored electrical or thermal energy (energy storage), power from on-site power generation with islanding capabilities, or power from local microgrids and distributed energy generators.

Property owners and managers may consider supplementing or replacing traditional standby generators with the following technologies to provide backup power in the event of a power outage or heatwave:

- Islandable Photovoltaics (PV) systems with battery storage.
- Combined Heat and Power (CHP) systems with or without energy storage.
- Fuel Cells and hydrogen storage.
- Vehicle-to-Grid (V2G) Technology and battery storage.

Energy storage and backup power generation support heatwave prevention and preparation in many ways. Backup power generation systems that utilize energy storage or islanding and microgrid ready capabilities can operate independently from the grid during outages or at times of system peak and increase grid reliability by managing system outages and peak demand. Separation from the electricity grid also offers protection from security threats. Energy storage and backup power generation allow customers to take full advantage of demand response programs that signal when to use, store, or sell energy back to the grid and encourage electric vehicle charging during off-peak, low-cost hours or charging back to the grid during periods of peak demand. Likewise, energy storage and on-site backup power help to support the development of the broader smart grid by providing a local, distributed energy resource and helping to manage the integration of clean and renewable energy to the grid.



Storage and Backup Power Considerations (Source: NREL)

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[42] Connected Devices Alliance. 2018. "Intelligent Efficiency - A Case Study of Barriers and Solutions - Smart Homes." March 2018.
[43] Connected Devices Alliance. 2018. "Intelligent Efficiency - A Case Study of Barriers and Solutions - Smart Homes." March 2018.
[44] DOE. "Smart Grid Investments Improve Grid Reliability, Resilience, and Storm Responses." https://www.smartgrid.gov/files/B2-Master-File-with-edits_120114.pdf (accessed May 1, 2018).
[45] New Jersey Climate Adaptation Alliance, Understanding New Jersey's Vulnerability to Climate Change. http://njadapt.rutgers.edu/docman-lister/working-briefs/75-nj-vulnerabilities/file
[46] E. Hotchkiss, I. Metzger, J. Salasovich, and P. Schwabe. 2013. Alternative Energy Generation Opportunities in Critical Infrastructure New Jersey. Produced under the direction of the U.S. Federal Emergency Management Agency by the National Renewable Energy Laboratory (NREL) https://www.nrel.gov/docs/fy14osti/60631.pdf (accessed Oct 3, 2018).
[47] Energy Storage Association. 2018. Distribute Grid-Connected PV Integration http://energystorage.org/energy-storage/technology-applications/distributed-grid-connected-pv-integration (accessed Oct 18, 2018).

A Guide to Integrated Pest Management

RUTGERS

New Jersey Agricultural Experiment Station
Cooperative Extension – Dept. of Entomology

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RUTGERS
Center for
GREENBUILDING

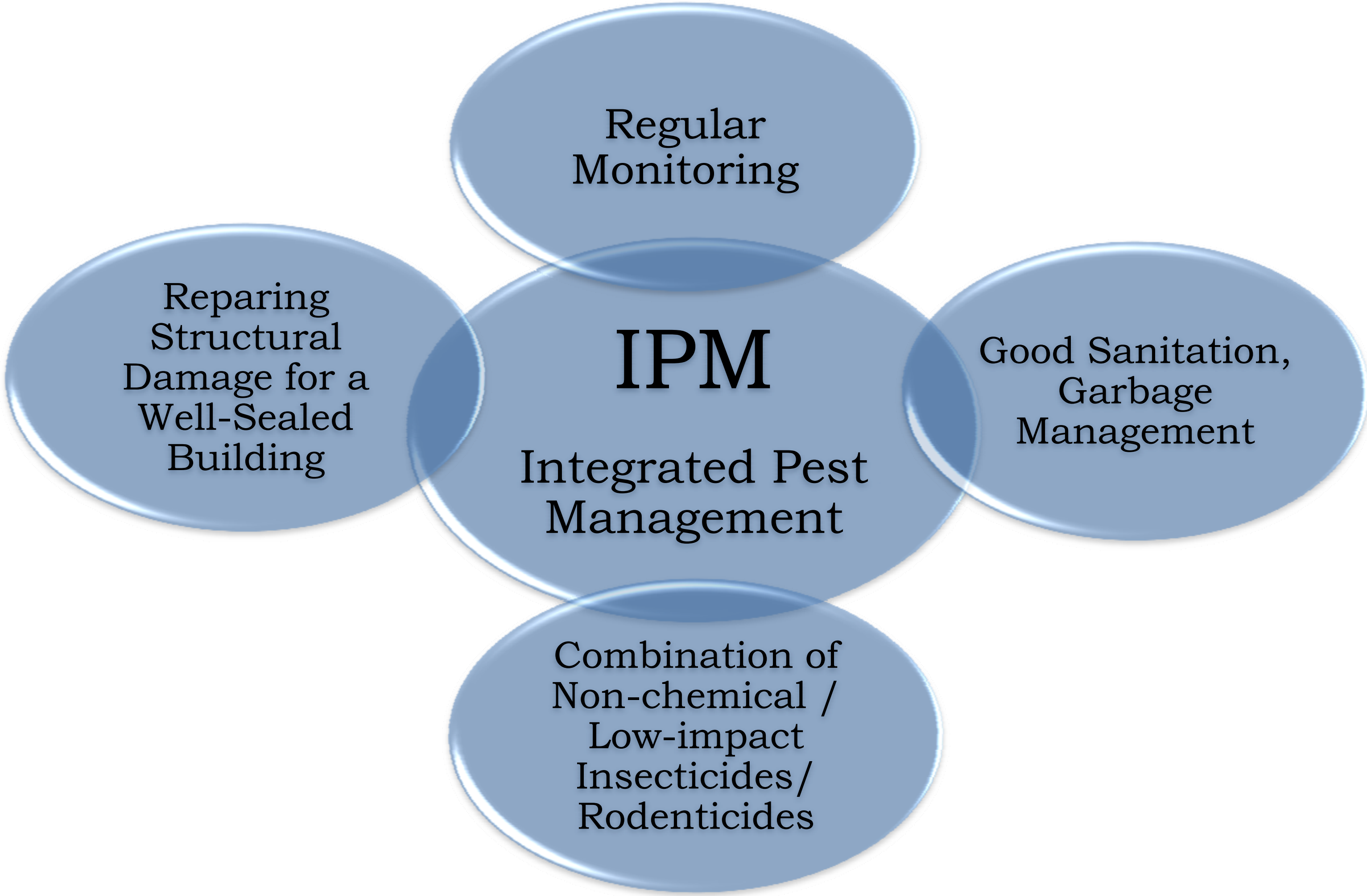
MaryAnn Sorensen Allacci, PhD

Why Integrated Pest Management?

Integrated Pest Management (IPM) is an effective and environmentally sensitive form of pest management that utilizes monitoring, prevention, and control techniques.

The objective of IPM is to combine several practices to prevent and control pest infestations. The result is a program that involves a decision-making process to identify the pest problem, determine all possible sources of the problem, and design a context specific plan of eradication and control of the problem through socially safer, more environmentally responsible means. That means less reliance on toxic chemicals and more proactive measures of correcting problems in the environment that attract pests.

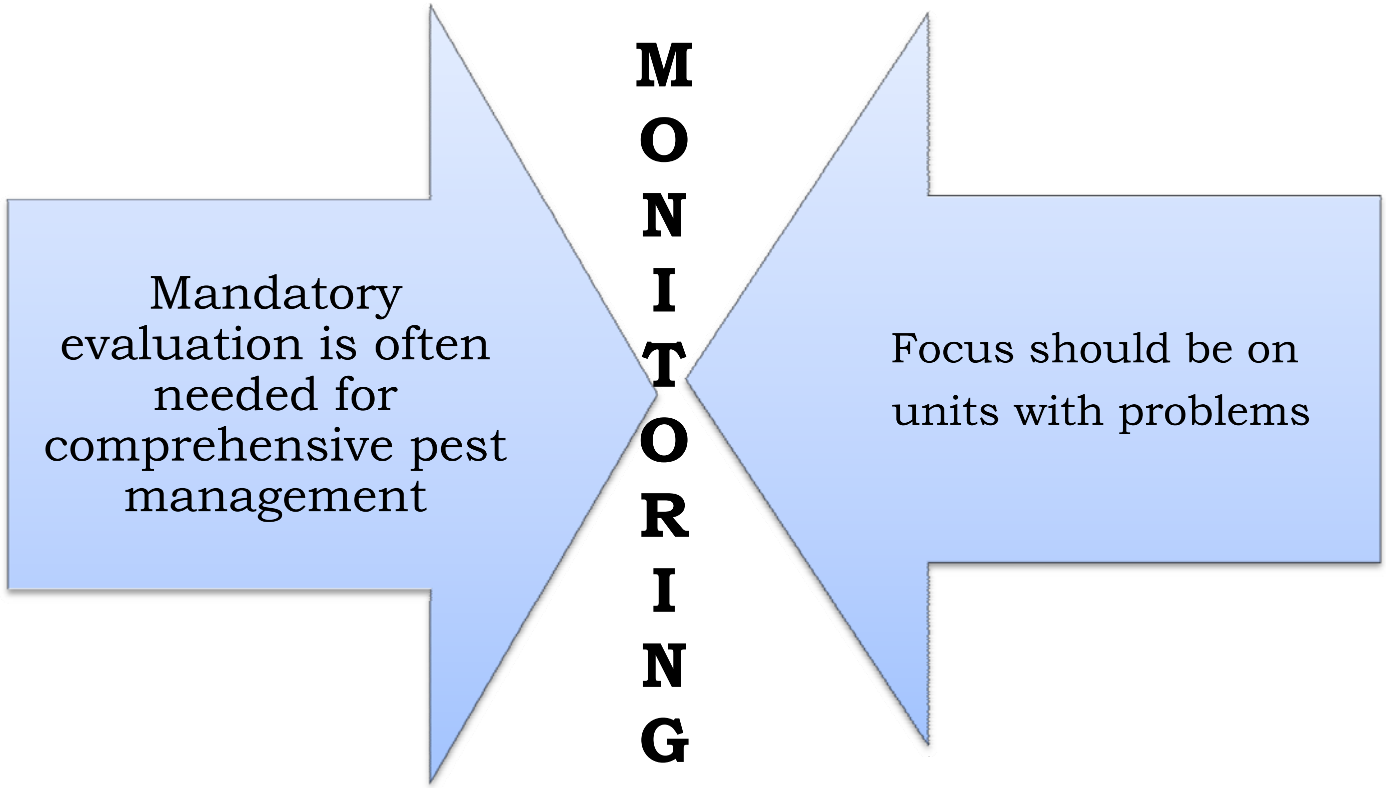
Relying less on toxic chemicals helps keep indoor and outdoor environments healthier for people and our larger world.



Components of IPM Protocol

IPM is the same as green pest management and requires a holistic approach throughout a residential building.

Pest management contractors should be experienced in IPM and provide guidance for preventing and eradicating rodent and insect problems.

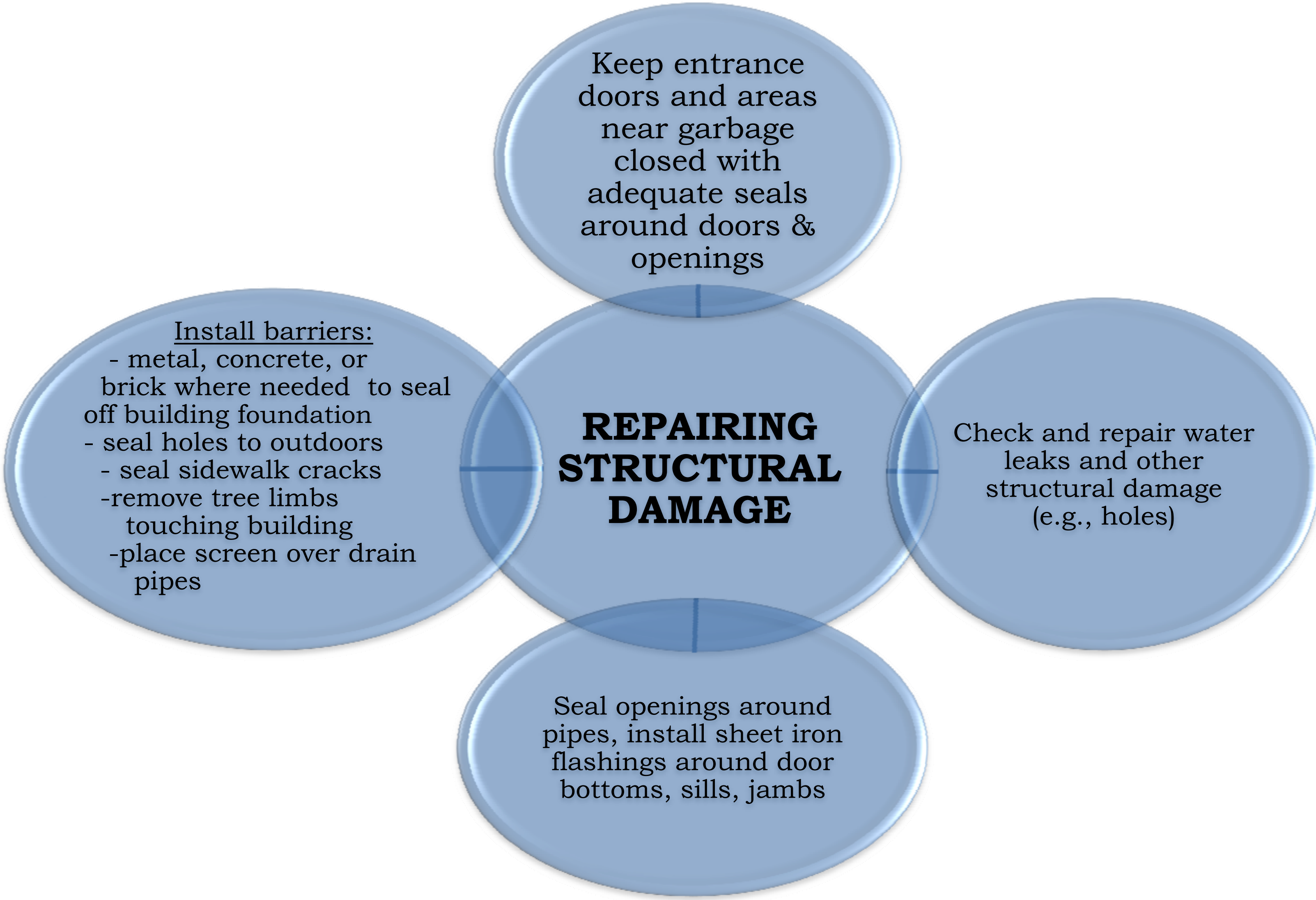


Monthly building monitoring is a typical schedule for buildings that have resolved pest control issues.

