Cost-Effective Methods for Detection & Improvement of Indoor Air Quality

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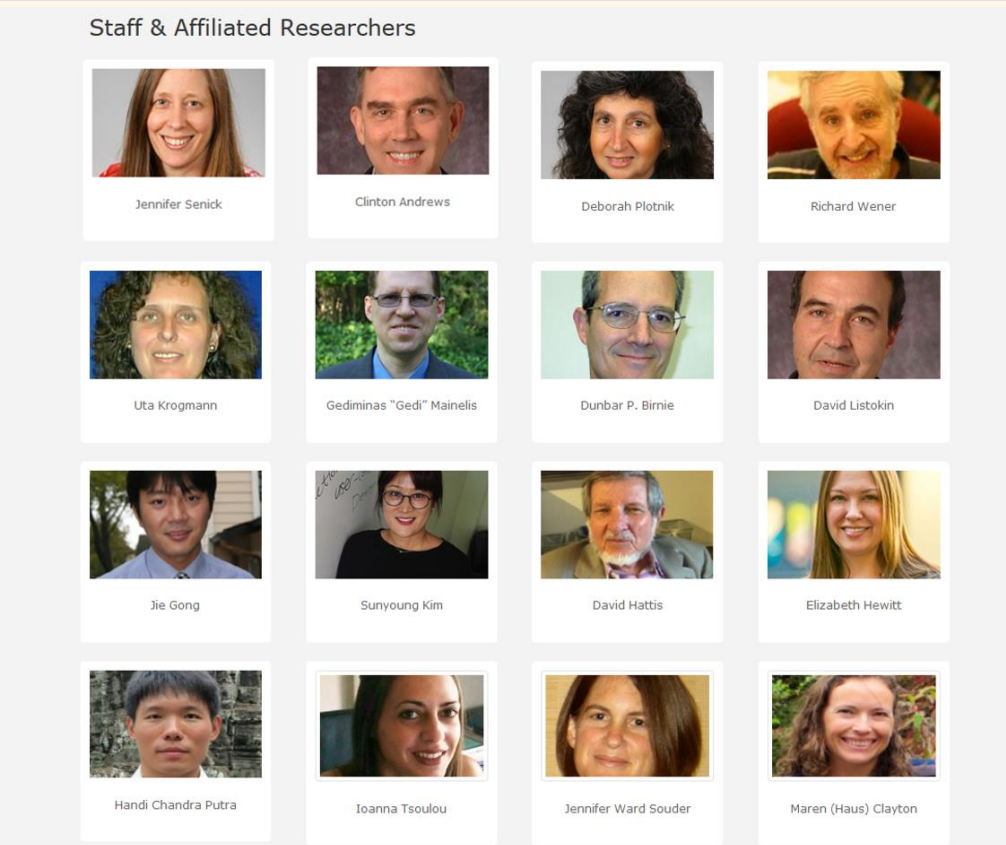

Rutgers Center for Green Building

The Rutgers Center for Green Building promotes green building through research, education, training, and partnerships with industry, government and non profits.

The Center is housed at the Edward J. Bloustein School of Planning and Public Policy with faculty drawn from diverse disciplines including at the School of Environmental and Biological Sciences, the School of Engineering, Computer Science Department, and other Rutgers units that are integral to developing and implementing innovative green building strategies.

SPIRIT* (Spatially Resolved Infrared Imaging Thermography)

*Rutgers Docket # 2016-102; **Cost-Effective Detection of Multi-Family Housing-Related Health and Safety Hazards,** HUD Healthy Homes Technical Studies, Grant # NJHHU0019-13

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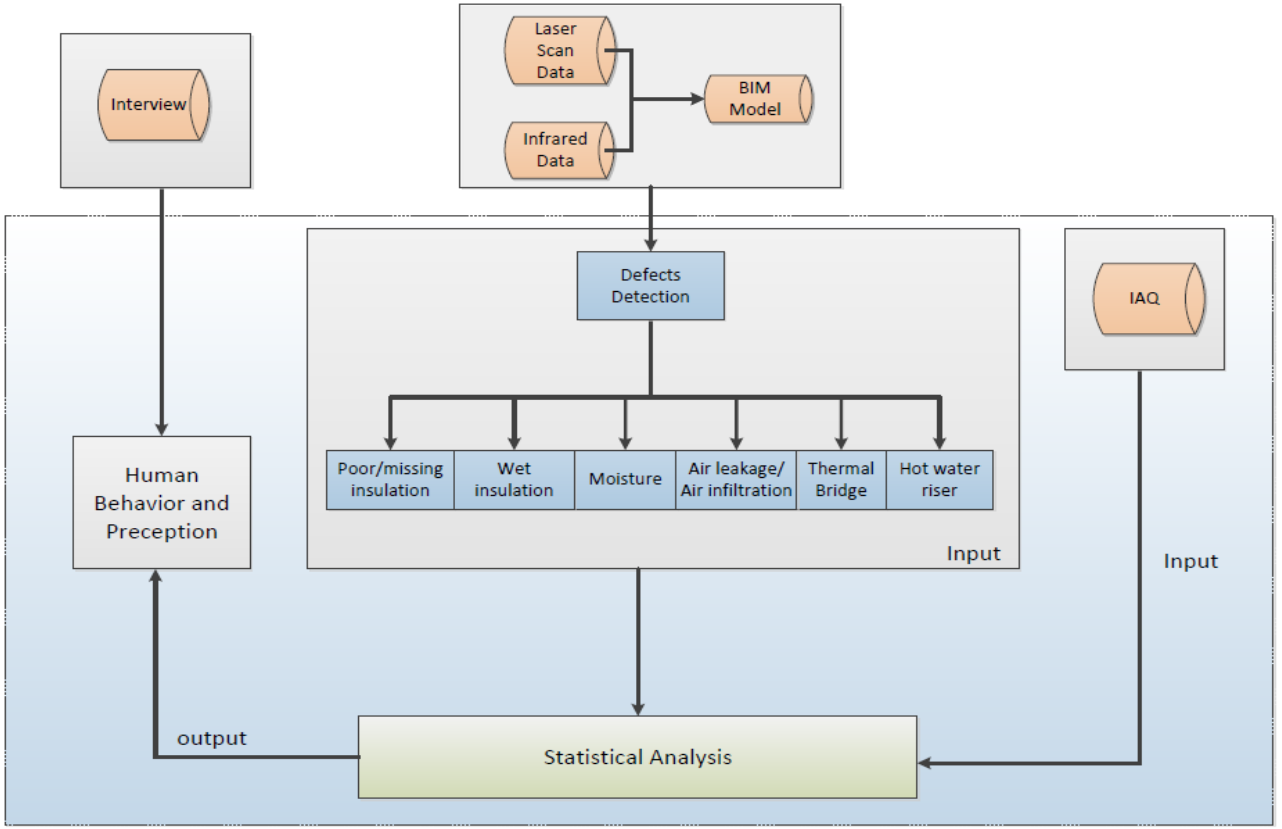
Data Collection, Integration and Analysis Framework for Building IAQ



