Indoor Air Quality: Monitoring Strategies and Results for a Multifamily Passive House Project

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Northeast Sustainable Energy Association (NESEA)
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Indoor Air Quality: Monitoring Strategies for a Multifamily Passive House Project
As a mission-driven nonprofit, New Ecology works nationally to bring the benefits of sustainable development to the community level, with a concerted emphasis on underserved populations.

We seek to make the built environment more efficient, healthy, durable, and resilient.
HRI is a local non-profit affordable housing organization that develops and preserves affordable, high-quality rental housing, with robust resident services for individuals and families throughout our portfolio.

We have a strong focus on responsible and sustainable practices through deliberate energy efficiency and material selection practices to both reduce our carbon footprint and to create healthy and comfortable homes for our residents.
Creating and Preserving Affordable Housing Opportunities

Agenda

1. IAQ Monitoring Program Design
2. Finch Cambridge IAQ Monitoring Results
3. Finch Cambridge IAQ Monitoring Uses
4. Future Work
5. Q&A
Providing Good IAQ

Source Control
- Materials selection
- Behavior (e.g. pesticide use, cooking)

Ventilation
- 100% outdoor air
- Energy recovery
- Exhaust and supply locations

Filtration
- MERV Rating

Monitoring and Corrective Action
IAQ Monitoring Program Design

Common IAQ Metrics

- ASHRAE Ventilation Rate Guidance (CO₂)
- EPA Radon Guidance
- RESET Air for Residential v1.0

### Ventilation and Resultant CO₂ Concentrations

<table>
<thead>
<tr>
<th>Carbon Dioxide</th>
<th>Outside Air (cfm per person)</th>
<th>CO₂ Differential (inside/outside)</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 ppm suggests about</td>
<td>20 cfm (or less)</td>
<td>500 ppm</td>
</tr>
<tr>
<td>1,000 ppm suggests about</td>
<td>15 cfm (or less)</td>
<td>650 ppm</td>
</tr>
<tr>
<td>1,400 ppm suggests about</td>
<td>10 cfm (or less)</td>
<td>1,050 ppm</td>
</tr>
<tr>
<td>2,400 ppm suggests about</td>
<td>5 cfm (or less)</td>
<td>2,050 ppm</td>
</tr>
</tbody>
</table>

*Note: The CO₂ values in this table are approximate, and based on a constant number of sedentary adult occupants, a constant ventilation rate, an outdoor air CO₂ concentration of about 380 ppm, and good mixing of the indoor air.*

*current atmospheric CO₂ concentration > 410 ppm: https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide*
IAQ Monitoring Program Design

Metrics: RESET Standard

- Monitors
- Buildings

<table>
<thead>
<tr>
<th>Particulate Matter</th>
<th>Total Volatile Organic Compounds</th>
<th>Carbon Dioxide</th>
<th>Temperature</th>
<th>Relative Humidity</th>
<th>Carbon Monoxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptable &lt; 35 μg/m³</td>
<td>Acceptable &lt; 500 μg/m³</td>
<td>Acceptable &lt; 1000 ppm</td>
<td>Monitored</td>
<td>Monitored</td>
<td>Acceptable &lt; 9 ppm</td>
</tr>
<tr>
<td>High Performance &lt; 12 μg/m³</td>
<td>High Performance &lt; 400 μg/m³</td>
<td>High Performance &lt; 600 ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although there are no requirements for temperature and humidity under RESET™ Air, both must be monitored given their impact on sensor readings for PM2.5 and TVOC. CO monitors are only required in spaces with combustion.
IAQ Monitoring Equipment
Creating and Preserving Affordable Housing Opportunities

IAQ Case Study

FINCH
CAMBRIDGE
Finch Cambridge Passive House
Green Building Certification Requirements

**PHIUS+ 2015**
- ASHRAE 62.2-2010
- Outside air to bedrooms

**EPA Indoor airPLUS**
- ENERGY STAR
- Low-CH₂O plywood and composite wood
- Low-VOC paints, finishes, carpet, carpet adhesives
- MERV 8 filtration for forced air space conditioning

**ENERGY STAR**
- ASHRAE 62.2-2010 or 2013 (residential)
- ASHRAE 62.1-2010 or 2013 (common space)
- <50% more than 62.1-2013

**Enterprise Green Communities 2015**
- ENERGY STAR
- Radon mitigation
- Low-VOC paints, coatings, primers, adhesives, sealants
Creating and Preserving Affordable Housing