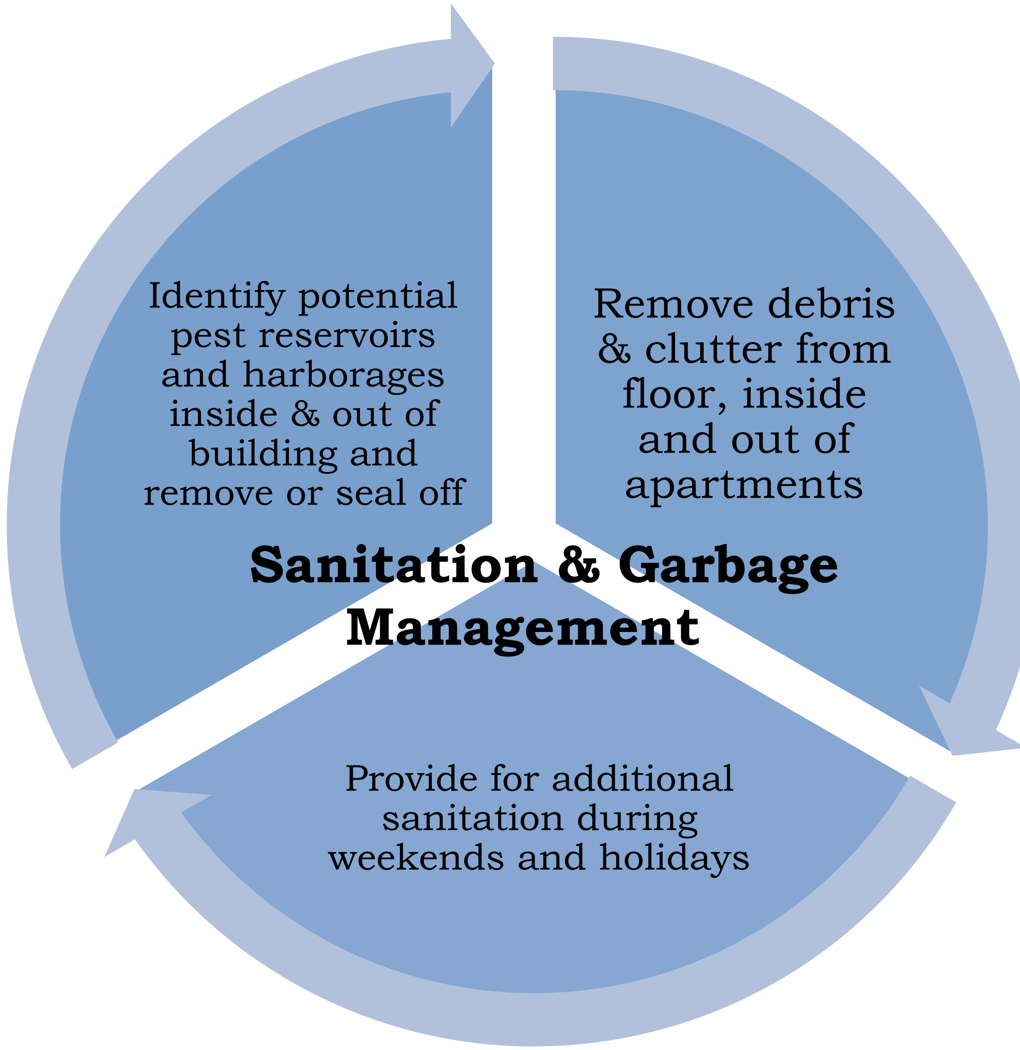
<u>Cockroaches</u>: Inspect every 2 weeks to a month until elimination
Contractor should set traps and return in a few days to examine number of roaches found in traps.

- Bait products and other tools can be used
- Contractors should inspect again every 2 weeks by placing traps until no roaches are found in traps

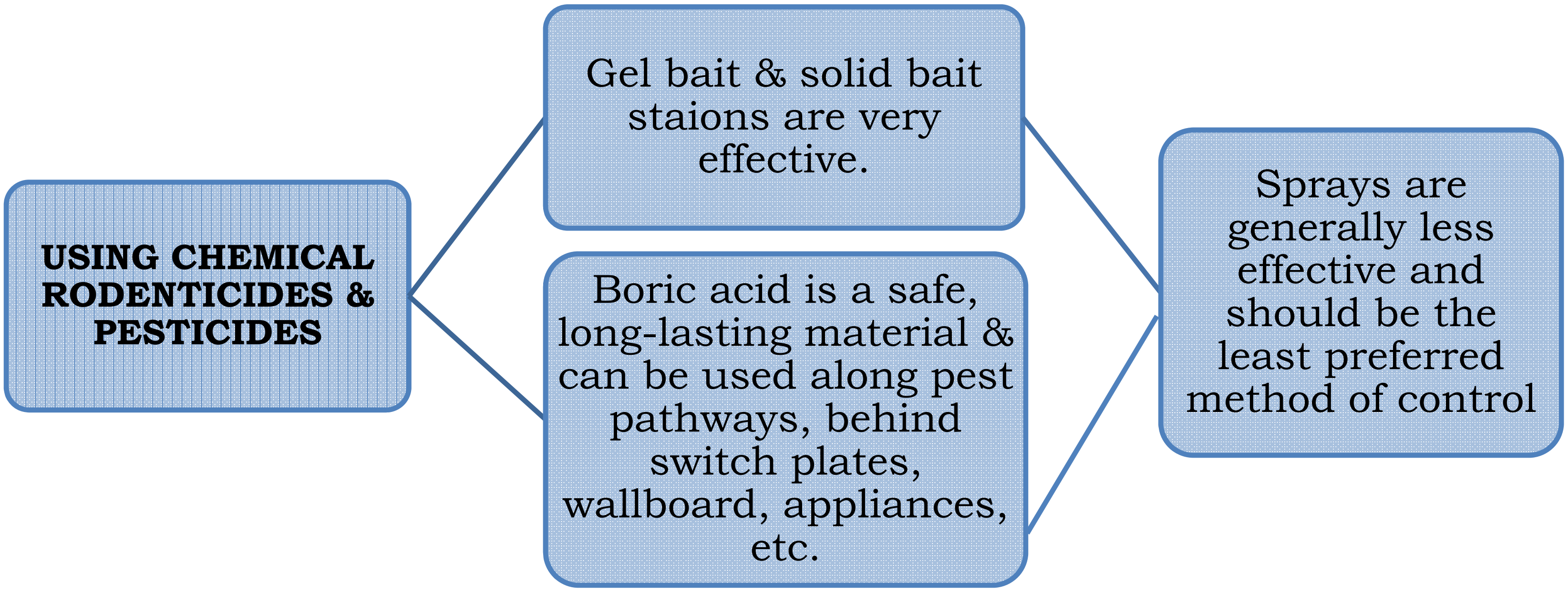
<u>Rodents:</u> Similarly, rodent activity may be monitored by the contractor looking for signs of droppings, setting up and baiting rodent stations, asking resident to clean-up droppings, and revisiting to examine areas for new droppings.



Contractors are typically more experienced than are general maintenance personnel in locating holes and pathways where pests are likely to frequent or gain access, including behind appliances. The contractor can seal cracks & small holes with caulking or steel wool, referring larger structural repairs to the maintenance staff.



In **exterior areas**, weeds and dense vegetation should be reduced or removed. Clean dumpsters, fallen fruits, and gardens. The contractor can help identify areas used by rodents as nests, runs or pathways.



Many chemicals such as Contrac, Ditrac, Acelepyrn, ECO-PCO, Zoecon Gentrol, & Steri Fab are commonly used in pest management.

Any chemical intervention should be used in conjunction with changes to the physical environment as part of an IPM protocol.

Property owners will often by-pass many IPM strategies perceived to be too time-consuming, costly, not immediately showing results, or that professionals will not guarantee. While the best of efforts may not completely eliminate pest problems, IPM strategies are an important component of safe pest management.

This IPM recommended protocol produced by
Rutgers Center for Green Building
In partnership with
Rutgers Cooperative Extension Specialist
in Urban Entomology

As part of a grant from HUD Healthy Homes and
Lead Hazard Control Program
January 2012
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RUTGERS
Edward J. Bloustein School
of Planning and Public Policy

Spatially Resolved Infrared Imaging for Building Performance Evaluation

Jie Gong , Clinton J. Andrews, Gedi Mainelis, Jennifer Senick,
MaryAnn Sorensen Allacci, Deborah Plotnik, Leonardo Calderon, Mengyang Guo, Nirmala Thomas, Yi Yu, Brian Pavilonis, Prarthana Raja, Bingsheng Liu

Outline

A. Background
B. Field Data Collection
C. Building Defects
D. 3D thermal data---project thermal imagery on to 3D point cloud
E. Building Attribute Extraction and Performance Grading
F. Summary of Performance Result
G. Conclusion

A. Background: Why should we care about residential building performance?

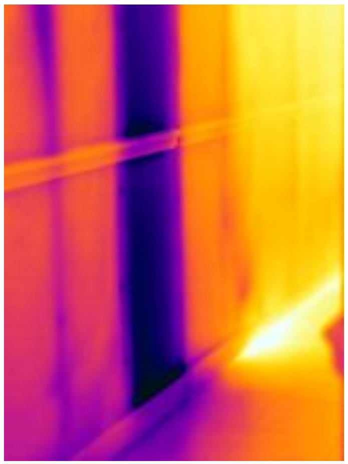
SBS and poor IAQ

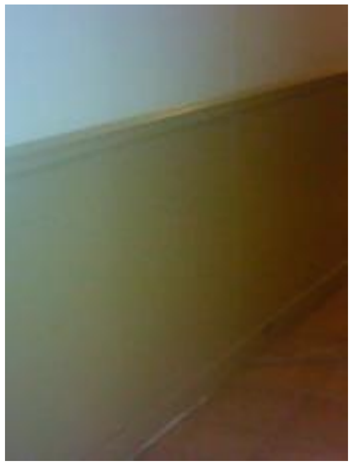
Cost from heat loss

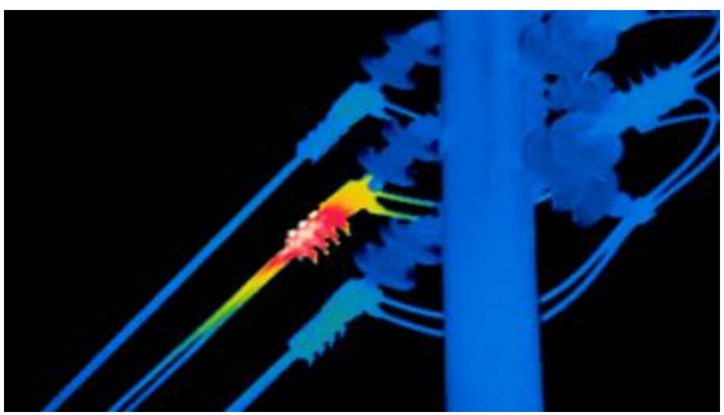
- Health and Safety
  - Sensory irritation of eyes, nose, and throat
  - Skin irritation
  - Neurotoxic symptoms
  - Odor and taste complains
  - Nonspecific reactions: asthma like symptoms and runny eyes or nose
- Energy
  - Heat loss/waste from building
  - Higher energy consumption from heating and cooling
  - Higher electrical bill for family
  - Increase electricity demand (during peak period)

Image from : http://www.healthadvice4life.com/sick-building-syndrome.html
And http://www.redriverroofing.com/home-energy-solutions

A. Background: Why do we want to use Infrared Technology for Building Diagnosis?





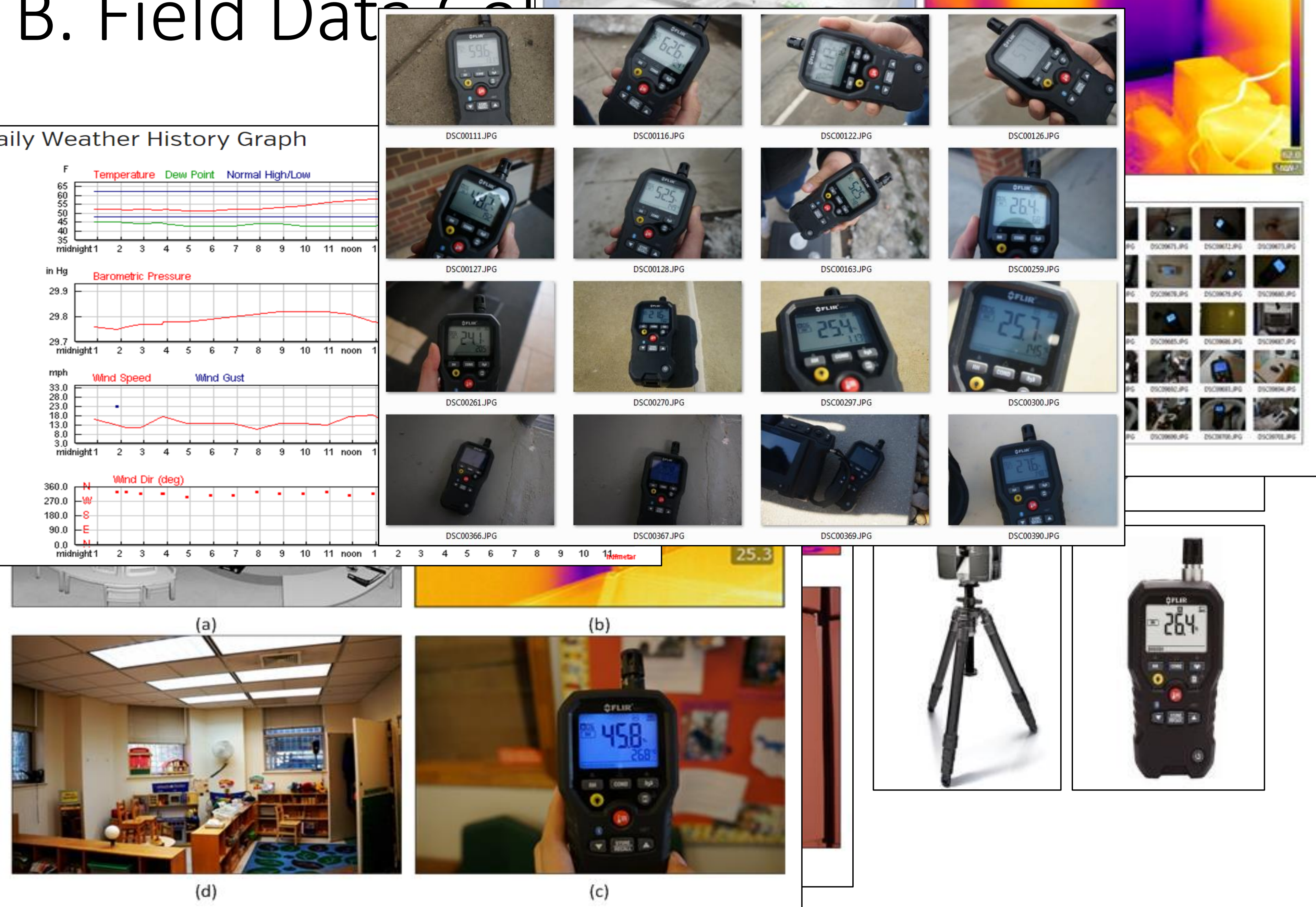


Benefit of thermal Infrared–based building diagnostic:

- Rapid data collection
- Provide visual and recordable information
- Nondestructive testing
- Safe working distance
- Price affordable

Power line image from: http://equipmenthealth.com/serv02.htm

B. Field Data Col

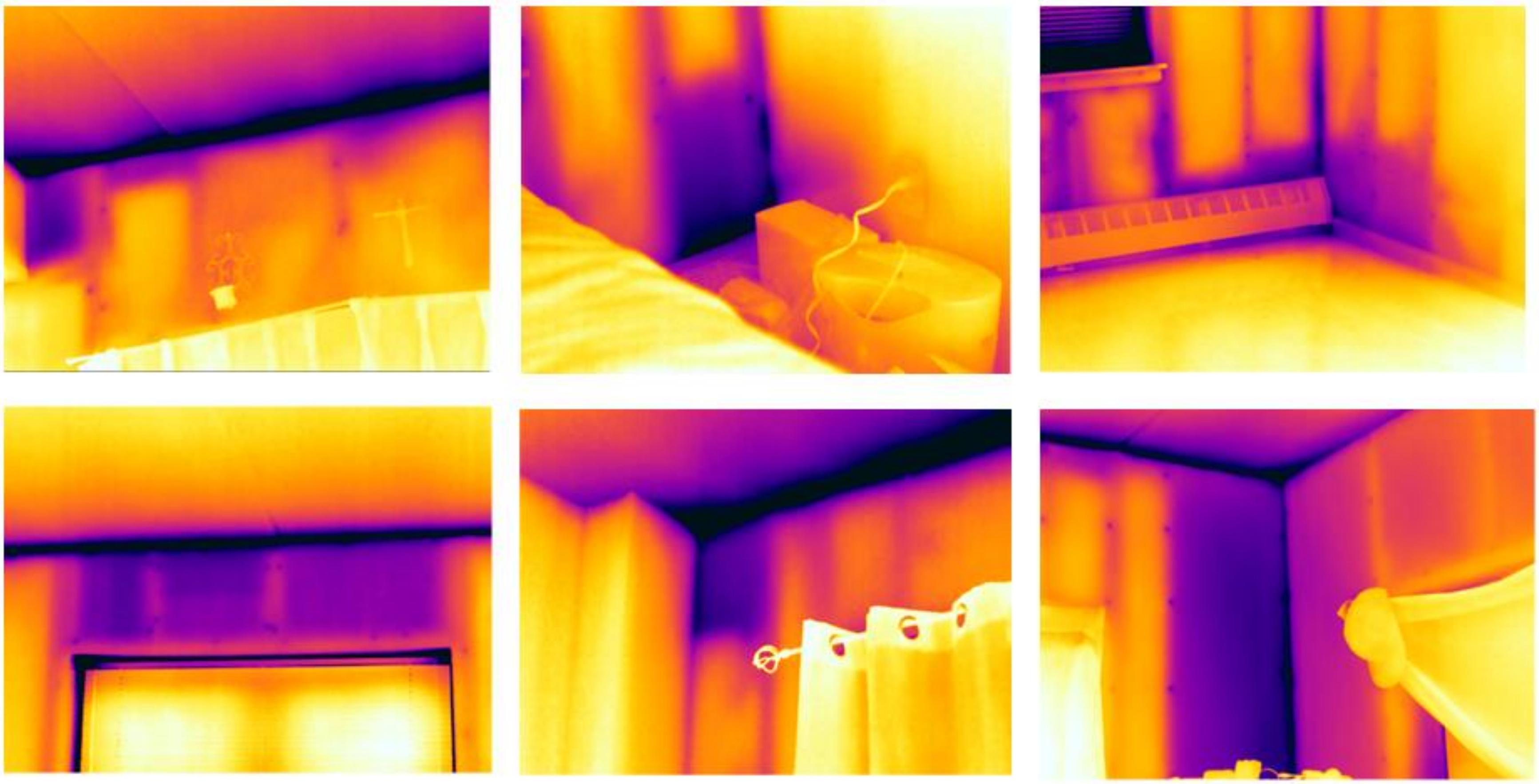


(a) (b) (d) (c)