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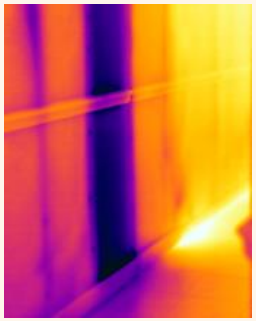
Infrared Technology for Building Diagnosis

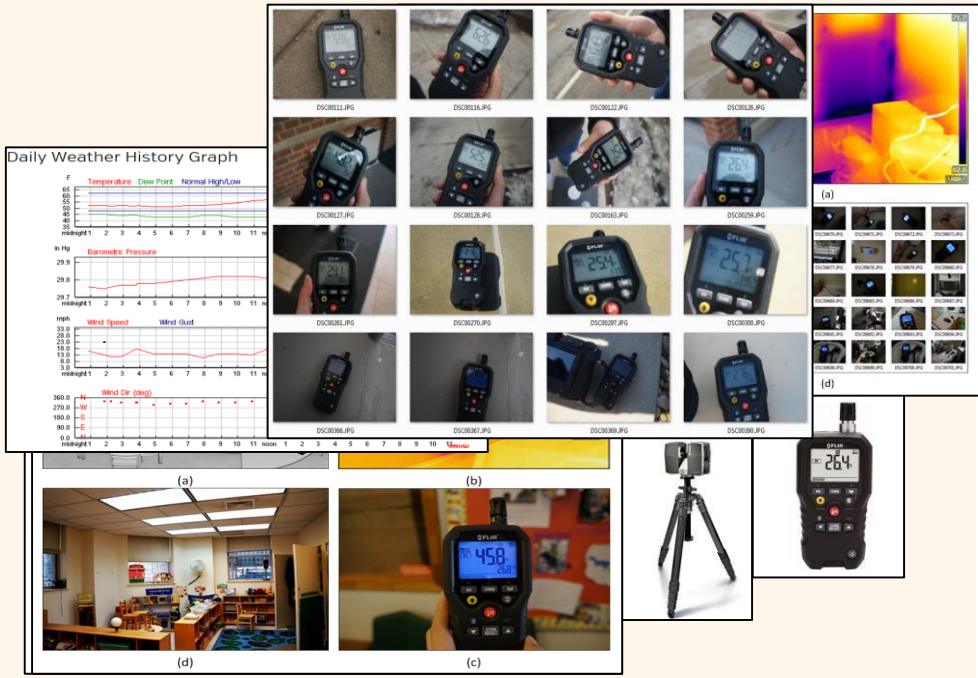


Benefits of thermal Infrared–based building diagnostic:

