Building Bridges to Net Zero

Passive House in Multi-Family: Challenges, Roadblocks and Opportunities

Lois B. Arena, PE CPHD
Overview

• Multi-family vs Single Family
• Thermal Envelope
• Ventilation
• Heating & Cooling
• Domestic Hot Water
PH DIFFERENCES: MULTIFAMILY VS. SINGLE FAMILY
Multifamily vs. Single Family

• Likely cooling dominated in a heating dominated climate
  – Density of apartments & appliance loads
  – Lack of external shading devices
  – Additional loads such as fitness centers, elevators, DHW circulation pumps and line losses, retail space, etc.
Multifamily vs. Single Family

Internal Gains
- More internal gains/ft$^2$ – people, appliances
- Internal gains dominate solar gains
- ↑ primary energy demand
- ↑ cooling energy demand,
- ↓ heating energy demand
Multifamily vs. Single Family

Solar Gains

- Shading is difficult & costly to incorporate
- SHGC of windows very important – low on all orientations

<table>
<thead>
<tr>
<th>Available solar heat gains $Q_S$</th>
<th>kWh/(m²a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal heat gains $Q_I$</td>
<td>17.1</td>
</tr>
<tr>
<td></td>
<td>29.8</td>
</tr>
</tbody>
</table>
Multifamily vs. Single Family

• Envelope efficiency requirements of less concern than comfort criteria
• Less insulation in slabs and roofs can help reduce cooling loads!
## Multifamily vs. Single Family

<table>
<thead>
<tr>
<th></th>
<th>Multifamily Project (200,000 ft²)</th>
<th>Single Family Home (1600 ft²)</th>
<th>PH Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kBtu/ft² yr (kWh/m² yr)</td>
<td>kBtu/ft² yr (kWh/m² yr)</td>
<td>kBtu/ft² yr (kWh/m² yr)</td>
</tr>
<tr>
<td><strong>Space heating demand</strong></td>
<td>2.5 (8)</td>
<td><strong>7.73 (24.4)</strong></td>
<td>4.75 (15)</td>
</tr>
<tr>
<td><strong>Space cooling demand</strong></td>
<td>4.75 (15)</td>
<td>3.95 (12.5)</td>
<td>4.75 (17)</td>
</tr>
<tr>
<td><strong>Primary energy demand</strong></td>
<td>37 (117)</td>
<td><strong>58 (183)</strong></td>
<td>38 (120)</td>
</tr>
<tr>
<td><strong>PH</strong></td>
<td>Yes</td>
<td>No</td>
<td>--</td>
</tr>
</tbody>
</table>
Auxiliary Spaces

• Common Area Lighting – pay attention to control strategies
• Fitness rooms – some equipment is very energy intensive
• Common Laundries – make up air for vented dryers
• Elevators – very little actual data, defaults
• Non-residential space ventilation – assume turn down when possible
## Potential Packages

<table>
<thead>
<tr>
<th>#</th>
<th>ft²</th>
<th># of units</th>
<th>Roof R-value</th>
<th>Wall R-value</th>
<th>Windows U-value/SHGC</th>
<th>Foundation R-value</th>
<th>Heating Demand kBtu/ft²·yr</th>
<th>Cooling Demand kBtu/ft²·yr</th>
<th>Primary Energy kBtu/ft²·yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>1267</td>
<td>1</td>
<td>90</td>
<td>48</td>
<td>0.16/0.62</td>
<td>21/37</td>
<td>4.2</td>
<td>0.33</td>
<td>26.7</td>
</tr>
<tr>
<td>#2</td>
<td>8770</td>
<td>10</td>
<td>102</td>
<td>46</td>
<td>0.15/0.6</td>
<td>20/41</td>
<td>4.47</td>
<td>1.16</td>
<td>28.9</td>
</tr>
<tr>
<td>#3</td>
<td>34,927</td>
<td>30</td>
<td>40</td>
<td>33</td>
<td>0.21/0.32</td>
<td>33/10</td>
<td>4.23</td>
<td>4.84</td>
<td>34.3</td>
</tr>
<tr>
<td>#4</td>
<td>39,482</td>
<td>52</td>
<td>60</td>
<td>30</td>
<td>0.25/0.33</td>
<td>10/10</td>
<td>3.24</td>
<td>5.1</td>
<td>37.6</td>
</tr>
</tbody>
</table>
Comfort Criteria

Pay Attention to These!