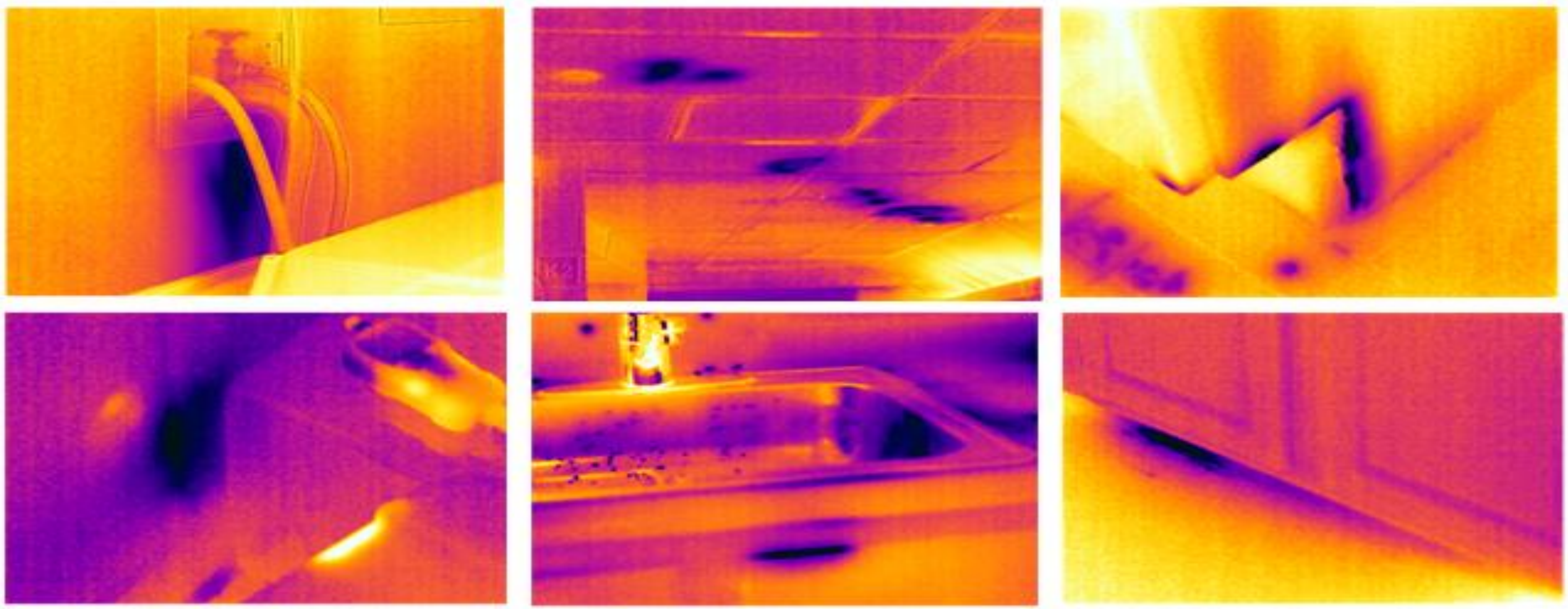
C. Types of Building Defects Detected By Infrared Camera

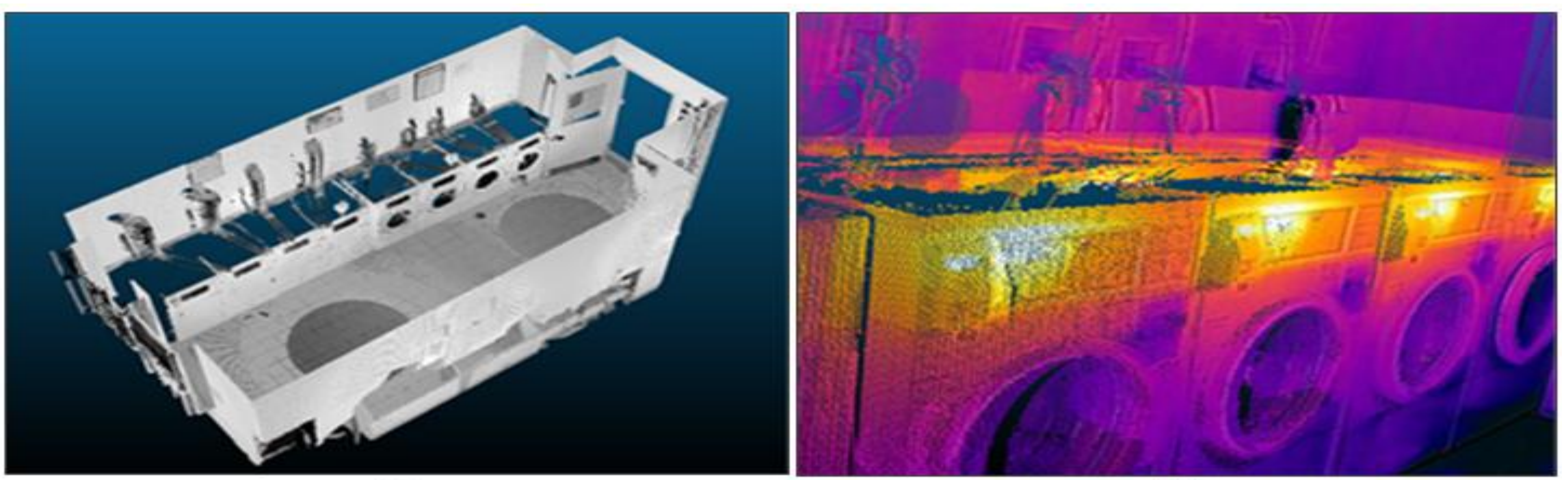
- Poor or missing insulation
- Moisture Issue
- Air leakage/ air infiltration
- Thermal Bridge
- Hot water riser poor insulated

C. Defect Detection Results: Missing or Poor Insulation



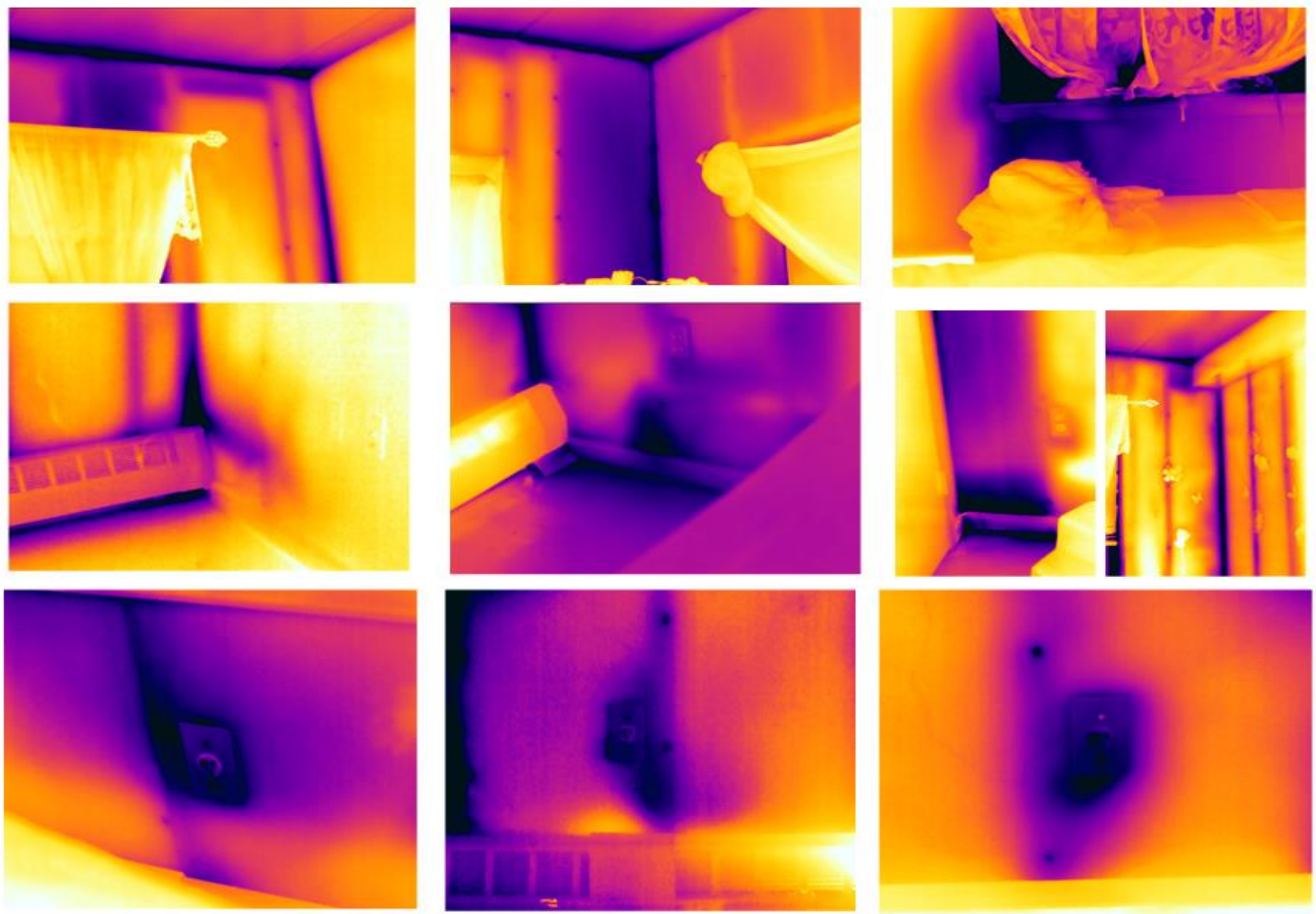
C. Defect Detection Results: Moisture Issue



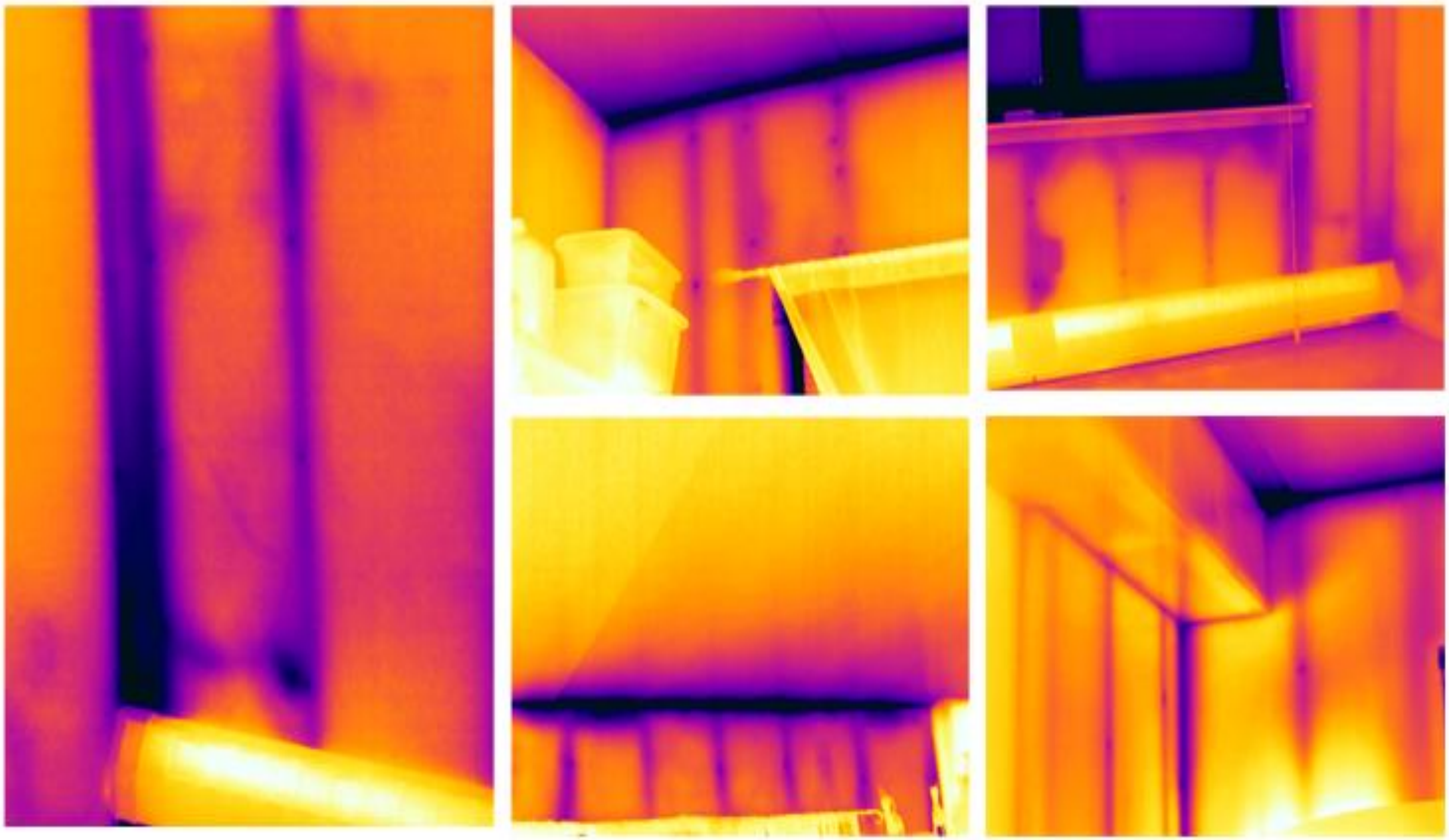


(a) (b)