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

Types of Building Defects Detected by Infrared Camera

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



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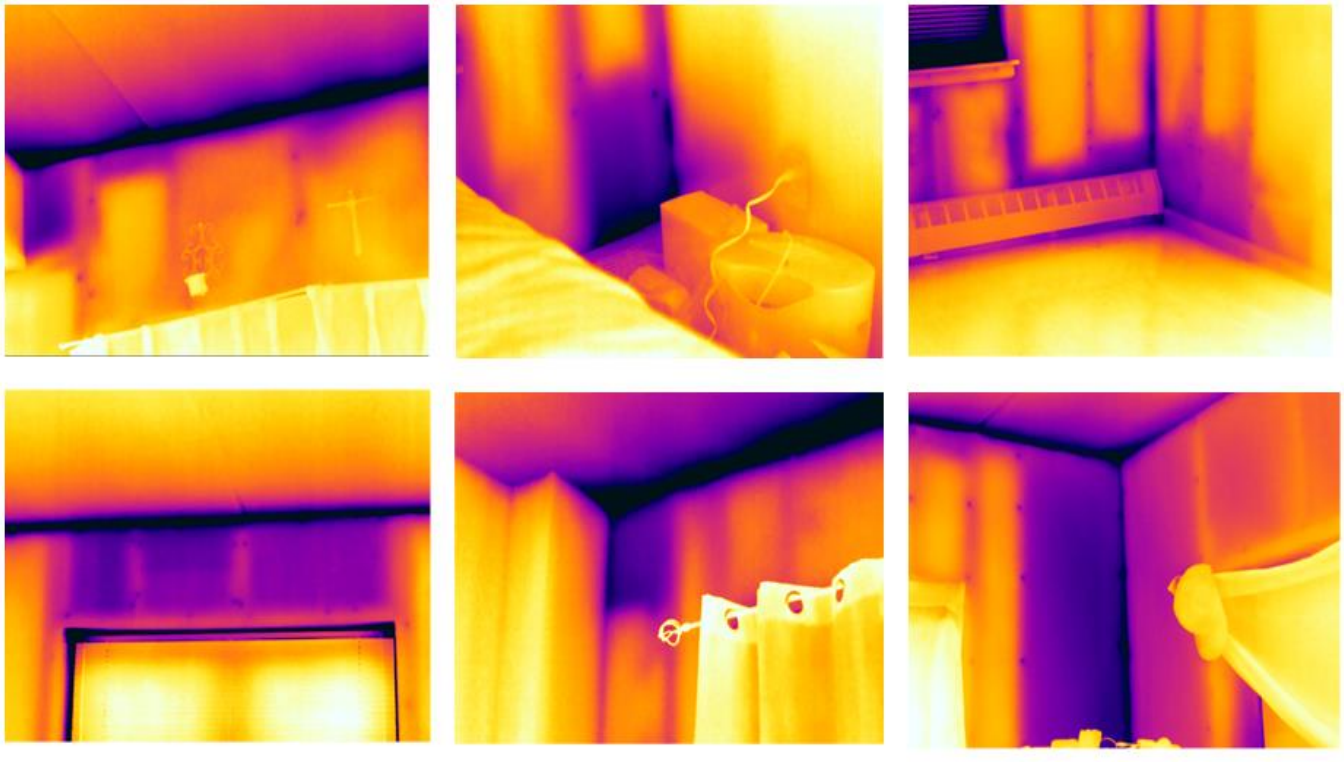
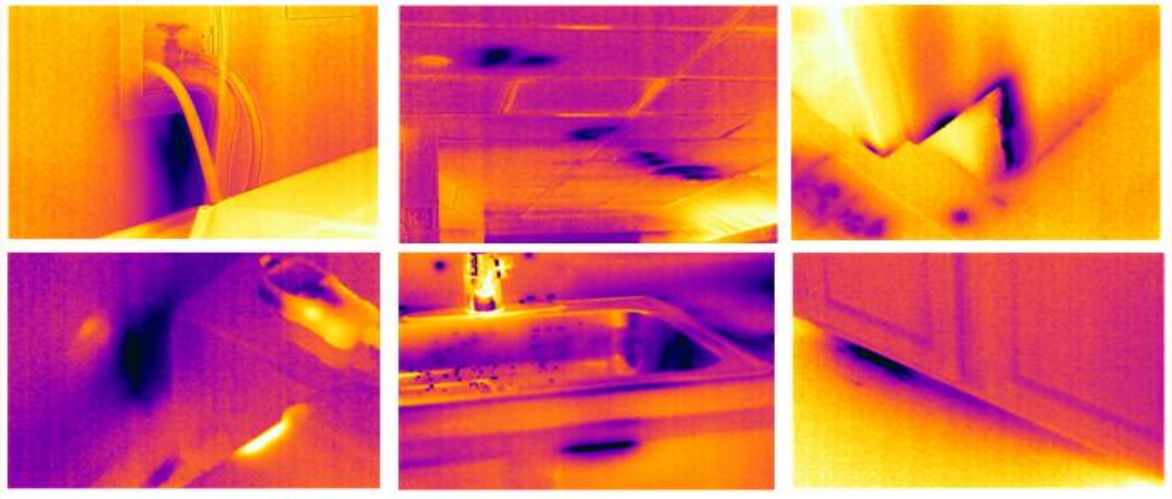
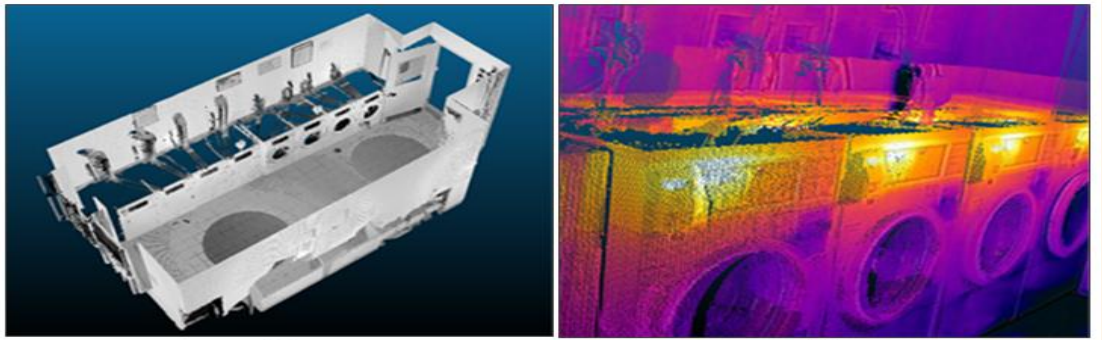
Missing or Poor Insulation