Finch Cambridge Passive House

Ventilation Systems

- Design
- Commissioning

MERV 13
## IAQ Monitoring Program Design

<table>
<thead>
<tr>
<th>Space Type</th>
<th>Radon</th>
<th>CO2</th>
<th>TVOC</th>
<th>Temp</th>
<th>RH</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lobby, Conference Room, Community Room, Lounge</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Apartments (Sample of 20)</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
<tr>
<td>Apartments (All 98)</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
<td>☑️</td>
</tr>
</tbody>
</table>
IAQ Monitoring Program Design
Creating and Preserving Affordable Housing Opportunities

IAQ Monitoring Program Design
IAQ Monitoring Program Design

<table>
<thead>
<tr>
<th>Arthlings Communication Hub</th>
<th>Ground Floor Offices</th>
<th>3rd Floor Tel/Data Room</th>
<th>4th Floor Storage Room (STO 09)</th>
<th>5th Floor Tel-Data Room</th>
<th>Community Room</th>
<th>N/A</th>
</tr>
</thead>
</table>
IAQ Monitoring Program Design

**Sensor sampling interval:** 5 minutes

**Sensor Resolution:**
- Temperature ± 0.1°C / ± 0.1°F
- Humidity ± 1%
- Pressure ± 0.15 hPa

**Settling time:**
- TVOC ~ 7 days
- CO₂ ~ 7 days

**CO₂ details:**
- NDIR Sensor (Non-Dispersive Infra-Red):
  - Measurement range 400-5000 ppm
  - Non-condensing 0 - 85% RH
  - Optimum Accuracy ±30 ppm ±3% within 15 - 35°C / 60 - 95°F and 0 - 80% RH

**Radon sampling:** Passive diffusion chamber

**Detection method:** Alpha spectrometry

**Measurement range:**
- 0 - 500 pCi/L / 0 - 20,000 Bq/m³

**Accuracy/precision:**
- At 5.4 pCi/L / 200 Bq/m³:
  - After 7 days ~ 10%
  - After 2 months ~ 5%
Creating and Preserving Affordable Housing Opportunities

- Smoke-Free Policy
- Green Guide
- IAQ Monitoring
- Integrated Pest Management
- Robust Resident Services

Property IAQ Policies

- Smoke-Free Policy
- Green Guide
- IAQ Monitoring
- Integrated Pest Management
- Robust Resident Services
IAQ Monitoring Findings

Temperature

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Average</td>
<td>32.0 °F</td>
<td>94.0 °F</td>
<td>69.1 °F</td>
<td>74.7 °F</td>
<td>71.2 °F</td>
</tr>
<tr>
<td>Lobby</td>
<td>n/a</td>
<td>n/a</td>
<td>53.8 °F</td>
<td>80.4 °F</td>
<td>71.2 °F</td>
</tr>
<tr>
<td>Conference Room</td>
<td>n/a</td>
<td>n/a</td>
<td>54.5 °F</td>
<td>81.4 °F</td>
<td>73.1 °F</td>
</tr>
<tr>
<td>Community Room</td>
<td>n/a</td>
<td>n/a</td>
<td>60.4 °F</td>
<td>89.5 °F</td>
<td>74.7 °F</td>
</tr>
<tr>
<td>Lounge</td>
<td>n/a</td>
<td>n/a</td>
<td>56.5 °F</td>
<td>90.4 °F</td>
<td>72.4 °F</td>
</tr>
</tbody>
</table>

Although there are no requirements for temperature and humidity under RESNET, these must be monitored given their impact on sensor readings for PM2.5 and TVOC.
IAQ: Temperature
IAQ: Temperature

Finch Lounge Temperature

Temperature (°F)
IAQ Monitoring Findings

Relative Humidity

<table>
<thead>
<tr>
<th>Space</th>
<th>Min. RH</th>
<th>Max. RH</th>
<th>Avg. RH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Average</td>
<td>27.5%</td>
<td>57.1%</td>
<td>44.0%</td>
</tr>
<tr>
<td>Lobby</td>
<td>5.0%</td>
<td>74.5%</td>
<td>38.9%</td>
</tr>
<tr>
<td>Conference Room</td>
<td>6.5%</td>
<td>78.5%</td>
<td>39.3%</td>
</tr>
<tr>
<td>Community Room</td>
<td>5.5%</td>
<td>84.0%</td>
<td>40.2%</td>
</tr>
<tr>
<td>Lounge</td>
<td>7.0%</td>
<td>81.5%</td>
<td>43.2%</td>
</tr>
</tbody>
</table>

Although there are no requirements for temperature and humidity under the RESET protocol, both must be monitored given their impact on sensor readings for PM2.5 and TVOC.
IAQ: Relative Humidity