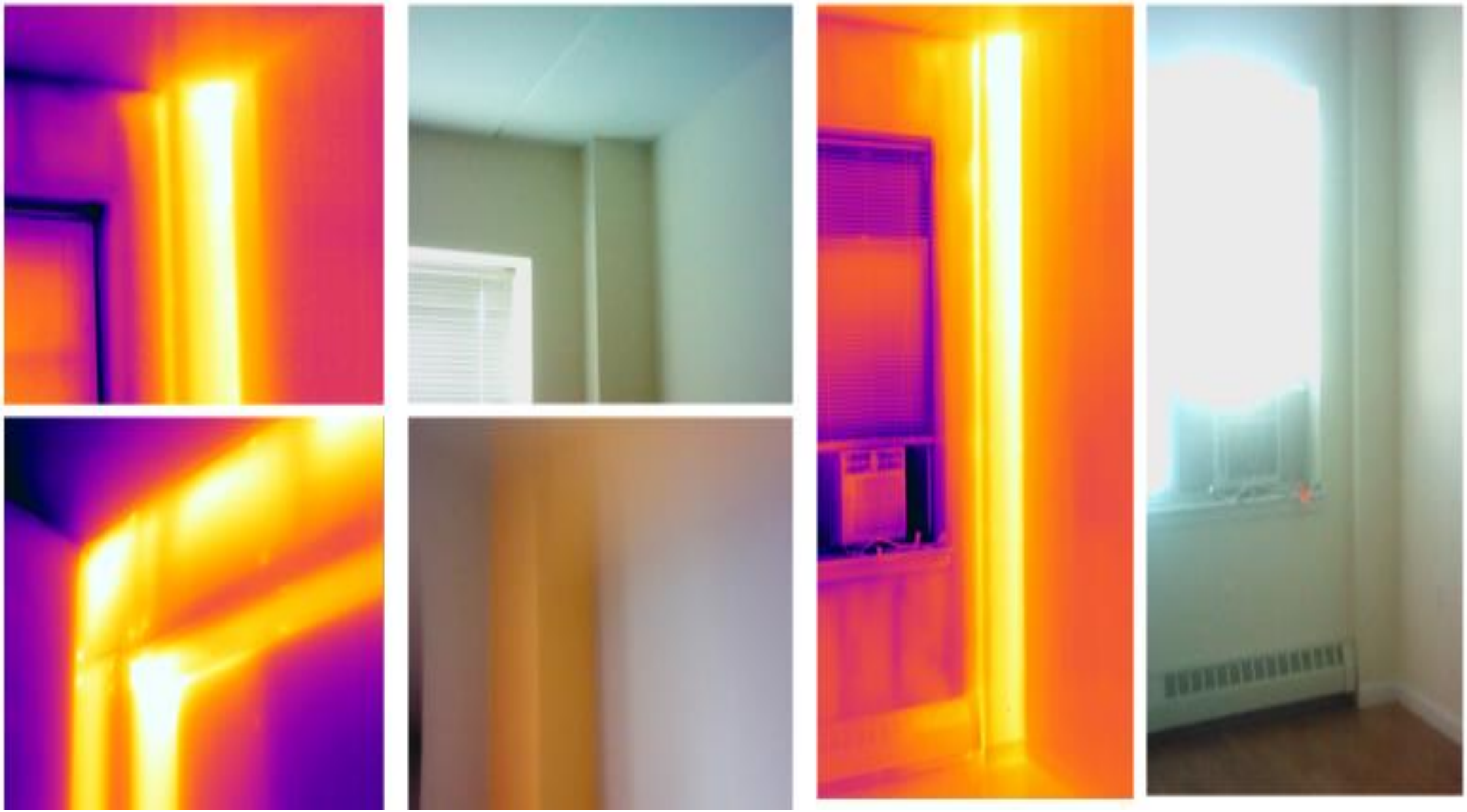
C. Defect Detection Results: Air leakage or Air infiltration



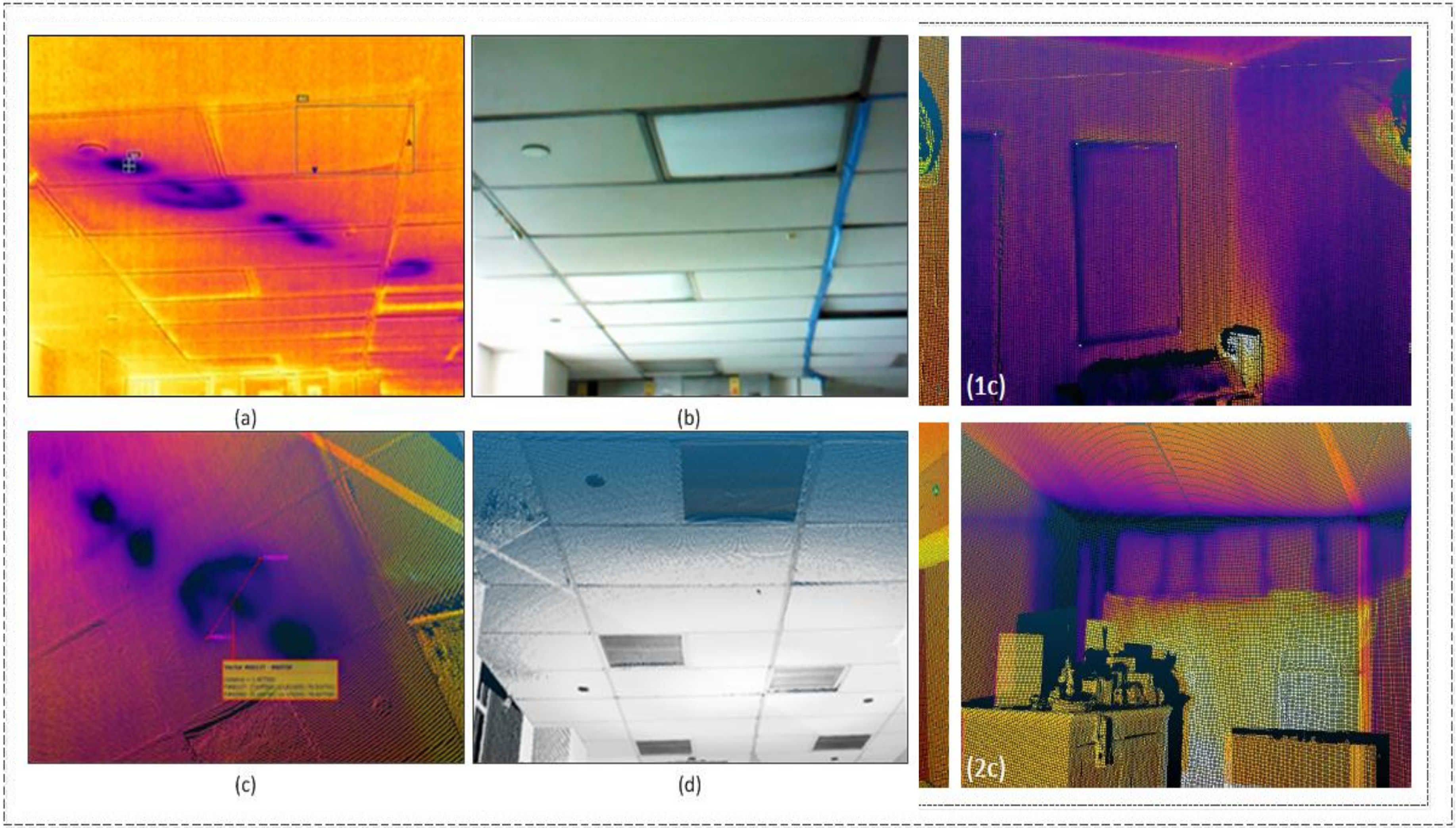
C. Defect Detection Results: Thermal Bridge



C. Defect Detection Results: Poorly Insulated Hot water riser



D. Projecting Infrared Image Onto Scan Data



Indoor 3D Thermal model: provide us with dimension and area information

E. Building Attribute Extraction and Performance Grading

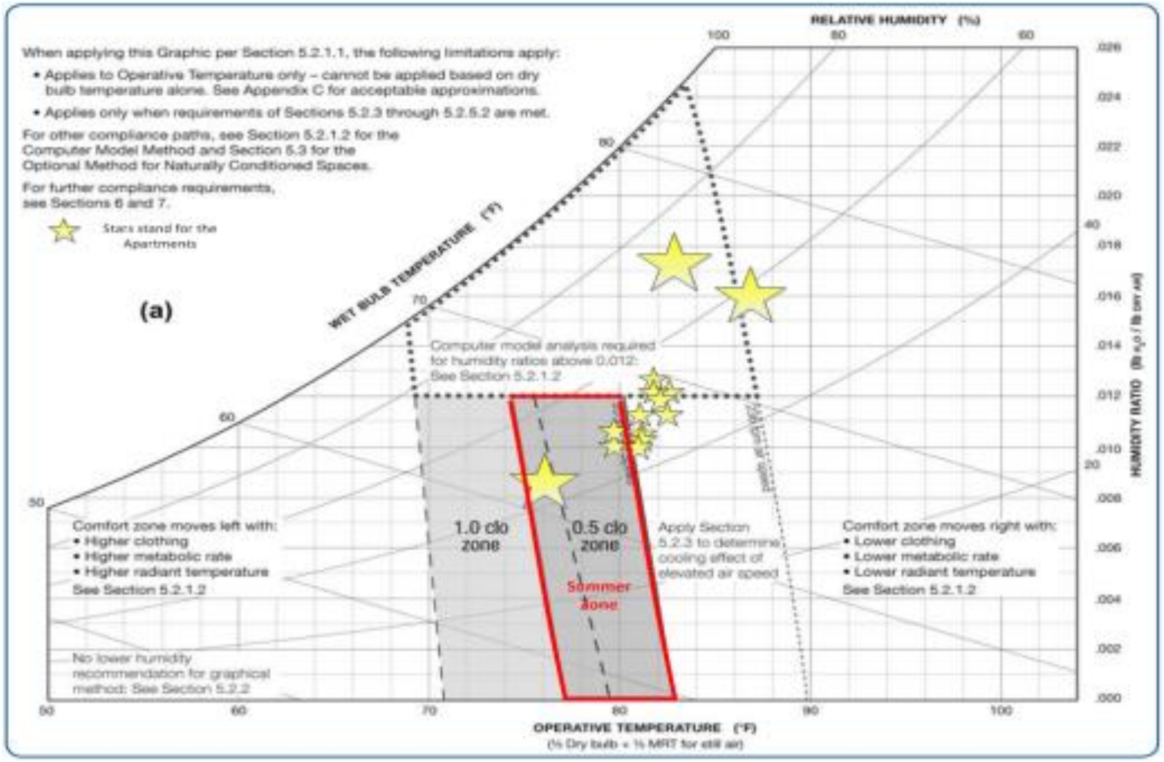
Apartment Location Information

- Floor information
- Corner information
- Orientation

E. Building Attribute Extraction and Performance Grading

Thermal Comfort

- Real-time indoor air temperature
- Real-time indoor air relative humidity
- Real-time thermal comfort level
- Dew Point



F. Summary of Performance Attributes for Building 1

Attribute	Apartment Unit		Thermal Comfort				Thermal Infrared Data	
Attribute	Top Floor	Corner	Real-time Indoor Air Temperature	Real-time Indoor Air Relative Humidity	Real-time Thermal Comfort Level	Indoor Air Temperature Variation	Insulation Level	Moisture Level
H1	0	1	81.5	56.47	3	1.08	1	1
H2	0	1	82.28	50.09	3	3.78	2	1
H3	1	1	82.87	54.83	3	2.34	3	2
H4	0	0	82.9	56.22	3	7.56	1	1
H5	1	1	82.46	50.03	3	7.92	2	2
H6	0	0	84.02	50.19	3	4.5	1	1
H7	0	0	81.14	46.7	3	10.26	1	1
H8	1	1	80.66	47.578	2	3.96	2	2
H9	0	1	81.2	46.43	3	0.18	1	1
H10	0	1	81.56	44.53	2	6.84	1	1
H11	0	1	79.34	50.5875	2	4.32	2	2
H12	0	1	82.9	56.22	3	2.88	1	1
H13	1	1	83.876	48.52	3	0.36	3	1
H14	0	1	78.14	43.66	2	1.08	2	2
H15	0	1	77.68	43.56	2	3.24	1	1

◆ **Poor Condition** ◇ **Fair Condition** ◇ **Good Condition**

F. Summary of Performance Attributes for Building 2

Attribute	Apartment Unit Information			Thermal Comfort				
Attribute	Top Floor	Corner	Face Inner Garden	Real-time Indoor Air Temperature	Real-time Indoor Air Relative Humidity	Real-time Outdoor Air Temperature	Real-time Thermal Comfort Level	Indoor Air Temperature Variation
H1	1	0	1	76.1	37.68	45.8	2	4.68
H2	0	0	0	76.865	39.21	45.65	2	0.72
H3	0	1	1	78.91077	46.45	46.8	3	3.78
H4	0	0	0	77.846	30.33	39	2	8.64
H5	0	0	1	75.38	42.26	40.45	2	7.74
H6	1	0	1	81.905	29.55	43.75	3	3.96
H7	0	0	0	75.66286	35.01	45.6	2	2.7
H8	1	1	0	78.815	36.47	47.2	3	3.78
H9	1	0	1	75.09714	31.9	39.1	2	6.3
H10	1	1	1	77	24.9	39.85	2	0.9
H11	0	0	0	71.672	25.06	40.75	2	4.32
H12	0	0	0	75.74	29.13	44.85	2	2.88
H13	0	0	0	78.26	27.98	45.6	2	1.98
H14	1	0	1	85.03	24.57	33.2	3	7.02
H15	0	0	1	76.82	30.82	33.95	2	2.34
H16	0	0	1	75.92	41.7	32.4	2	5.76

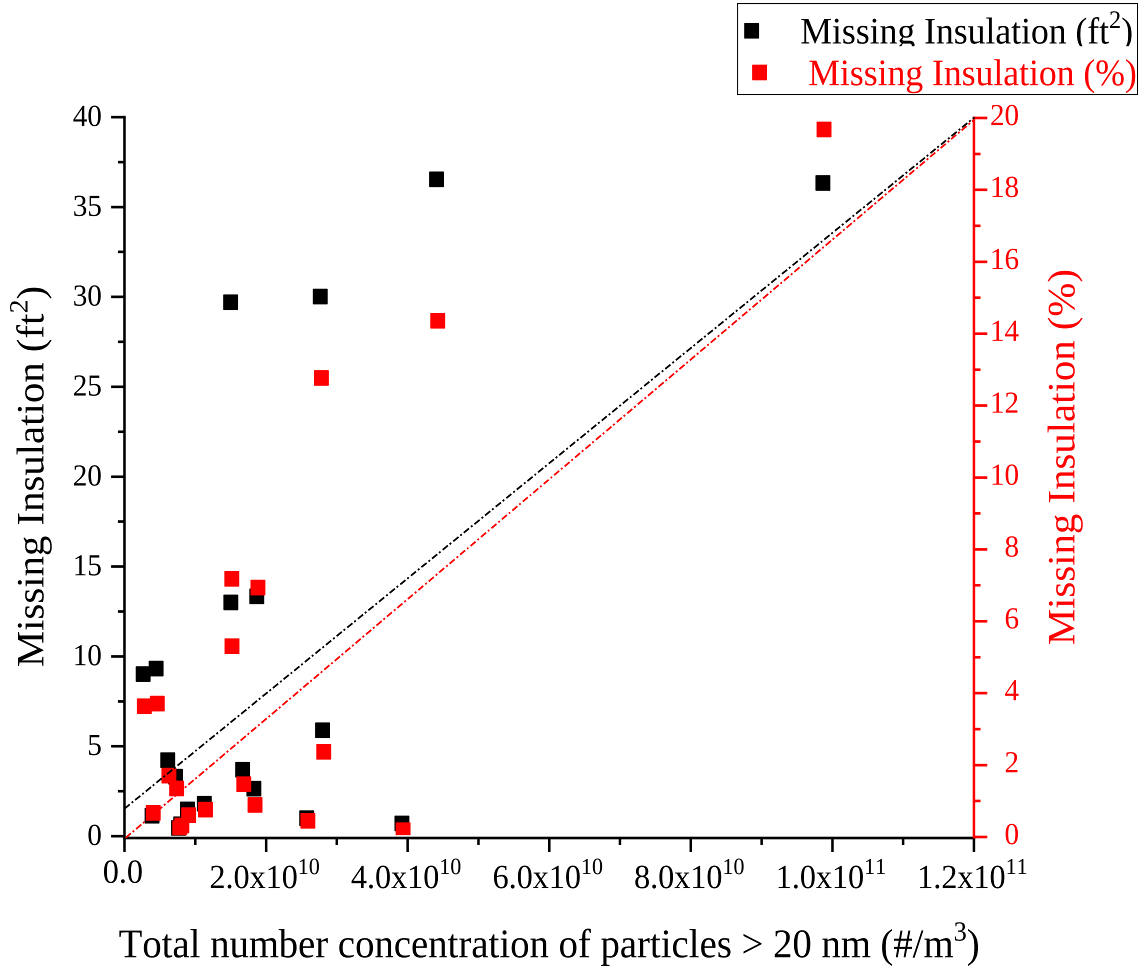
F. Summary of Performance Attributes for Building 2

