THE BASICS

SIZE: 4 Story, 78,011 sq. ft.
UNITS: (61) Senior Apartments

OCCUPANCIES:
Residential, Parking Garage, Tenant Space

CONSTRUCTION:
VA Construction Class
Wood-framed (Floor/Roof Trusses, Wall Panels)

EXTERIOR FINISHES: Brick, Fiber Cement

CONSTRUCTION START: December 2015
CONSTRUCTION COMPLETE: March 2017
CONSTRUCTION COST: $11.2 million
COST/Sq. Ft. $144/sq. ft.

PASSIVE HOUSE: PHA PHI (EUROPE)

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
PROJECT TEAM

PENNSYLVANIA HOUSING FINANCE AGENCY (PHFA)
STATE FUNDING AGENCY

PENNROSE PROPERTIES (PHILADELPHIA, PA)
OWNER / DEVELOPER / MANAGEMENT CO.

S.B. CONRAD (CHESTER HEIGHTS, PA)
GENERAL CONTRACTOR

KITCHEN & ASSOCIATES (COLLINGSWOOD, NJ)
ARCHITECT / MEP ENGINEER / SYSTEMS COMMISSIONING

WRT (PHILADELPHIA, PA)
PASSIVE HOUSE CONSULTANT

INNOVA (PHILADELPHIA, PA)
OWNER'S REPRESENTATIVE / ENERGY SERVICES RATER

MPP ENGINEERS (JACKSON, NJ)
STRUCTURAL ENGINEER

T&M (BETHLEHEM, PA)
CIVIL ENGINEER

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
FIRST FLOOR

*Residential Lobby, Community Room, Management Suite, & Utility Rooms

*Covered Parking Garage

*Commercial Tenant

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
TYPICAL UPPER FLOOR

*(21) Residential Apartments per floor

*Common Laundry

*Amenity Space

*Roof Deck (4th Floor)
PROJECT TIMELINE

Late 2013  Project first submitted to PHFA for funding – Not Funded
Late 2014  PHFA modifies its evaluation criteria to include PH incentive points
Early 2015  Project resubmitted to PHFA for funding incorporating Passive House
June 2015  Project awarded LIHTC funding
August 2015  Design Development & Construction Document drawing process
December 2015  Construction commences
February 2017  Construction nears completion – Substantially Complete
April 2017  Punch list process, Energy Star & Passive House testing
July 2017  Project submitted to PHA/PHI for final certification
?  Final Passive House certification

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
PASSIVE HOUSE ENVELOPE

Airtight and insulated envelope

Connection details are critical

Heavy detailing work and strategies determined early on.

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
EXTERIOR WALL & FOUNDATION

Exterior Wall (R-31 total)
- Brick/Fiber Cement
- 2” Polyiso Insulation
- Zip Sheathing System (Air Barrier)
- 2x6 Stud panels w/ Kraft R-21 (Vapor Retarder)
- 5/8” Gypsum Board

Slab on Grade (R-11 typical)
- 4” Reinforced concrete slab
- 6 Mil Polyethylene (Air/Vapor Barrier)
- 2” XPS Insulation / 3” (R-15) at perimeter
- 1” Thermal break at slab

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
Roof (R-62 total)

- EPDM system
- 4” Polyiso Insulation
- ¾” OSB Sheathing (Air Barrier)
- 11” Open Cell Spray Foam Insulation
- Pre-fabricated Wood Roof Trusses
- ½” Resilient Channels
- 5/8” Gypsum Board
WINDOWS

Triple pane, Thermally-broken
Tilt & Turn, UPVC
U-values 0.16 - 0.18

Fabricated and shipped from Europe

Liquid Flashing System
Expanding Foam Tape

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
DOORS

- Aluminum frames
- Thermally broken frames
- Double pane glazing, verified with PHPP

U-value 0.24, SHGC 0.39

American doors avoided conflicts with electronic hardware
**BIG PICTURE CHALLENGES**

**Time Constraints**
*Developer closes on financing

*One year construction schedule is typical

**Cost Limitations**
*Development cost limitations per square foot

**Other Considerations**
*Training/Learning Curve (Professionals & GC/Subs)

*Interaction of team and need for integrated design

**ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE**
Trash Chute & Compactor Room
Trash chute vents through the roof above

Taped zip sheathing creates air barrier around chute

Liquid air barrier on walls and taped zip sheathing at ceiling help isolate Compactor Room
IN / OUT OF ENVELOPE

Parking Garage
(12) Spaces of covered parking

Originally planned for blown-in insulation. Due to multiple holes required for blow-in process, open cell foam was used to allow installation prior to air barrier installation.