Relative Humidity at Finch
## IAQ Monitoring Findings

### Total VOCs

<table>
<thead>
<tr>
<th>Space</th>
<th>Min. TVOC</th>
<th>Max. TVOC</th>
<th>Avg. TVOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Average</td>
<td>74 µg/m³</td>
<td>442 µg/m³</td>
<td>202 µg/m³</td>
</tr>
<tr>
<td>Lobby</td>
<td>0 µg/m³</td>
<td>8,295 µg/m³</td>
<td>1,306 µg/m³</td>
</tr>
<tr>
<td>Conference Room</td>
<td>0 µg/m³</td>
<td>1,311 µg/m³</td>
<td>155 µg/m³</td>
</tr>
<tr>
<td>Community Room</td>
<td>0 µg/m³</td>
<td>8,277 µg/m³</td>
<td>197 µg/m³</td>
</tr>
<tr>
<td>Lounge</td>
<td>0 µg/m³</td>
<td>8,287 µg/m³</td>
<td>231 µg/m³</td>
</tr>
</tbody>
</table>
IAQ: Total VOCs

Unit Average Total VOCs

μg/m³

July 2020
August 2020
September 2020
October 2020
November 2020
December 2020
January 2021
February 2021
March 2021
April 2021
May 2021
June 2021
July 2021
August 2021
September 2021
October 2021
November 2021
December 2021
January 2022
February 2022
IAQ: Total VOCs

Average Community Room Total VOCs

µg/m³
### IAQ Monitoring Findings

**Carbon Dioxide (CO₂)**

<table>
<thead>
<tr>
<th>Space</th>
<th>Min. CO₂</th>
<th>Max. CO₂</th>
<th>Avg. CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Average (ERV 1)</td>
<td>433 ppm</td>
<td>2,596 ppm</td>
<td>783 ppm</td>
</tr>
<tr>
<td>Apartment Average (ERV 2)</td>
<td>428 ppm</td>
<td>2,082 ppm</td>
<td>691 ppm</td>
</tr>
<tr>
<td>Lobby</td>
<td>385 ppm</td>
<td>954 ppm</td>
<td>486 ppm</td>
</tr>
<tr>
<td>Conference Room</td>
<td>382 ppm</td>
<td>2,114 ppm</td>
<td>482 ppm</td>
</tr>
<tr>
<td>Community Room</td>
<td>368 ppm</td>
<td>1,114 ppm</td>
<td>474 ppm</td>
</tr>
<tr>
<td>Lounge</td>
<td>360 ppm</td>
<td>1,475 ppm</td>
<td>485 ppm</td>
</tr>
</tbody>
</table>
IAQ: CO₂

Average Community Room CO₂
IAQ: CO$_2$
IAQ Monitoring Findings

Radon

<table>
<thead>
<tr>
<th>Space</th>
<th>Min. Radon</th>
<th>Max. Radon</th>
<th>Avg. Radon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment Average</td>
<td>0.09 pCi/L</td>
<td>1.29 pCi/L</td>
<td>0.23 pCi/L</td>
</tr>
<tr>
<td>Lobby</td>
<td>0.00 pCi/L</td>
<td>2.35 pCi/L</td>
<td>0.53 pCi/L</td>
</tr>
<tr>
<td>Conference Room</td>
<td>0.00 pCi/L</td>
<td>3.32 pCi/L</td>
<td>0.71 pCi/L</td>
</tr>
<tr>
<td>Community Room</td>
<td>0.00 pCi/L</td>
<td>2.19 pCi/L</td>
<td>0.28 pCi/L</td>
</tr>
<tr>
<td>Lounge</td>
<td>0.00 pCi/L</td>
<td>1.97 pCi/L</td>
<td>0.22 pCi/L</td>
</tr>
</tbody>
</table>

EPA Action level = 4 pCi/L
IAQ Monitoring Uses by Property Management

**Resident Experience**

*Thermal Comfort*
- Limited Thermostats
- Resident Requests for higher heat and lower A/C

*Odors in Common Areas*
- Troubleshooting malfunctioning ERVs and confirming repairs

**Systems Management**

IAQ monitors help confirm issues with the ERV systems
IAQ Monitoring Uses by Property Management

Balancing Real Time Data with Resident Privacy

- Provide a healthy comfortable environment for our residents
- Avoid policing resident behavior unless it affects the health and safety of other residents and/or staff
- Examples of disastrous IAQ situations due to misguided resident behavior that we try and avoid
  - Ex: Resident humidification causing dramatic mold growth
  - Ex: Resident use of space heaters, risk of fire
Future Work

Deployment
- All units, selected units, portable monitors
- Common spaces
- Ventilation air flow monitors
- Wireless hub connectivity in masonry and concrete buildings

PM2.5 monitoring
Too much data, not enough information
HUD-NCHH PM2.5 monitoring in passive house vs. conventional multifamily
Future Work

Too much data, not enough information.
Thank You!

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