• Interior surface temperatures should not deviate by more than 7.6°F from the average operative temperature on the inside;
• the surface temperature must not be lower than 55.4°F or greater than 132°F at any point;
• the surface temperature of the floor must be between 66°F and 81°F.
Windows - Efficiency

- ISO vs. NFRC
  - Lots of confusion for US manufacturers
  - No direct conversion
  - ISO values are required
Windows - Shading

- Overhangs not typical in Multifamily
  - Vertical shading elements can help
  - Can set window back in wall toward interior
  - Set back issues in NYC?
Windows – Lot Line Issues

• Fire rated windows needed on lot lines
• No PH fire rated windows in US
• Do NOT meet PH comfort criteria
• Special design needed to mitigate potential for condensation
BALANCED VENTILATION W/ HEAT RECOVERY
Ventilation: Project Requirements

• PH Requirements
  – Balanced continuous mechanical ventilation
  – Heat recovery for cold climates
  – 75% or better recovery efficiency
  – Minimum ventilation of 0.30 ACH continuous
  – Occupant ability to boost to higher levels when desired
    • Minimum boost in kitchen – 35 cfm
    • Minimum boost in bathrooms – 24 cfm
Certification Programs

- LEED, ENERGY STAR, DOE ZERH, Living Building Challenge – all reference ASHRAE 62.2 or IMC (25 cfm in kitchen vs. 5ACH)
- Passive House – own program requirements, much lower than 62.2
- Enterprise Green Communities – either 62.2 or PH requirements if project is being certified and commissioned.
# Ventilation Rates

<table>
<thead>
<tr>
<th></th>
<th>PH</th>
<th>ASHRAE 62.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Supply</strong></td>
<td>&gt;= 0.3 ACH balanced</td>
<td>#(beds + 1) x 7.5 + area x 0.01</td>
</tr>
<tr>
<td><strong>Exhaust</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Kitchen</strong></td>
<td>35 cfm boost</td>
<td>5 ACH continuous*</td>
</tr>
<tr>
<td><strong>Bath</strong></td>
<td>24 cfm boost</td>
<td>20 cfm continuous</td>
</tr>
<tr>
<td><strong>Balanced</strong></td>
<td>Yes</td>
<td>Not required</td>
</tr>
<tr>
<td><strong>Verified</strong></td>
<td>Yes</td>
<td>Not required</td>
</tr>
<tr>
<td><strong>Efficiency Requirement</strong></td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

*ENERGY STAR: 25 cfm continuous in kitchen OK for PH projects if:
  - balanced ERV/HRV and
  - no open combustion appliances.
Ventilation Rates Example

Assumptions:
- 500 ft$^2$ Aptmt
- 8 ft ceilings
- 1 bedrooms
- Ithaca, NY
- 1 full bath
- Balanced ERV 80%
- 50 ft$^2$ kitchen

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<tr>
<td>Supply</td>
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</tr>
<tr>
<td>Bath</td>
<td>10/24</td>
<td>20 cfm</td>
</tr>
<tr>
<td>ACH</td>
<td>0.40 ave</td>
<td>0.86</td>
</tr>
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Central vs. Local ERV’s

![Graph showing ERV Power vs. Date]

- **120 Watts**
- **220 Watts**

**Images:**
- Exterior view of a building with an ERV intake.
- Interior view of an ERV.
Central vs. Local ERV’s

• If central in multi-family,
  – recommend constant volume to reduce complexity of controls
  – Must balance code and PH requirements
  – Special consideration from both parties may be necessary
  – Efficient equipment not available yet
Central vs. Local ERV’s

<table>
<thead>
<tr>
<th>Individual ERV</th>
<th>Central ERV</th>
</tr>
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<tr>
<td><strong>Pros</strong></td>
<td><strong>Cons</strong></td>
</tr>
<tr>
<td>• Resident Meter</td>
<td>• Owner Meter</td>
</tr>
<tr>
<td>• No slab penetrations</td>
<td>• No PH certified units available</td>
</tr>
<tr>
<td>• Continuous, boost flow easily achievable</td>
<td>• Floor space reduction</td>
</tr>
<tr>
<td>• PH certified units available</td>
<td>• Large slab penetrations</td>
</tr>
<tr>
<td>• Precedent for unitized ERV</td>
<td>• Fire rated shafts/dampers needed</td>
</tr>
<tr>
<td>• Reduction in horizontal ducts</td>
<td>• Complexity of controls for variable flow rates</td>
</tr>
<tr>
<td>• Continuous, boost flow achievable</td>
<td>• No precedent for central balanced system w/ HR in US</td>
</tr>
<tr>
<td>• Significantly reduced maintenance</td>
<td>• No wall penetrations</td>
</tr>
<tr>
<td>• No wall penetrations</td>
<td>• Filter change 3x/yr</td>
</tr>
<tr>
<td>• Ceiling height issues</td>
<td>• Loss of floor space if ceiling space unavailable</td>
</tr>
<tr>
<td>• Exhaust/intake separation restrictions</td>
<td>• Exterior maintenance of grills</td>
</tr>
<tr>
<td>• In-unit maintenance, filter change 3x/yr</td>
<td>• Large slab penetrations</td>
</tr>
<tr>
<td>• Loss of floor space if ceiling space unavailable</td>
<td>• Fire rated shafts/dampers needed</td>
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<td>• Complexity of controls for variable flow rates</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td><strong>Pros</strong></td>
</tr>
<tr>
<td>• 2 penetrations/apartment</td>
<td>• Resident Meter</td>
</tr>
<tr>
<td>• Ceiling height issues</td>
<td>• No slab penetrations</td>
</tr>
<tr>
<td>• Exhaust/intake separation restrictions</td>
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DESIGN CONSIDERATIONS
Delivery System Leakage