Attribute	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
Thermal Bridge Temperature	64.5	68.3	67.2	74.3	64.3	75.2	66.8	66.9	73.4	67.7	73.4	74.0	74.5	79.7	71.2	71.1
Thermal Bridge Temperature Factor	0.6	0.7	0.6	0.9	0.7	0.8	0.7	0.6	1.0	0.7	1.1	0.9	0.9	0.9	0.9	0.9
Air Leakage Temperature	61.5	67.0	66.7	67.2	55.1	64.3	64.5	58.4	63.7	58.1	73.3	70.9	72.6	68.5	64.3	66.0
Air Leakage Temperature Factor	0.5	0.7	0.6	0.7	0.4	0.5	0.6	0.4	0.7	0.5	1.1	0.8	0.8	0.7	0.7	0.8
Missing Insulation Area (sf)	1.4	3.6	13.0	0.65	36.5	1.79	0.99	2.63	4.21	36.3	9.32	9.018	1.13	0.45	5.89	3.30
Missing Insulation Area (%)	0.55%	1.41%	5.25%	0.26%	14.30%	0.70%	0.39%	0.83%	1.65%	19.62%	3.65%	3.58%	0.61%	0.18%	2.31%	1.29%
Insulation Grading	2	2	4	1	4	2	1	2	2	4	3	3	2	1	3	2
R-value	0.53	0.67	1.97	0.90	0.30	1.21	0.54	0.85	1.13	0.31	4.06	2.01	1.52	2.70	1.68	2.09

F. Summary of Performance Attributes for Building 2

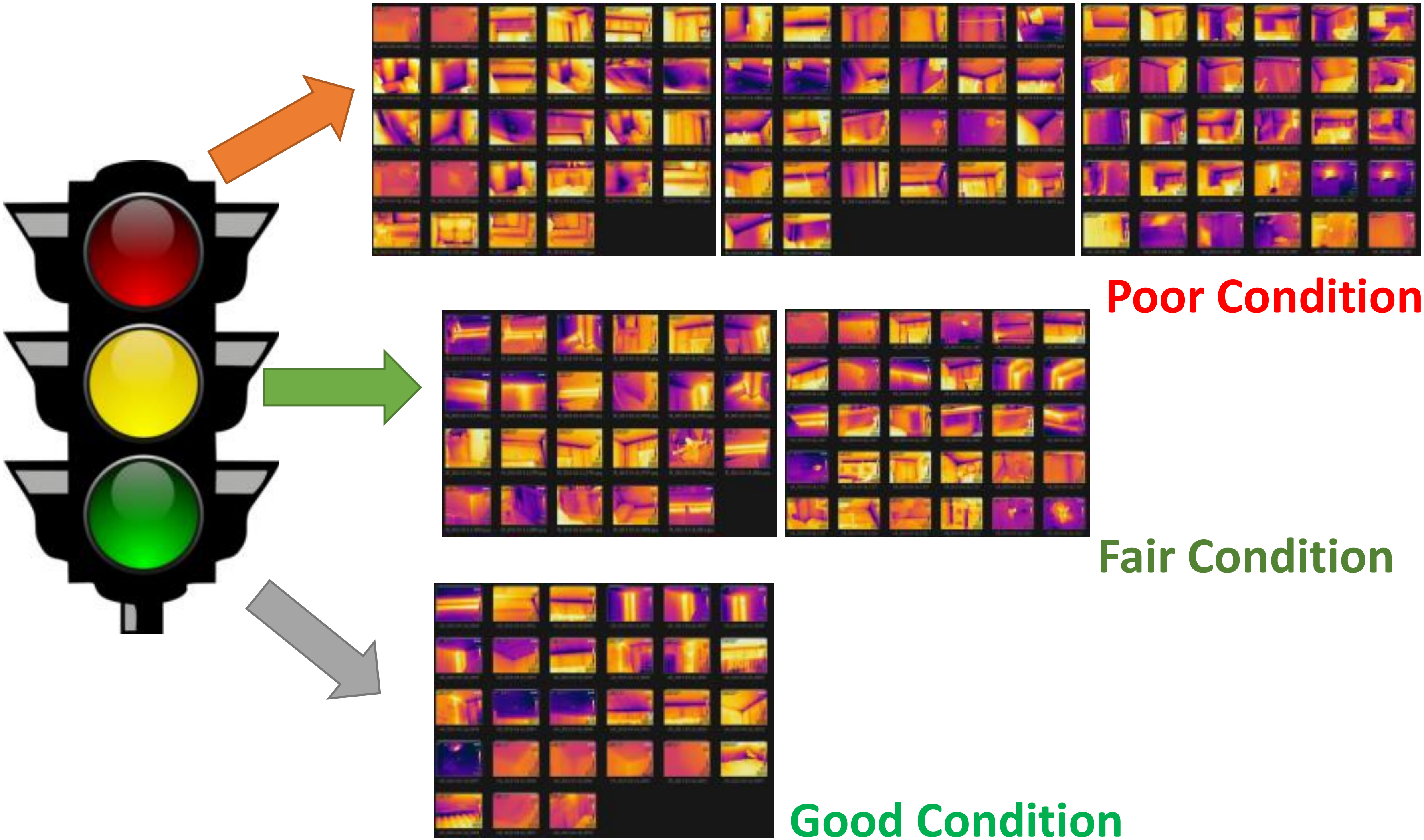
Attribute	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10	H11	H12	H13	H14	H15	H16
Dew Point	53.7	55.0	59.6	52.8	54.6	56.5	52.3	55.9	50.6	50.0	44.7	50.2	52.3	57.9	51.9	54.9
Dew Point Warning	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hot Water Riser Temperature Difference	5.2	4.1	0	13.2	5.9	1.2	0	12.6	0	0	10.2	6.2	0	7.2	4.3	3.9
Hot Water Riser poor insulated	1	0	0	1	1	0	0	1	0	0	1	1	0	1	0	0

Missing Insulation and Particle Concentration



Source: Thomas, N., Calderón, L., Senick, J., Sorensen-Allacci, M., Plotnik, D., Guo, M., Yu, Y., Gong, J., Andrews, C., Mainelis, G. Application of three different data streams to study building deficiencies, indoor air quality, and residents' health – Submitted to Building and Environment, November 2018

F. Apartment Condition Rating



G. Conclusion

In this study we explored the integration of infrared thermography and laser scanning for building hazard detection. The integration allows quick and objective measurement of common building defects that are relevant to healthy home. A systematic method that consists of infrared and laser scan data collection, data fusion, and data analysis was developed. The proposed approach was validated on two large multi-family multi-story buildings. A total of 30 apartments were surveyed and analyzed according to several quantitative metrics including moisture issue, thermal bridge, air infiltration, and missing insulation.

The evaluation shows varied conditions in these apartments, some of them having alarming concerns on thermal performance and hazardous conditions. The field study shows the proposed method can generate systematic measures that can be used to gauge the performance of the apartments and potentially these data can be correlated with other condition data such as indoor air quality data to gain better understanding how these factors correlate with each other. Future research can be devoted to integrating with other data streams to evaluate the predictive power of the features quantified in this research. Also, the question on how to scale the algorithms used in this research to other lower quality sensors, such as those smart phone based infrared sensors, would be another promising direction.

thank you!

Appendix: Description of Attributes

Location Information

Attribute	Value	Description
Top Floor	Top (1); Other(0);	The apartment unit is on the top floor or not
Corner	Corner(1) Other(0);	The apartment unit is in the corner of the building or not
Orientation	Face Inner Garden(1); does not (0)	The apartment unit faces the inner garden or not

Thermal Comfort

Attribute	Value	Description
Real-time Indoor Air Temperature	Number (°F)	Average indoor air temperature from the moisture meter during inspection
Real-time Indoor Air Relative Humidity	Number (%)	Average indoor air relative humidity from the moisture meter during inspection
Real-time Outdoor Air Temperature	Number (°F)	Average outdoor air temperature during inspection from local weather station
Real-time Thermal Comfort Level	Cold(1); Normal(2); Hot(3)	Thermal Comfort of the indoor environment base on the real-time indoor air temperature and relative humidity. ASHRAE Comfort Zone was used for Standard.
Indoor Air Temperature Variation	Number (°F)	The variation of the indoor air temperature in one apartment unit
Dew Point	Number (°F)	Dew point temperature calculated from air temperature and humidity
Dew Point Warning	Yes(1); No(0)	Exterior wall temperature under dew point or not

Appendix: Description of Attributes

Thermal Infrared and Scan Data

Attribute	Value	Description
Thermal Bridge Temperature	Number (°F)	Minimum thermal bridge temperature in the apartment unit
Thermal Bridge Temperature Factor	Number (0-1)	Describe the Thermal bridge condition; the higher the better
Air Leakage Temperature	Number (°F)	Minimum air leakage area temperature in the apartment unit
Air Leakage Temperature Factor	Number (0-1)	Describe the Air Leakage; the higher the better
Missing Insulation Area (sf)	Number (Square Feet)	Describe the accumulated area of missing insulation in one apartment unit
Missing Insulation Area (%)	Number (%)	Describe the percentage of accumulated area of missing insulation in one apartment unit out of total exterior wall area

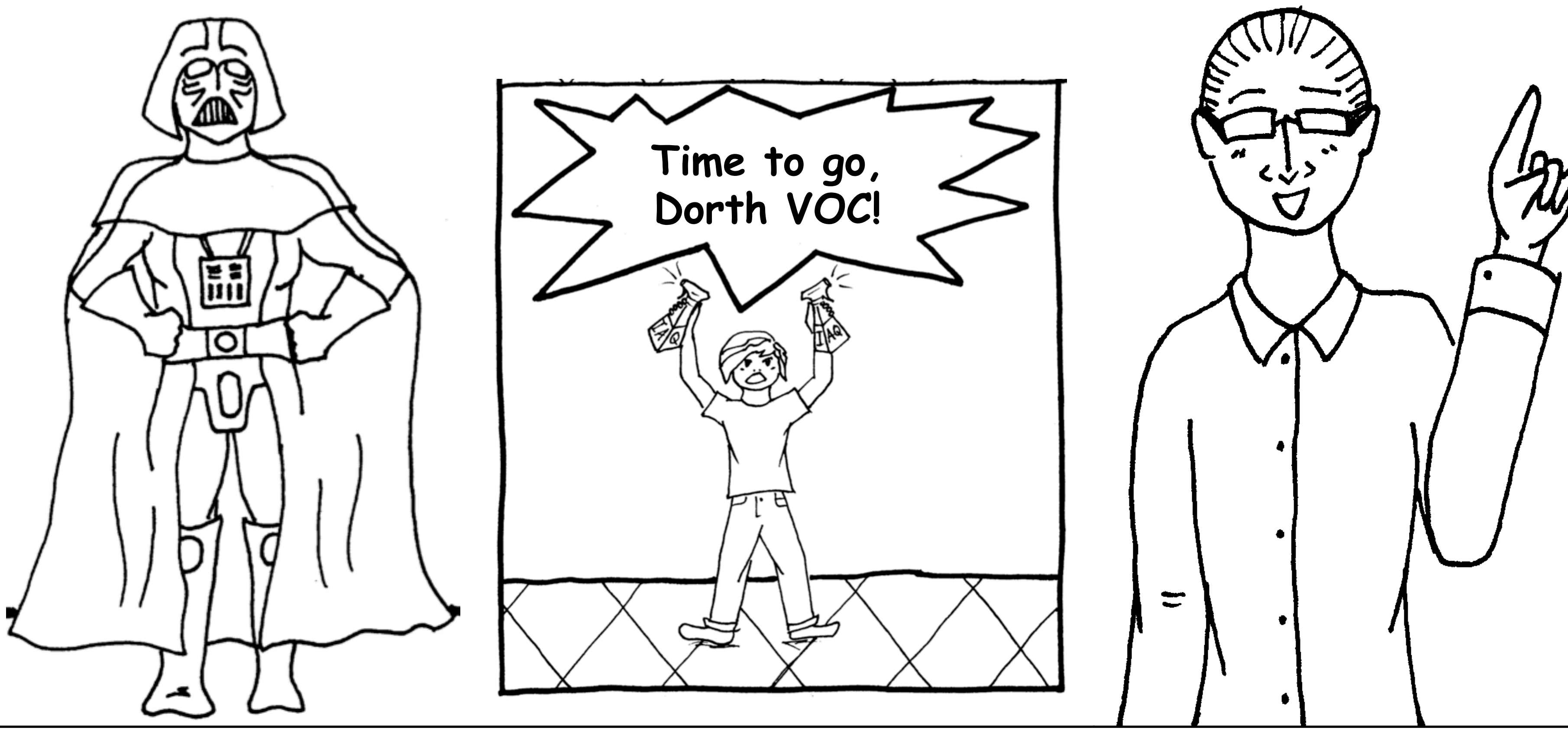
Appendix: Description of Attributes

Thermal Infrared and Scan Data

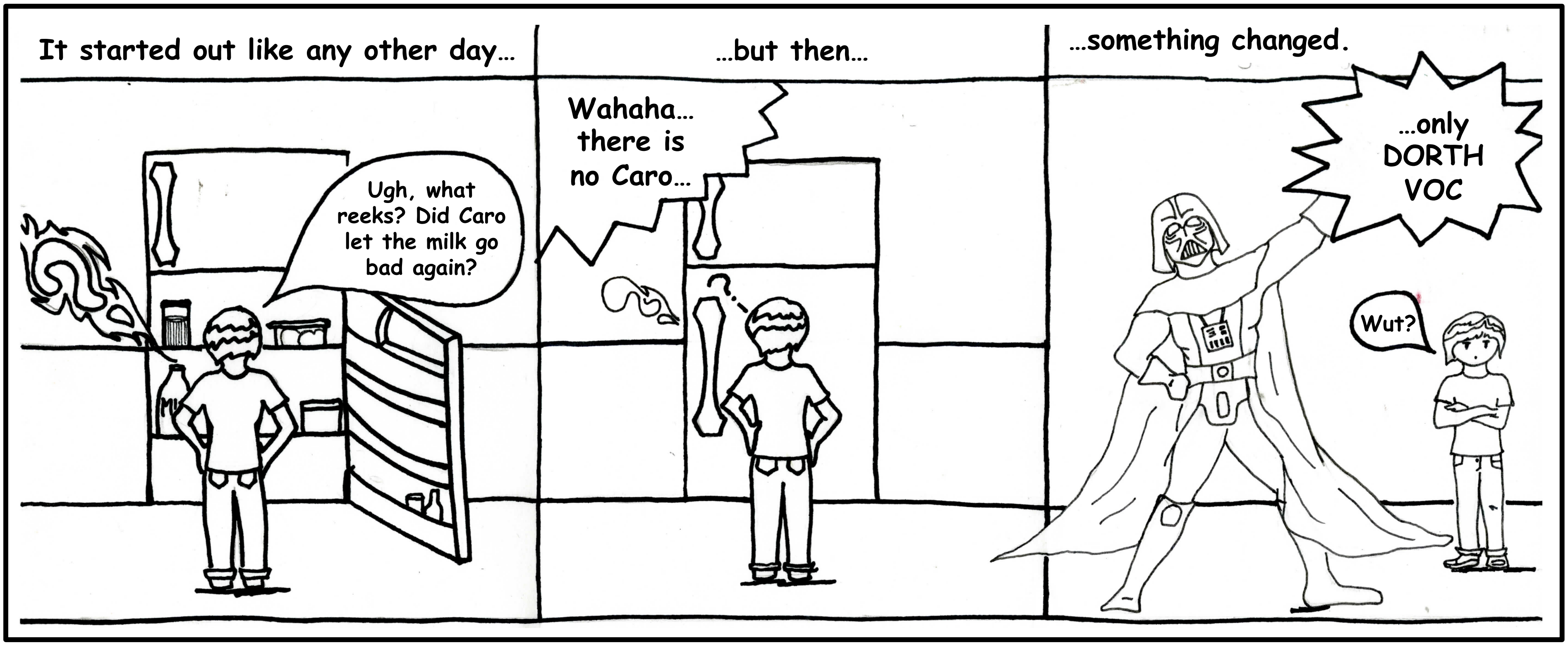
Attribute	Value	Description
Insulation Grading	Grade I; Grade II; Grade III; Worse than Grade III;	Insulation Grading Standards designed by RESNET Grade I: not infrared detectable anomalies; Grade II: insulation installed with anomalies found to be between 0.5 % and 2% for all inspected walls Grade III: An insulation installation having between 2% to 5% anomalies found for all inspected walls Worse than Grade III: The condition that insulation installation having more than 5% of the anomalies found for all the inspected walls
R-value	Value ($\mathrm{W/m^2K}$)	The calculated R-value for one apartment's worst condition room
Hot Water Riser Temperature Difference	Value (°F)	The temperature difference between hot water riser and surrounding wall
Poorly Insulated Hot Water Riser	Yes(1); No (0)	Infrared detectable hot water riser under the wall with a temperature over 5° compare to surrounding wall