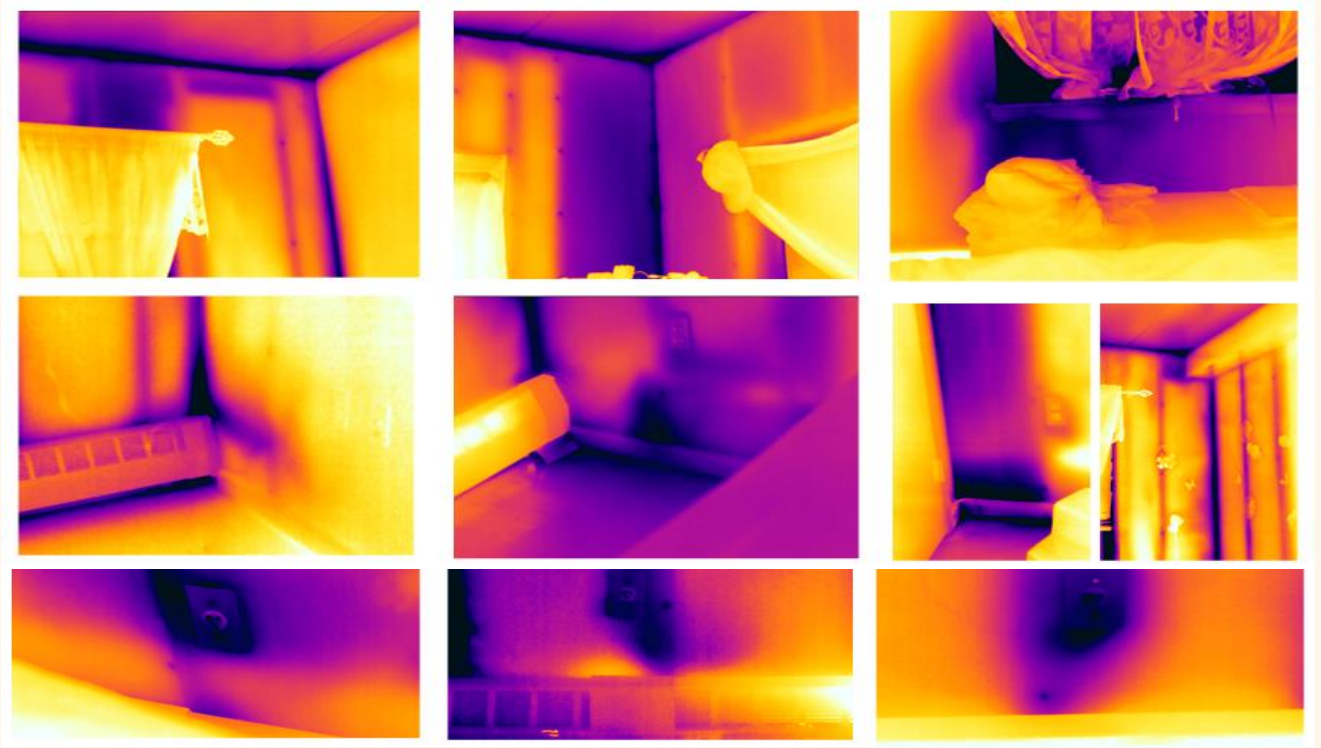
Moisture Issues



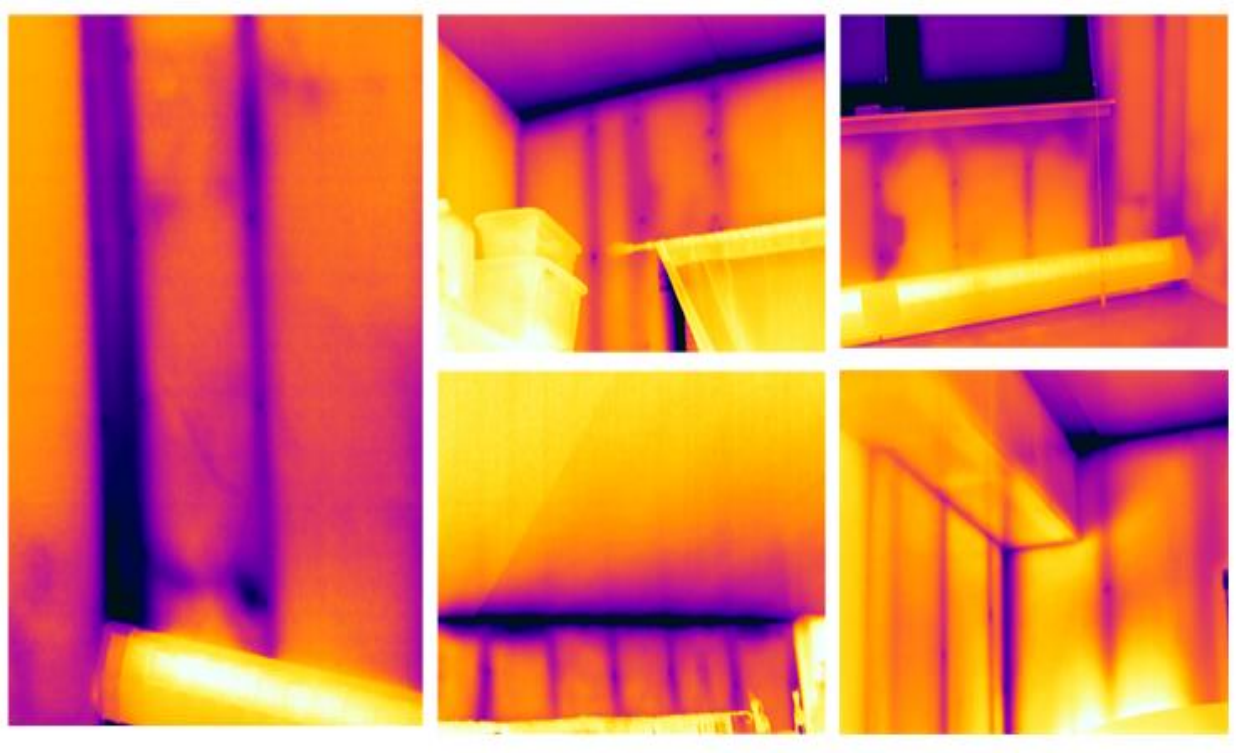


(a) (b)