Implications of exhaust system leakage not as well understood by contractors

Leakage at sheetrock connections

Leakage at shaft/sheet metal connections
Integration Issues

• Exhaust from bathrooms?
• Integrate with central duct system?
Example ASHP

ERV

Supply from ERV to return plenum of AHU

Air handler return grill in LR
Comfort in Small Units

• 30 cfm is high for one small room
• Temperature of air very important - 80% efficient ERV will supply 56°F air to space if 0°F outside, 62°F if 30°F outside
• Preheat should be included for v. cold weather
• Pay attention to direction of throw from vent
• Need efficient preheat -90% or better
Other Considerations

- Increasing ventilation rate from 0.3 ACH to 0.45 ACH increases heat demand 17%
- ERV efficiency change from 0.85 to 0.75 increases heat demand by 23%
- Measurement is an issue under 10 cfm
- Duct tightness crucial to deliver proper flows
- # of occupants in certain types of buildings
HVAC: Multifamily Requirements

• Heating and cooling needed
• Individual control to accommodate different comfort levels
• Very energy efficient
• Limited ceiling heights and floor plans
• Renewables - not currently required, can help reach higher tiers
HVAC: Multifamily Options

- Options for multi-family buildings
  - central boiler + window A/C
  - Individual apartment air handlers
  - Mini-splits
HVAC: Potential Issues

• Central boiler + window A/C
  – Pro’s
    • Lower first cost
    • Can properly size heating system
  – Con’s
    • Through wall AC typically inefficient
    • Leakage hard to control
    • Thermal bridge through envelope
HVAC: Potential Issues

- Individual air handlers
  - Pro’s
    - Easy to meter occupants
  - Con’s
    - Small enough systems not readily available, efficiency suffers
    - Floor plan alterations to accommodate ductwork
    - Electric is typical to eliminate venting
HVAC: Potential Issues

• Mini-splits
  – Pro’s
    • Easy to meter occupants
    • Most efficient option for combined system
    • Part load operation easily achieved w/ VRF
  – Con’s
    • First cost
    • Refrigerant charge limitations
DOMESTIC HOT WATER
DHW Options

High Efficiency Options for PH

• Condensing gas boilers
• HPWH
• Solar thermal
• Geothermal
DHW Options - Central Systems

Pros

• Fuel options – gas venting easy
• Space savings in apartment

Cons

• Pump power must be minimized, incorporate on-demand controls where possible
• Extensive piping for recirc loops
• Need to insulate the recirc lines
DHW Options - Individual Systems

Pros

- No recirc piping needed
- Tenants billed directly

Cons

- Gas is difficult because of venting,
- HPWH not recommended in small spaces,
- More difficult to incorporate solar
Solar Costs & Benefits

Hot Water use: ~20 gal/unit-day

**Gas** cost w/o solar: $1,000/y
    w/ solar: $ 300/y
    Solar savings: $ 700/y

**Elec.** cost w/o solar: $3,600/y
    w/ solar: $ 1,100/y
    Solar savings: $2,500/y

Costs: $31,000 before; ~$9,000 after incentives

Solar “Issues”

- Operation & Maintenance
  - Smooth operation the exception?
- Monitor performance
- Clear O&M Instructions
- Explore service contracts
- Explore PPAs
Heat Pump Water Heaters

• Becoming more widely used
• No venting needed
• Efficient option compared with electric resistance tanks
• PV can offset DHW energy consumption
• Most manufacturers specify 750 to 1000 ft³ of space
• Vents should not be obstructed
Heat Pump Water Heaters

- AO Smith Commercial HP
  - Same issues as residential units
  - May be able to use waste heat from other spaces
  - Don’t install in spaces under 50°F
Other Options

- Ground-source heat pumps, split systems, CO2 HPWH
Questions?

Thank You.

Lois B. Arena, PE, CPHD