The Adventures of Dani Jay: Dorth VOC vs Indy IAQ

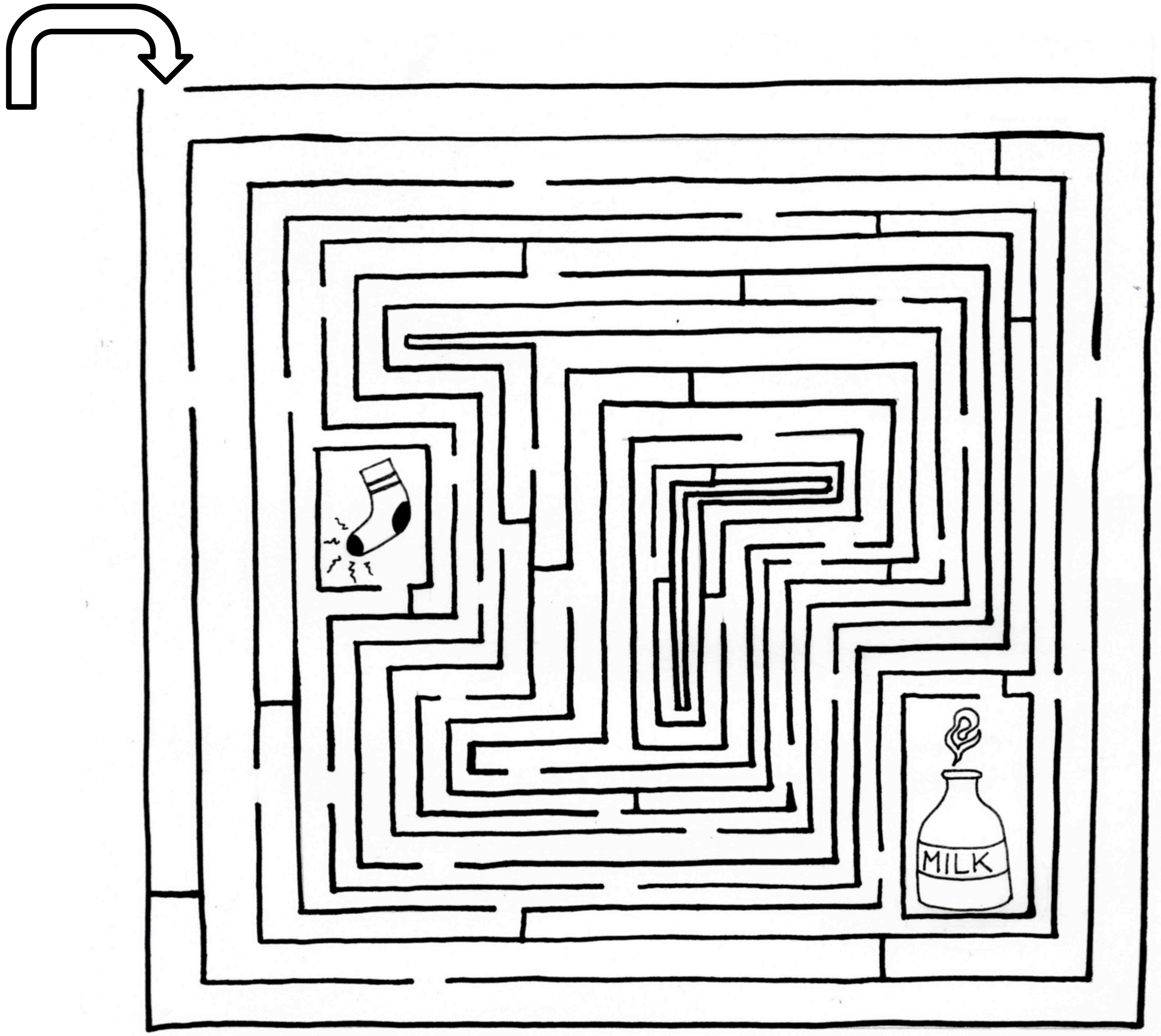
By Diana Siegel-Garcia



Meet Dani Jay. Dani lives in Trenton, New Jersey, likes playing videogames, dancing when no one is watching, and is really good at making empanadas. Dani has an older sister named Caro who likes to make life interesting for Dani…



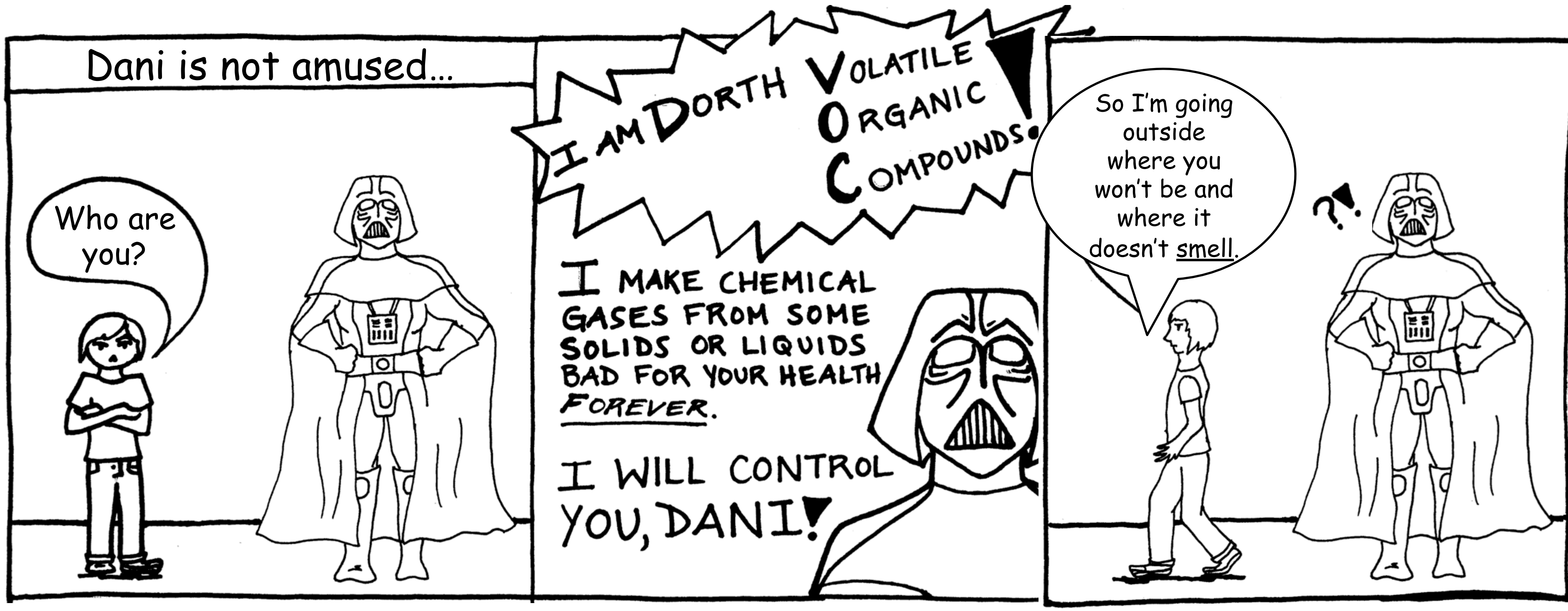
Uh-oh! Caro, or should I say *Dorth VOC*, forgot to throw away the milk again! Can you find it before it goes bad and leaves a stinky smell?



Green Cleaning Tip

Sometimes Dani doesn't throw away Caro's old milk in time. But that's okay! To get rid of that smell, try this:

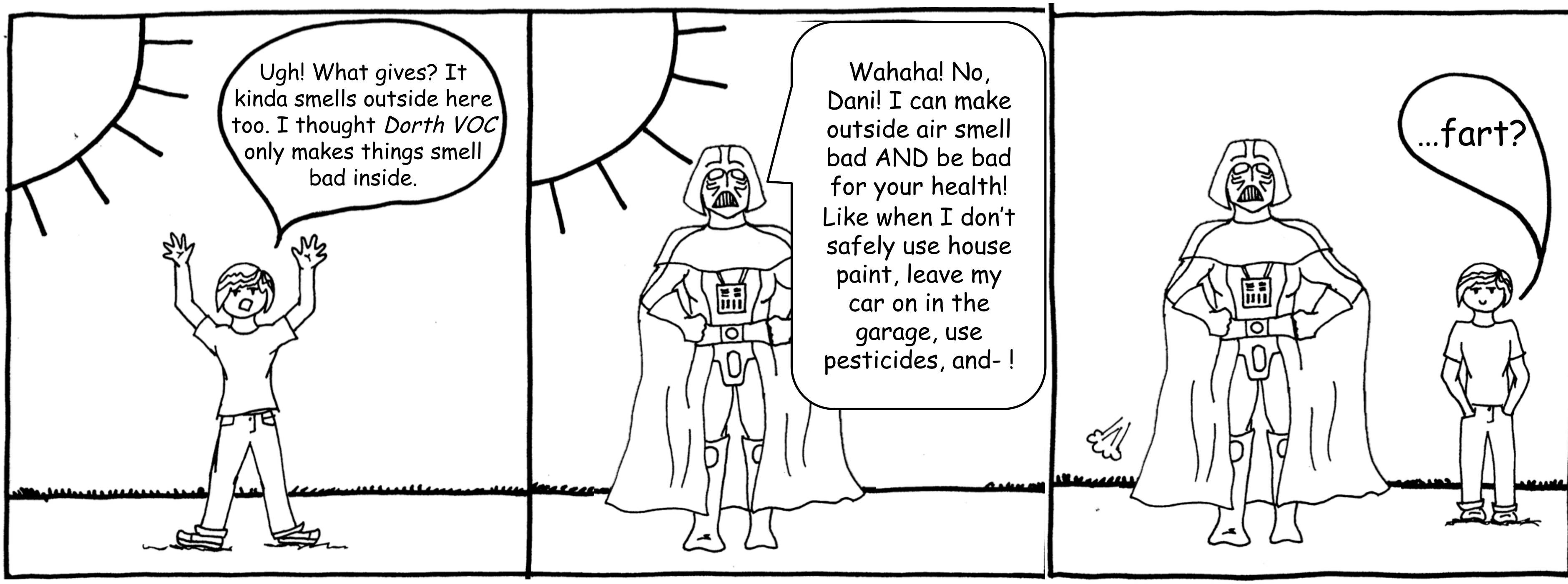
Rinse the area where the old food was with soap and water. Spray with white distilled vinegar. Wipe with a damp cloth or sponge. Place a small container of baking soda inside. Leave for a few days and the smell should be gone!



Did You Know...?

VOC stands for Volatile Organic Compounds. You can't see them but they can be really bad for you! Like *Dorth VOC*, they are gases that come from some solids and liquids. They can be bad for you right now or bad for you for a really long time! But there are ways you can stop them from hurting you.

Source: http://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality



Did You Know...?

You may not always smell it, but some of these activities Dorth VOC talks about can be really bad for your health right now and affect you for the rest of your life. It's best to do stuff like this outside and protect yourself! You should **work outside** and **wear a face mask** when:

Painting and paint stripping

Gluing (with really strong glue!)

Sanding (down wood or other materials)

Activities like these can create high levels of pollutants. So can letting the car, lawnmower, or other engines on when in the garage. You might not be doing these things but when you see other people are, let them know how to be careful. Don't let Dorth VOC win!

Source: http://www.epa.gov/indoor-air-quality-iaq/care-your-air-guide-indoor-air-quality

TRY IT! From the cloud, write or draw which activities you can do inside safely and which ones are better to do outside.