Air Leakage or Air Infiltration



Thermal Bridge



Poorly Insulated Hot Water Riser

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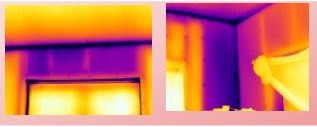
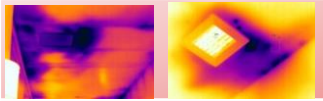
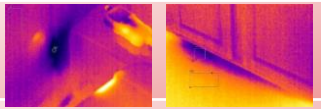
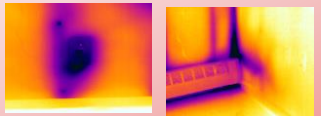
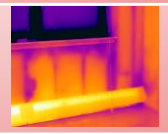
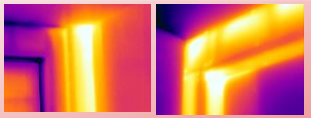
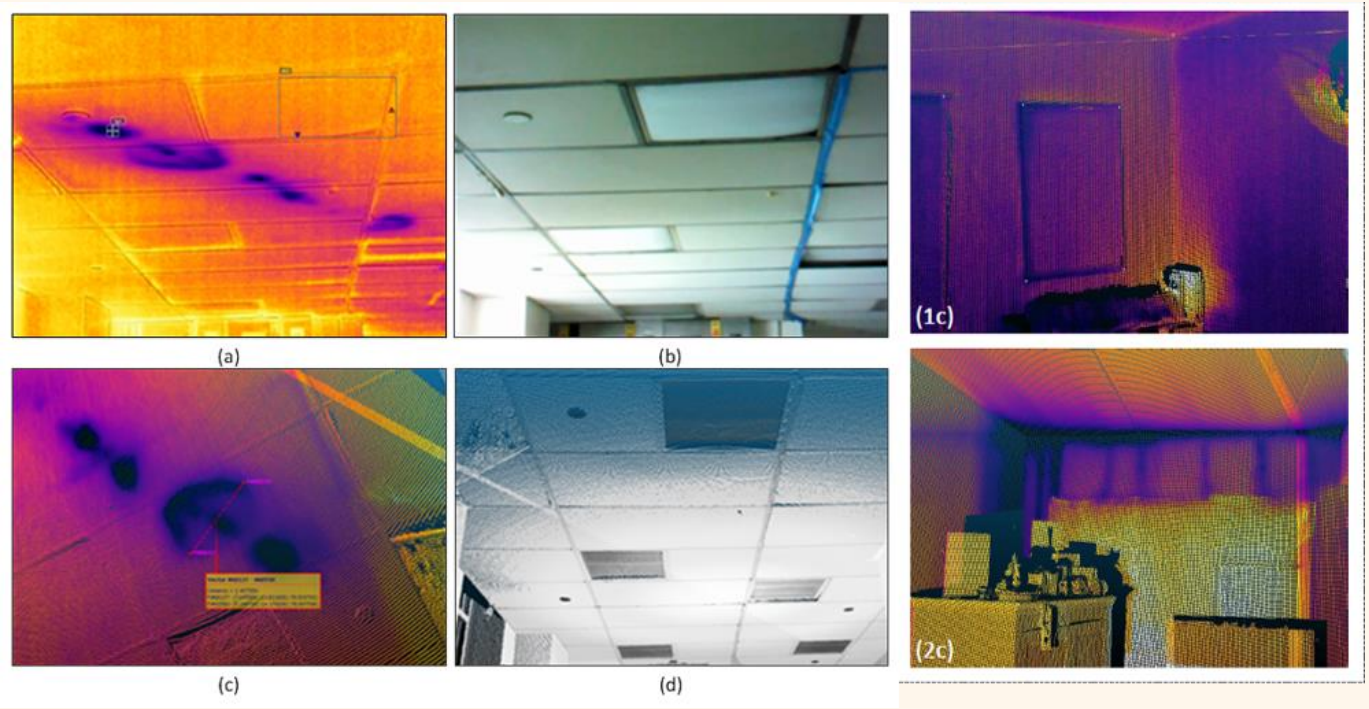
Detectable Building Defects by Infrared Thermography

Defect Types	Description	Infrared Image	Quantification
Poor/ missing insulation	Missing or poor insulation areas appear as light/dark colored patches with distinct edges outlining the problematic areas.		1. Poor or missing insulation area (sf) 2. Percentage of missing insulation (%)
Wet insulation	Wet insulation is often temporary and usually appears as areas without distinct edges.		1. Wet insulation area (sf) 2. Percentage of wet insulation area (%)
Moisture	Moisture areas usually appear as dark/cool areas without distinct edges.		1. Moisture issue area (sf)
Air leakage / Air infiltration	Air leakage usually appears as light/dark areas in building corners or near structural joints.		1. Temperature factor (f_{Rsi})
Thermal bridge	Thermal bridges usually appear as light/dark areas with linear features as they are often related to structural components that penetrate the insulation layers.		1. Temperature factor (f_{Rsi})
Hot water Riser	Components of HVAC systems are not well insulated, causing elevated temperature in part of wall surfaces.		1. Hot water riser surface area (sf) 2. Hot water riser surface temperature (°F)

Projecting Infrared Image Onto Scan Data



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

Building Attribute Extraction and Performance Grading

Apartment Location Information

- Floor information
- Corner information
- Orientation

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

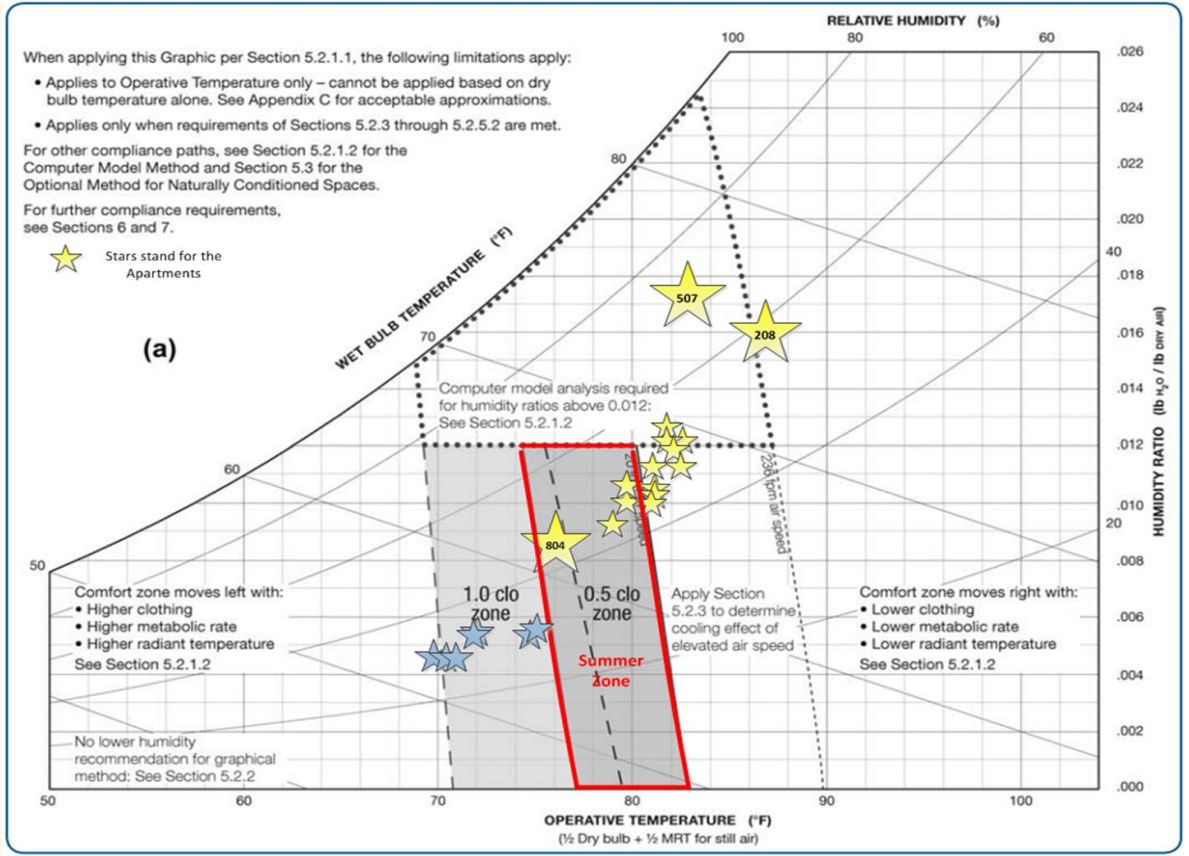


Figure 2: The new Graphic Comfort Zone Method, Figure 5.2.1.1 in Standard 55-2010 (IP version shown).

Clo: a measure of clothes thermal insulation
MRT: Mean Radiant Temperature

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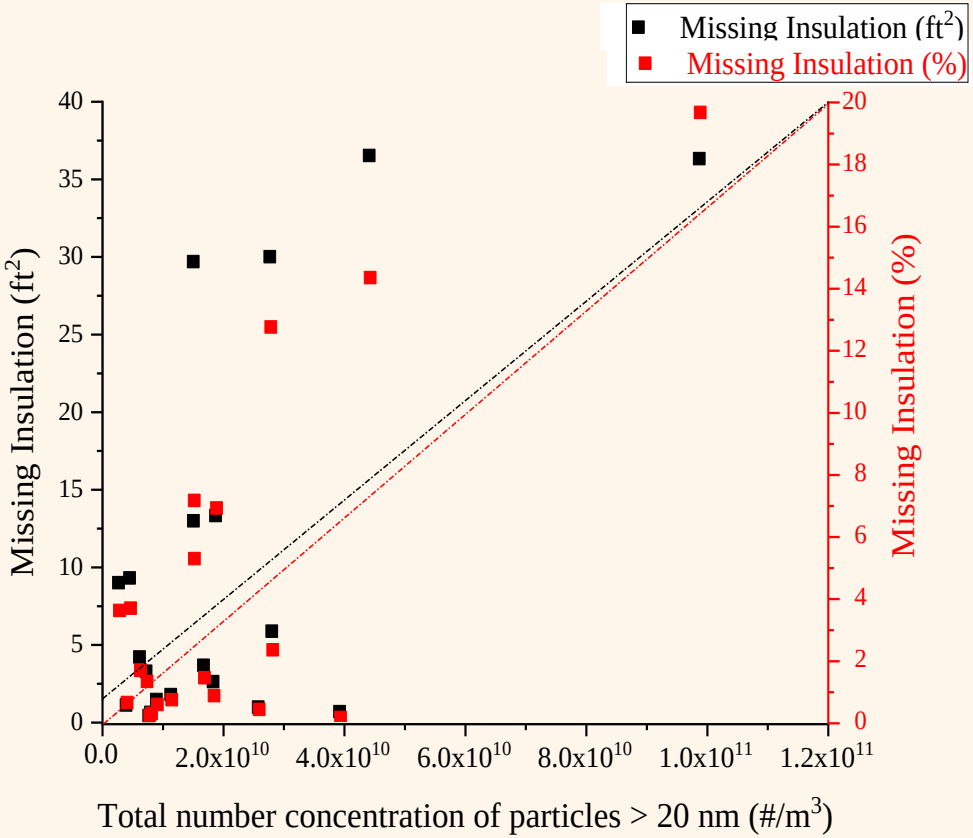
Performance Grading by Performance Attributes

Variable for assessing housing-related health & safety hazards **n = 20 apts**.

Attribute (Median value)	Good Insulation (n = 4)	Fair Insulation (n = 12)	Poor Insulation (n = 4)
Thermal Bridge Temperature	70.55	71.15	65.75
Thermal Bridge Temperature Factor	0.78	0.87	0.63
Air Leakage Temperature	65.85	65.15	58.70
Air Leakage Temperature Factor	0.69	0.74	0.55
Missing Insulation Area (sf)	0.68	3.91	24.82
Missing Insulation Area (%)	0.22%	1.53%	10.59%
R-value	0.89	1.37	0.63