Painting with washable paints

Gluing paper

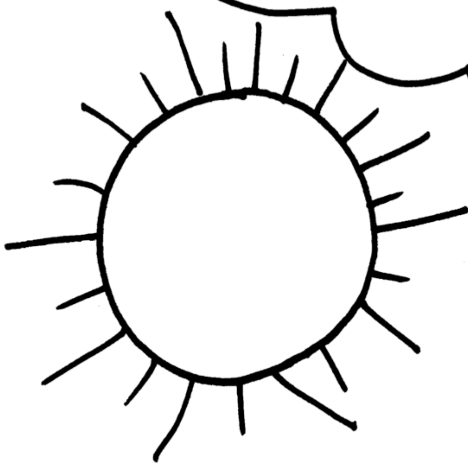
Sanding wood

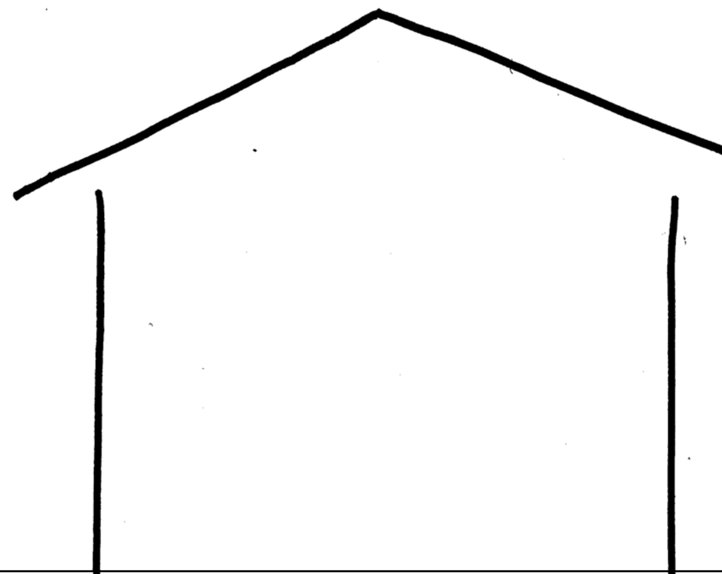
Spraying pesticides

Cooking BBQ

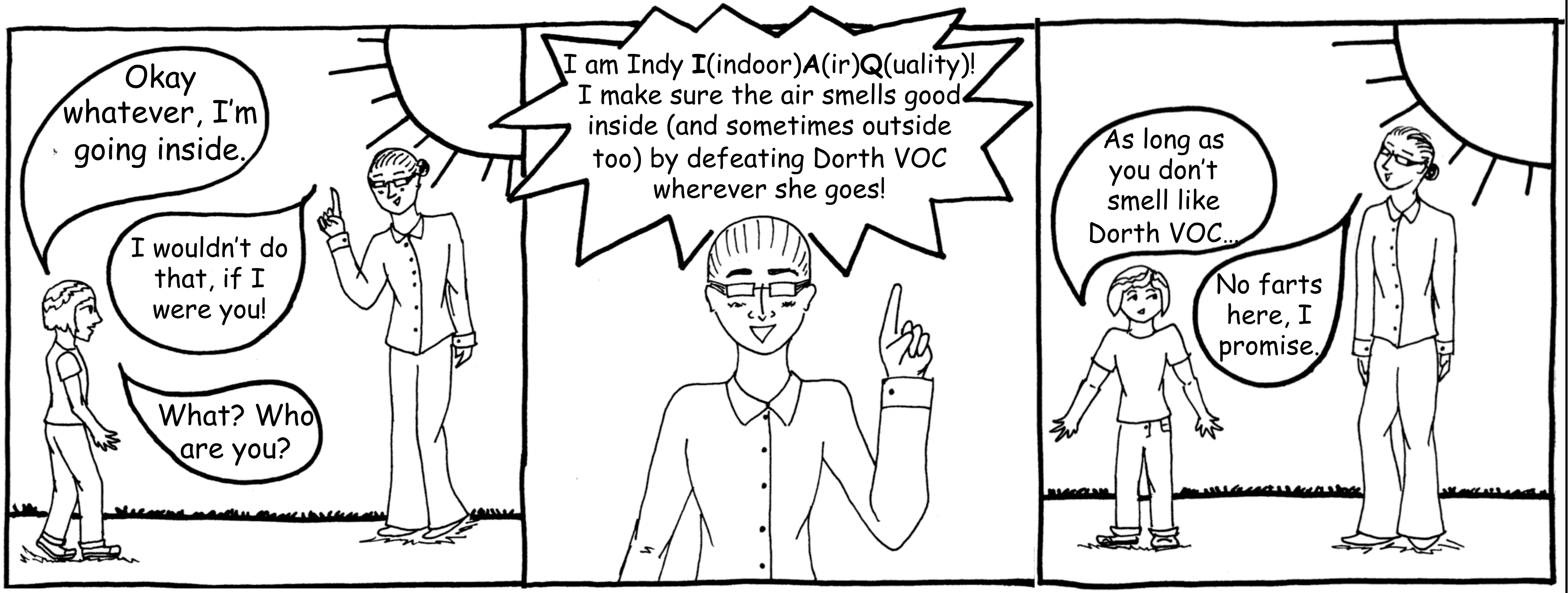
Painting with nail polish

Using hairspray





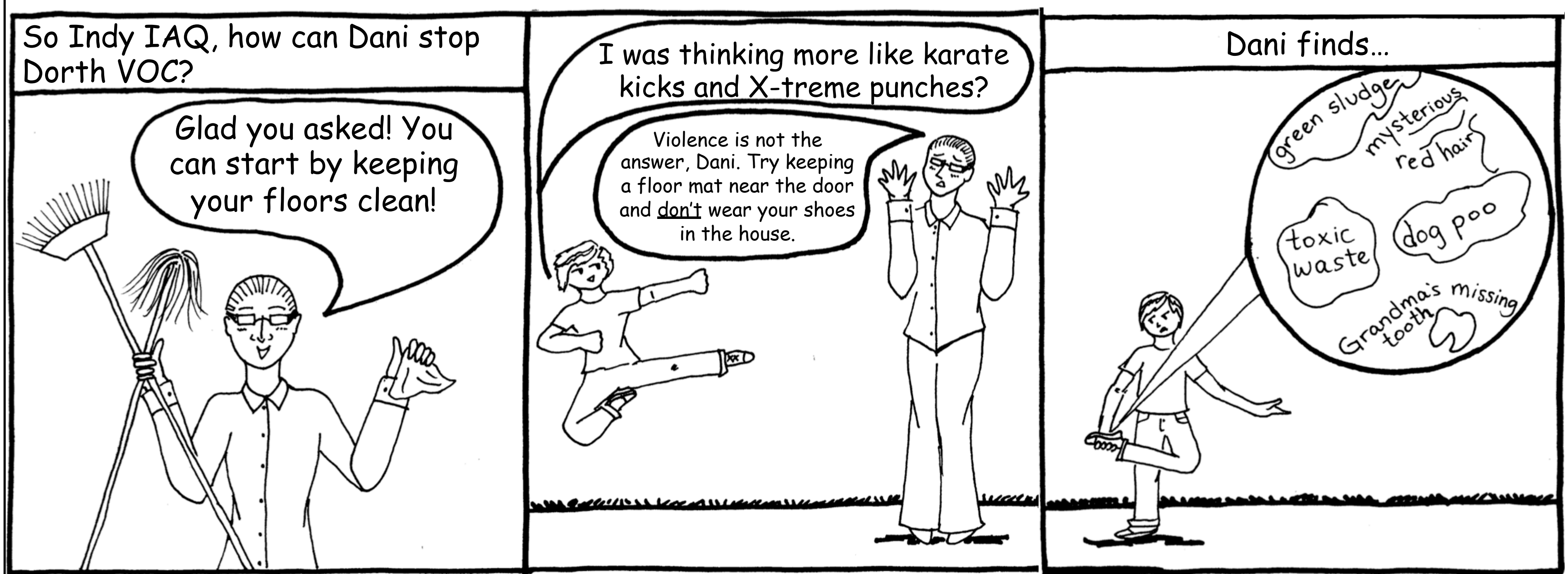
Answers: Indoors – painting with washable paints, gluing paper. Outdoors – sanding wood, spraying pesticides (but try not to do this!), cooking BBQ. Indoors **with good ventilation** – painting with nail polish, using hairspray



Did You Know...?

IAQ means **Indoor Air Quality**; this means how good is the air inside and around buildings. IAQ is affected by mold, bacteria, harmful gases, dust, and when Dorth VOC is your best friend (or when 'volatile organic compounds' are found in the air). IAQ is tested through air samples and by tracking how many pollutants are found inside a building. By keeping track of your house's IAQ, you can make it better!

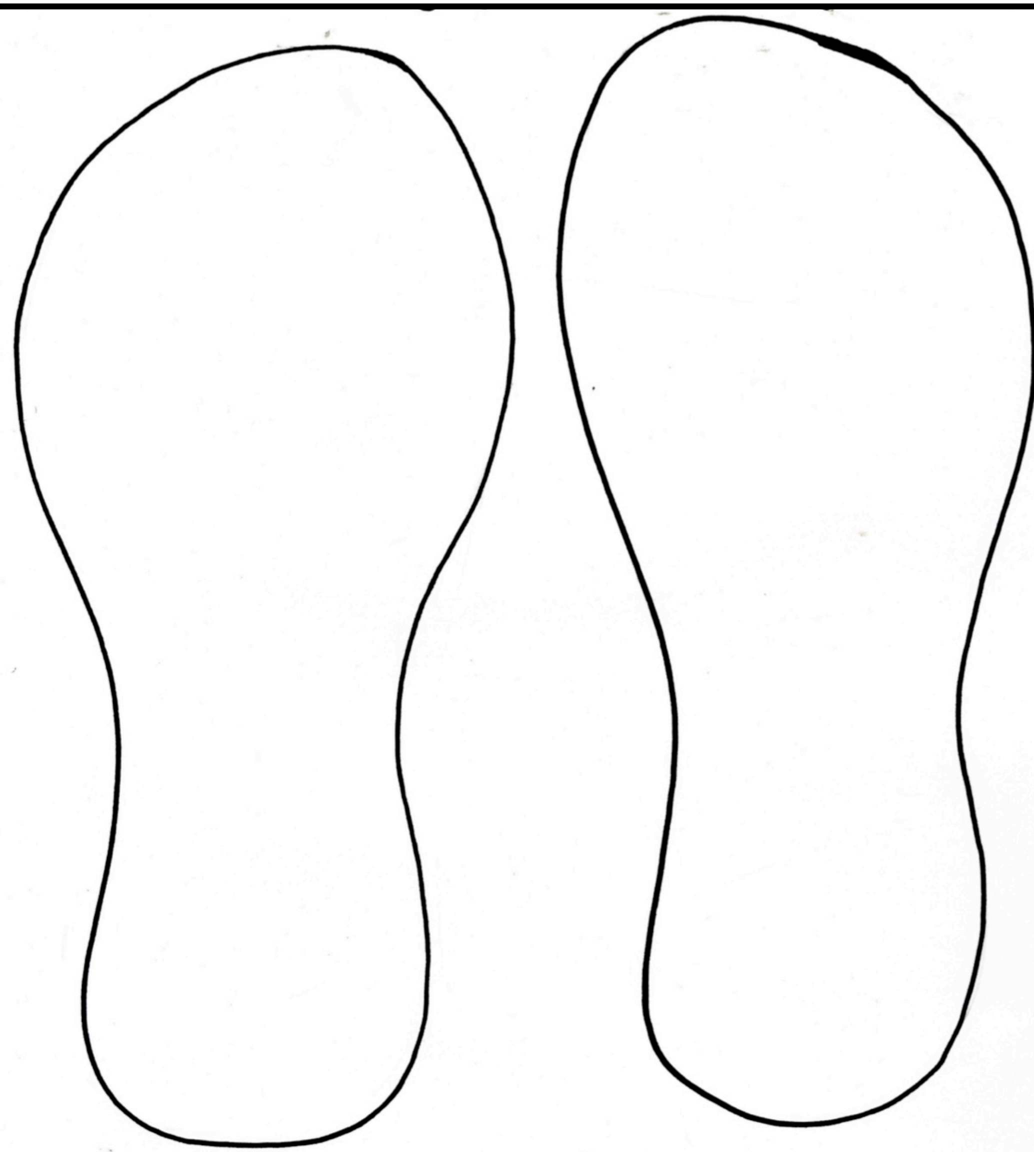
Source: http://www.epa.gov/indoor-air-quality-iaq/care-your-air-guide-indoor-air-quality



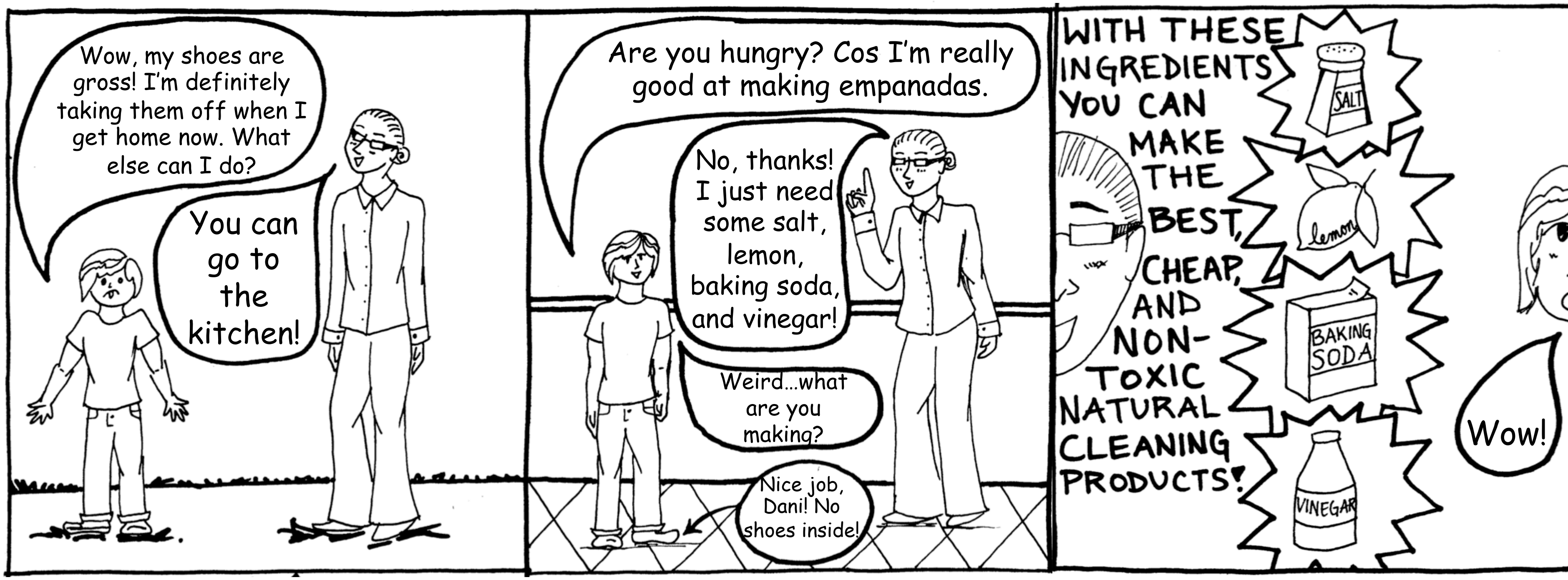
Green Cleaning Tip

Keep floors clean by keeping a doormat by your entrances and exits. Vacuum and sweep often. Take off your shoes right after stepping inside your house and keep slippers by the door. By doing this, you can help stop Dorth VOC entering your home!

DRAW IT! What's on the bottom of your shoes? Where do you go everyday? What do you walk through? Dani found Grandma's missing tooth - what's the weirdest thing you've found on your shoes?



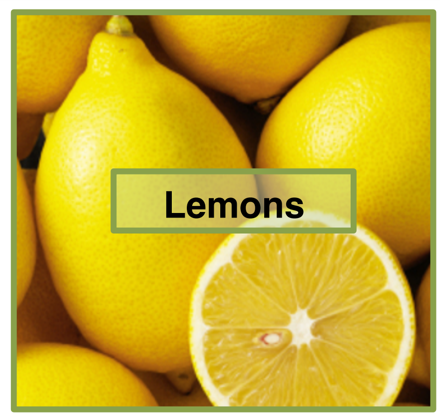
Do you want what you find on your shoes in your house? In your bedroom? By taking off your shoes right after stepping inside your home, you can help stop Dorth VOC!

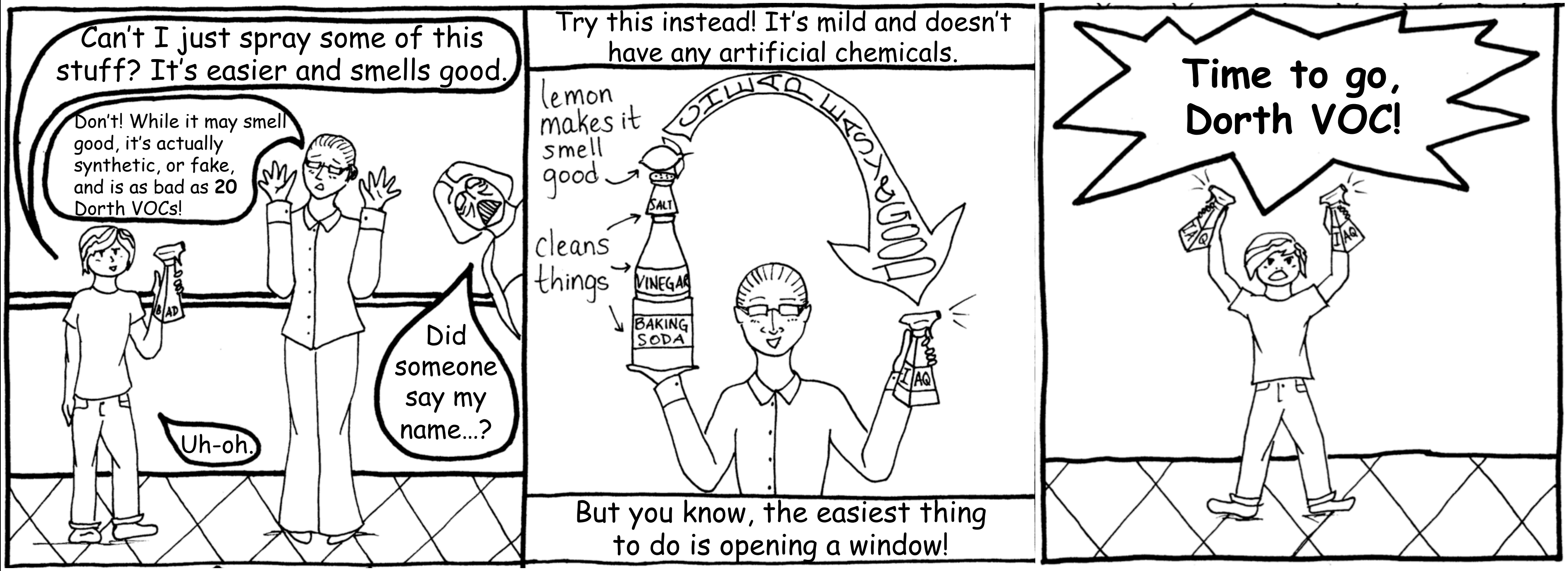


The Fabulous Four

By combining salt, lemon, baking soda, and white distilled vinegar, you can clean pretty much anything. Check out some easy solutions at the back of this book. Watch science work it out!