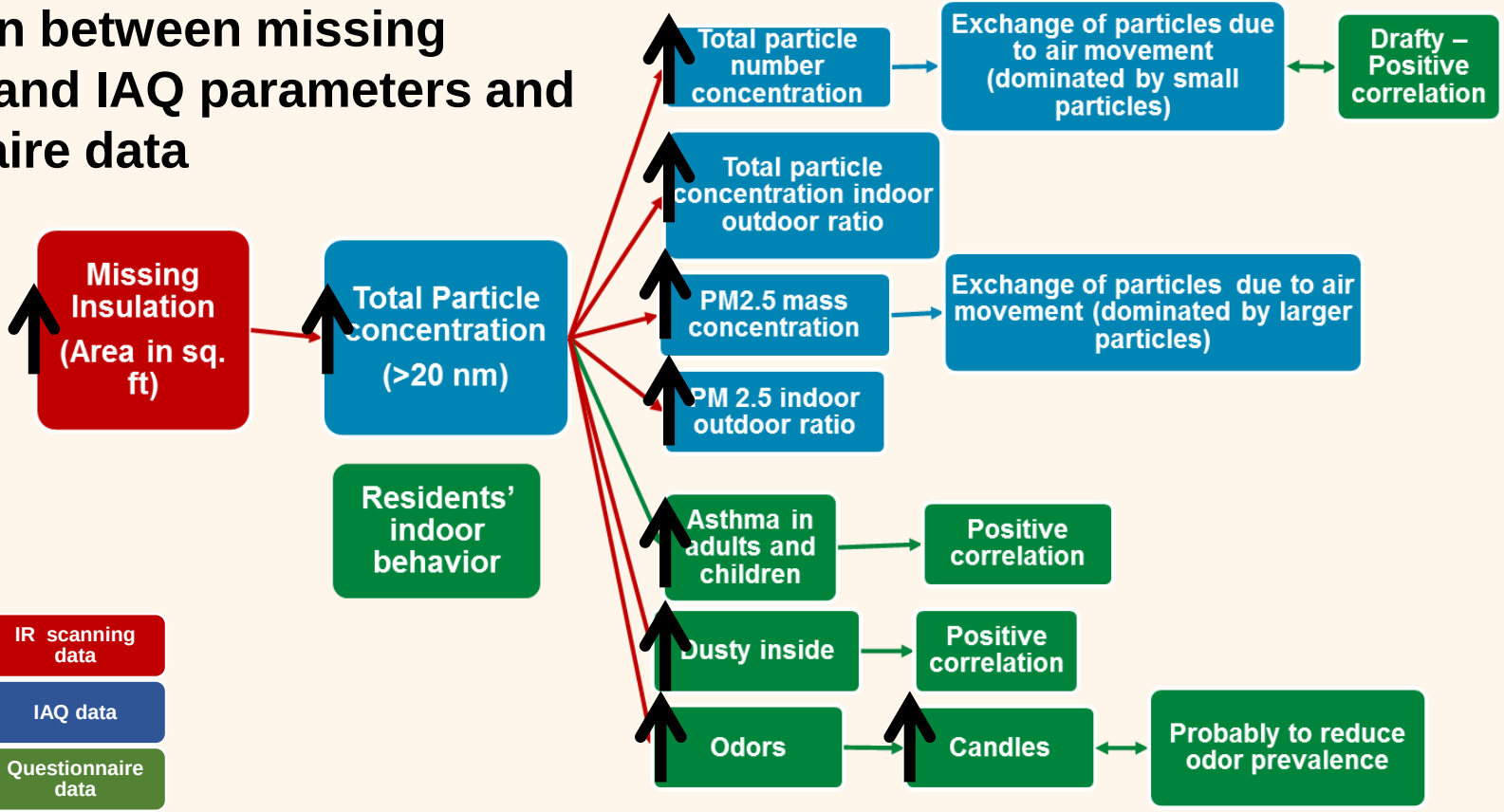
Apartment with Good Insulation Condition (Missing Insulation Area < 0.5%)
Apartment with Fair Insulation Condition (Missing Insulation Area < 5%)
Apartment with Poor Insulation Condition (Missing Insulation Area > 5%)



Correlation of 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

Association between missing insulation and IAQ parameters and questionnaire data



Cost-Effective Envelope Improvements

Storm door installed to provide added protection

Ducts sealed with mastic

Added insulation in basement (before barrier)*

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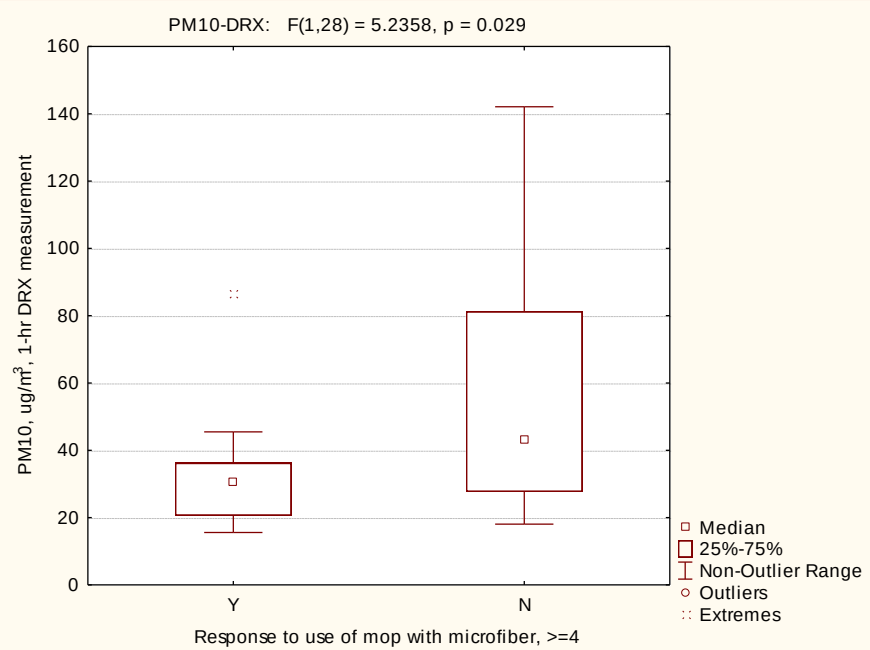
http://greenmanual.rutgers.edu/existing-residential/; https://www.energystar.gov/ia/partners/publications/pubdocs/DIY_Guide_May_2008.pdf

Low-Cost Cleaning Interventions (1of 2)



Use of mop with microfiber cloth

- Lower PM2.5, PM10 and total PM observed in apartments where mop with microfiber cloth was used and satisfaction was positive. Statistically significant for Phases II & III.

Use of microfiber cloth

- Lower PM concentrations observed with the 1-hr direct reading instrument in Phase III vs Phase I where microfiber cloth was used and satisfaction was positive.