WDV
= White Distilled Vinegar

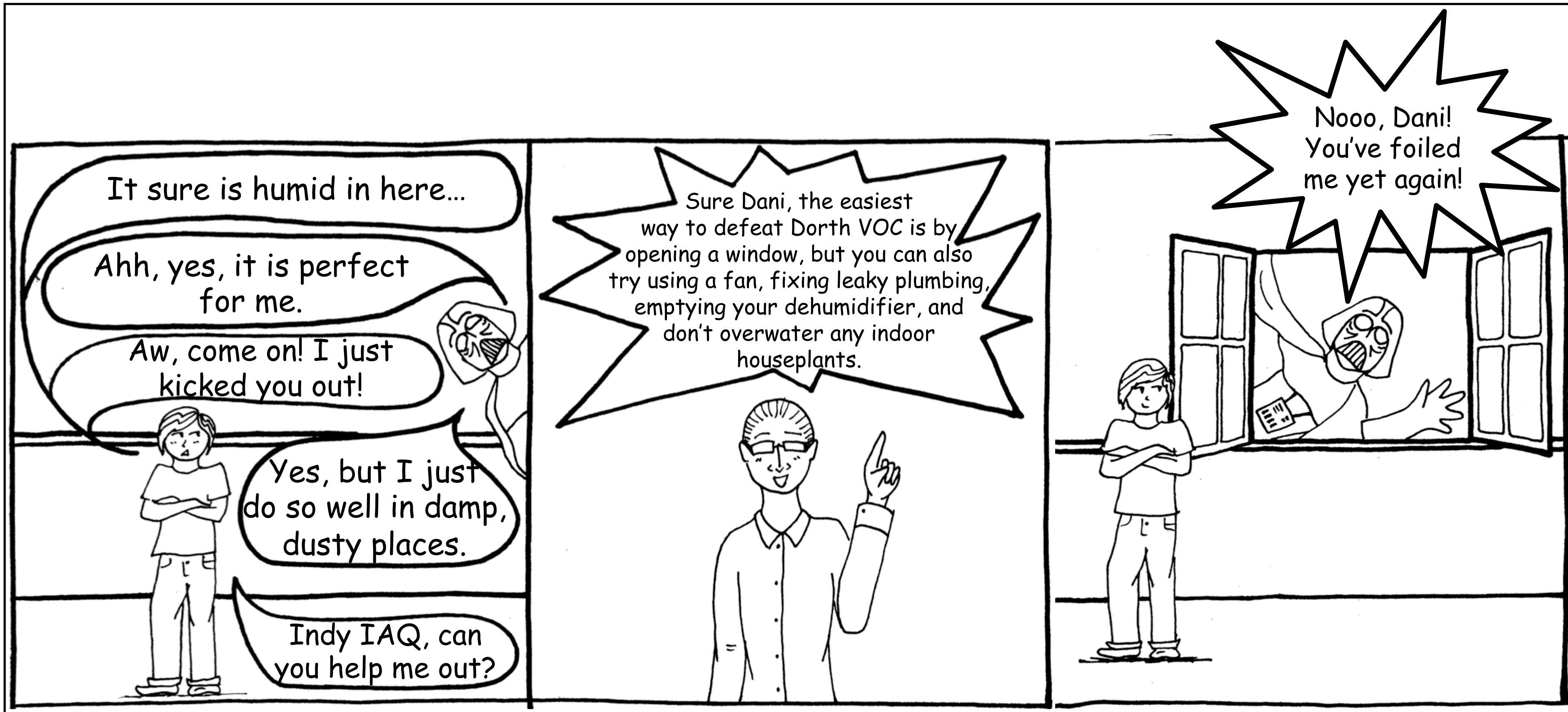




A Quick Guide to Green Cleaning

Here are a few easy green solutions! Check out the Green Cleaning Guide in the back for more.

Problem: SMELLY, DIRTY TOLIET BOWL **Solution:** Pour 3 C. of WDV in toilet bowl. Leave for about 30 minutes to a couple of hours. Scrub well. Flush.	**Problem:** SMELLY BATHROOM AIR **Solution:** Spray into the air a solution of: 1 tsp. baking soda 1 Tbsp WDV 1 C. water	**Problem:** FRUIT FLIES **Solution:** Set out a small dish of undiluted WDV.	**Problem:** GERMY, DIRTY SURFACES **Solution:** Spray or wipe a cloth soaked in full-strength WDV. Wipe dry. *Don't use on marble countertops.



Did You Know…?

Having indoor houseplants are a really great way to filter air. They look good, smell good, and improve a building's IAQ. Some of Indy IAQ's favorites are below but you can find out more in *Nature's Air Filters*.

Find it! Can you spot all 12 indoor houseplants?

Aloe	Bromeliads	Fern	Christmas Cactus
Peach Lily	Yucca	Succulents	Dracaena
English Ivy	Chrysanthemums	Spider Plant	Bamboo

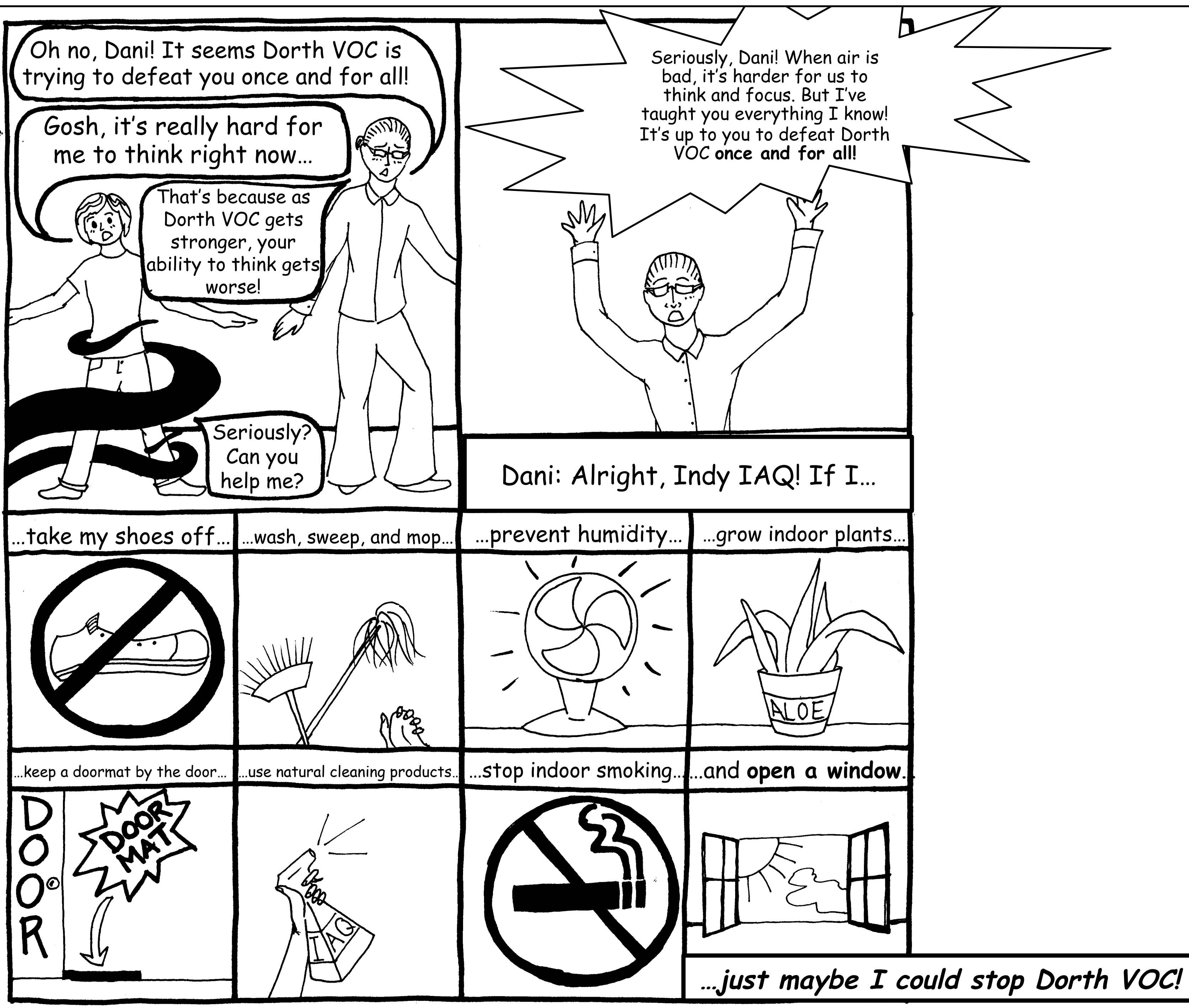
s	r	s	p	i	d	e	r	p	l	a	n	t	s	s
y	u	s	w	q	c	j	a	a	r	b	t	m	u	u
a	e	c	e	q	x	r	k	e	r	a	u	k	e	t
a	n	g	c	v	u	r	a	o	l	m	i	g	e	c
p	i	e	f	u	h	j	m	y	e	e	r	e	c	a
x	r	v	a	q	l	e	d	h	u	n	k	g	i	c
e	q	r	a	c	l	e	t	o	a	g	o	i	f	s
s	s	g	k	i	a	n	n	c	a	l	o	e	k	a
c	f	t	a	e	a	r	c	t	q	i	b	g	s	m
g	f	d	b	s	m	u	d	x	s	s	m	c	b	t
r	s	e	y	v	y	c	e	m	k	h	a	x	m	s
q	b	r	r	s	u	r	d	h	e	i	b	r	d	i
l	h	i	j	n	s	w	t	l	r	v	v	s	d	r
c	y	l	i	l	h	c	a	e	p	y	b	q	s	h
b	v	z	b	g	p	o	v	q	q	e	z	k	c	c

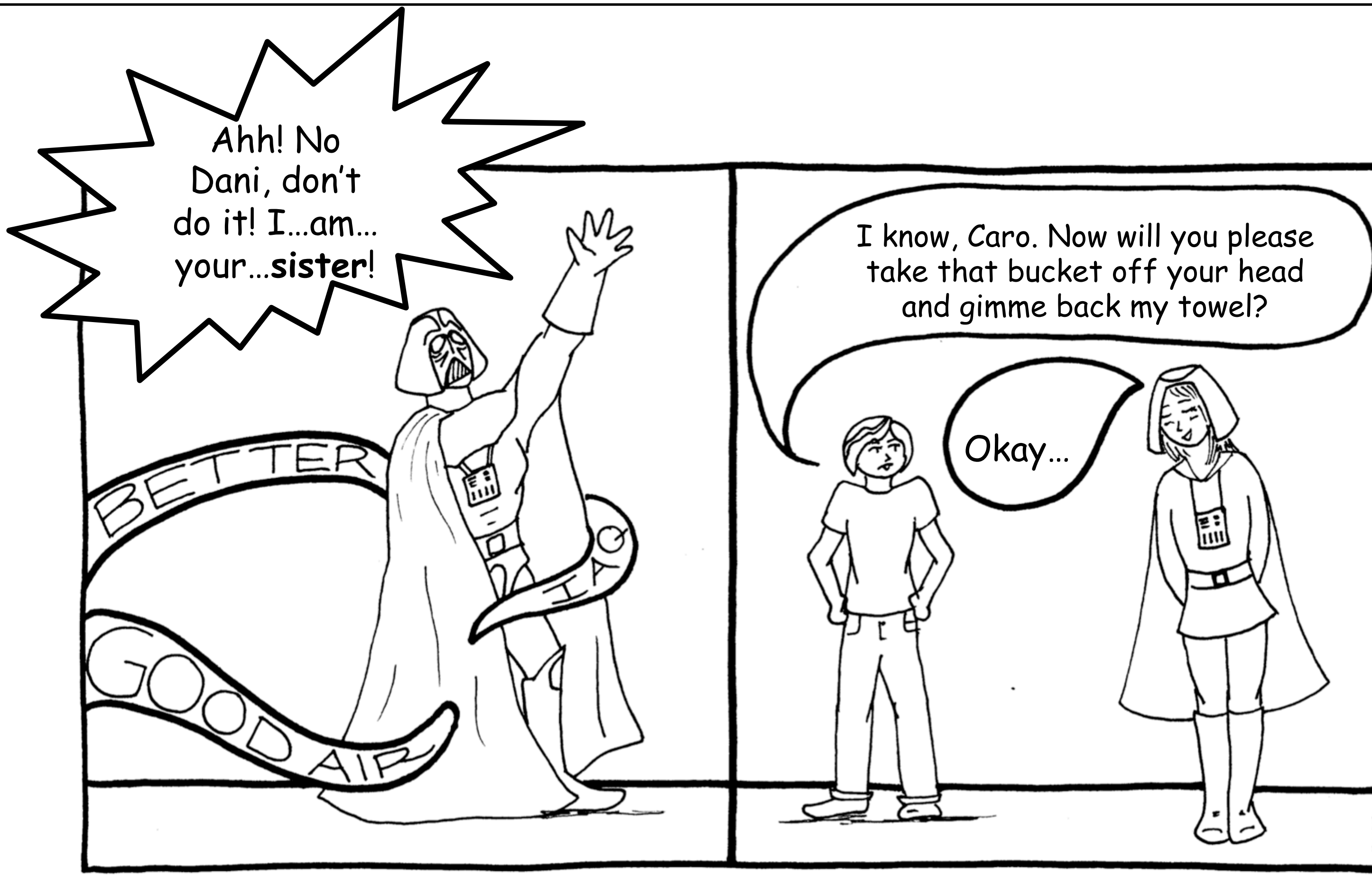
Made with: http://puzzlemaker.discoveryeducation.com/WordSearchSetupForm.asp

Did You Know...?

Secondhand smoke is really bad for you. There are short-term and long-term risks if you are around it for too long. You can get sick more often, have more lung infections (like bronchitis and pneumonia), get more ear infections, and you are more likely to cough and be short of breath. Secondhand smoke can lead to asthma, leukemia, brain tumors, and a lot of different types of cancers. Please be careful around secondhand smoke, **especially** when indoors.

Source: http://www.cancer.org/cancer/cancercauses/tobaccocancer/secondhand-smoke


Oh no, Dani! It seems Dorth VOC is trying to defeat you once and for all!
Gosh, it's really hard for me to think right now...
That's because as Dorth VOC gets stronger, your ability to think gets worse!
Seriously? Can you help me?
Seriously, Dani! When air is bad, it's harder for us to think and focus. But I've taught you everything I know! It's up to you to defeat Dorth VOC **once and for all!**
Dani: Alright, Indy IAQ! If I...
...take my shoes off...
...wash, sweep, and mop...
...prevent humidity...
...grow indoor plants...
ALOE
...keep a doormat by the door...
DOOR
DOOR MAT
...use natural cleaning products...
IAQ
...stop indoor smoking...
...and **open a window**...
...just maybe I could stop Dorth VOC!



Did You Know...?

The air you breathe indoors really <u>does</u> affect your thinking! It's best to change up your air whenever you can. Either by taking a quick walk around the block, to the bathroom, or jumping up and down, it's really good to stay active and breathe different types of air. By improving IAQ with any of the tips Indy IAQ recommends to Dani, you'll think be more alert, responsive during an emergency, and be able to focus longer.

Source: http://www.hsph.harvard.edu/news/press-releases/green-office-environments-linked-with-higher-cognitive-function-scores/

Adapted from the Rutgers Center for Green Building's Healthy Families Study's publications: *A Green Cleaning Guide* and *Improve the Air Quality in your Home*.

Additional Resources:

http://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality

http://www.epa.gov/indoor-air-quality-iaq/care-your-air-guide-indoor-air-quality

http://puzzlemaker.discoveryeducation.com/WordSearchSetupForm.asp

http://www.cancer.org/cancer/cancercauses/tobaccocancer/secondhand-smoke

http://www.hsph.harvard.edu/news/press-releases/green-office-environments-linked-with-higher-cognitive-function-scores/

http://globegazette.com/forestcitysummit/air-may-need-improvement-in-the-winter/article_13c956c9-a93a-5a1d-80db-e59ca2350bae.html

PLAN4Health
An American Planning Association Project

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TRENTON HEALTHY COMMUNITIES INITIATIVE

Prepared by the Bloustein School Planning Healthy Communities Initiative, May 2016

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