Low-Cost Cleaning Interventions (2 of 2)

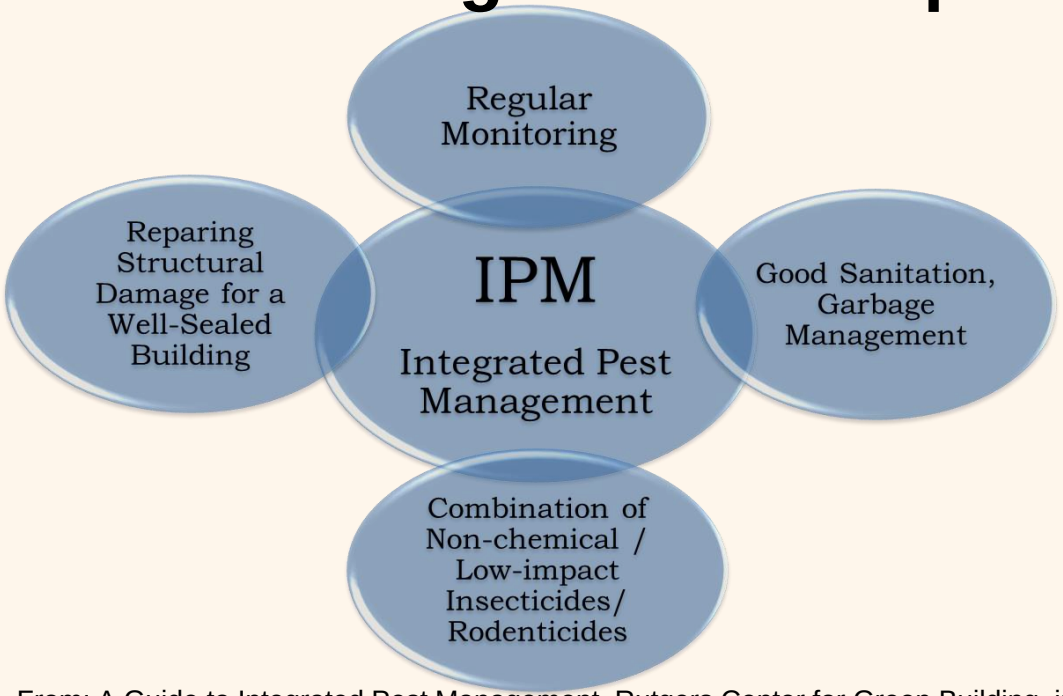
Vinegar

Statistically significantly lower indoor/outdoor PM mass concentration ratios (PM1, PM2.5, PM10, Total PM) where vinegar was used and satisfaction was positive

Use of baking soda as cleaner

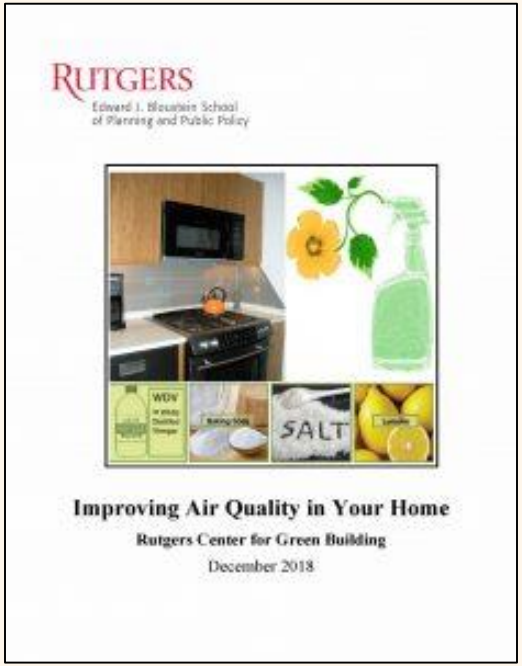
- Lower PM2.5, PM10 and total PM mass concentrations observed in apartments where baking soda was used for cleaning and satisfaction was positive, *NS.*
- Statistically significant for 5-10 µm particle number concentrations measured using direct-reading instruments.

Cost-Effective Building and Site Improvements

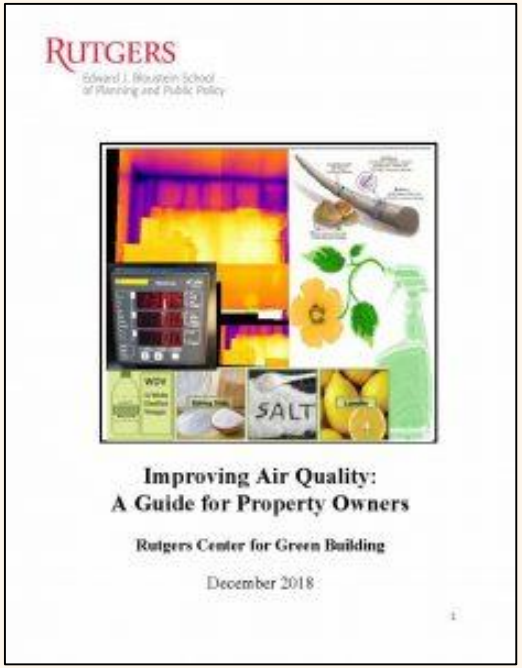


From: A Guide to Integrated Pest Management, Rutgers Center for Green Building, in partnership with Rutgers Cooperative Extension Specialist in Urban Entomology, as part of a grant from HUD Healthy Homes and Lead Hazard Control Program, January 2012

Improving Air Quality: A Guide for Tenants



Improving Air Quality: A Guide for Owners



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THANK YOU!

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Publications

Thomas, Nirmala, Calderón, Leonardo, Senick, Jennifer, Sorensen-Allacci, MaryAnn, Plotnik, Deborah, Guo, Mengyang, Yu, Yi, Gong, Jie, Andrews, Clinton J., Mainelis, Gediminas. (2019). “Investigation of Indoor Air Quality Determinants in a Field Study using Three Different Data Streams” Building and Environment 154 (2019) 281–295. https://doi.org/10.1016/j.buildenv.2019.03.022

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Wang, Z., Calderón, L., Patton, A., Sorensen-Allacci, M.S., Senick, J., Wener, R., Andrews, C.J., and Mainelis, G. (2016). Evaluation of Real-time Instruments and Gravimetric Method Used to Measure Particulate Matter (PM) in a Green Building. Journal of the Air & Waste Management Association, 66 (11) 109-1120.

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Xiong, U. Krogmann, G. Mainelis, L. Rodenberg, C.J. Andrews. (2015) Indoor air quality in green buildings: A case-study in a residential high-rise building in the northeastern US. *Journal of Environmental Science and Health*, Part A, 50(3): 225-242. DOI:10.1080/10934529.2015.98110

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