Taped zip sheathing creates air barrier

4" continuous polyiso insulation used below zip sheathing

Steel framing created challenges: zones + envelope wrapped around framing

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
IN / OUT OF ENVELOPE

Common Laundry
Common dryers required makeup air and exhaust venting through the envelope

Drawing air from room would have caused issues with the balanced ERV system

Tenant Space
Tenant fit out work scheduled for after construction completion and Passive House testing

Owner must convey importance of exterior envelope to future tenant

Elevator Hoistway Venting
2009 IBC required smoke venting of elevator hoistway

Low leakage, alarm-activated damper used to mitigate air leakage

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
AIR BARRIER CONTINUITY

Slab to Exterior Wall Connection
Detail called for underslab vapor barrier to route through foundation detail and lap on to zip sheathing system

Lap over was left exposed to elements, loose, and mistakenly cut in locations
Solution applied liquid air barrier on interior at floor/wall joint

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
OTHER CHALLENGES

Wall Panel Studs
2x6 wall panels were heavy with studs due to opening headers and panel joints

Stick framing may have been beneficial in certain locations

Window Clips & Expanding Foam Tape
Window clips were used as a better way to secure heavy windows

Clips pinched foam tape

Foam tape continuous at corners requiring caulk

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
MECHANICAL SYSTEMS

• Are there economical mechanical systems that can effectively condition the dwelling unit having such reduced heating & cooling loads?

• What’s the availability of the equipment?

• What’s the overall maintenance cost?

• What defines effective conditioning?

• What’s the performance criteria?

• What are the short and long term effects of oversized heating and cooling systems?

• Right-sizing the HVAC equipment
Typical Passive House Heating and Cooling peak loads range

- For a 1-Bedroom Dwelling Unit, roughly 700 SF, the heating load were approximately 6000 BTUH and Total Cooling was 7500 BTUH (Total Sensible 6500 BTUH)

- For a 2-Bedroom Dwelling Unit, roughly 845 SF, the heating load were approximately 7000 BTUH and Total Cooling was 9400 BTUH (Total Sensible 8100 BTUH)

REMEMBER…. These are worst case (peak load condition) scenarios

Real World
- Cooking (creates heat and moisture)
- Showering (creates heat and moisture)
- Open doors or windows (affect heating and cooling and relative humidity)
- Other occupant behavior (activity level, personal thermal comfort, habits, etc.)
Oversizing of HVAC equipment is a common practice

- Reduces comfort and energy efficiency
- Results in higher first costs (purchasing larger equipment)
- Negatively impacts the effects of residential air conditioning on utility peak demand. The immediate starting and stopping of the compressor causes quick and sudden burst of energy usage.
- One major issue of oversized equipment is humidity removal… especially in Passive House buildings.
Using Air Conditioners to remove moisture

- The air conditioner must remove excess humidity before cooling the air (Latent Cooling)
  - The absolute worst condition: using the AC to remove moisture during the swing months (when outdoor temperatures are low and humidity is high)
  - Manufacturers slow down the fan to allow cooling, which results in excessively cold air causing metal ducts to condense.

Use a Whole House De-Humidifier?

- It will de-humidify the home, especially during the shoulder months
  - But will introduce sensible heat into the home
  - Additional equipment and increased first cost
  - Adds complexity to the system
SPACE CONDITIONING

Apartment Units:
VRF Heat Pumps, ducted, ceiling mounted

Common Spaces:
VRF Systems: Vertical ducted, wall mounted, and ceiling ducted

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
Central Energy Recovery Ventilation Equipment, (1) per floor, corridor ducted in/out of every apartment

Performance statements: Does stated performance meet actual field installed performance?
EQUIPMENT SELECTION
CONSIDERATIONS

Lessons Learned:

• Equipment selection drives costs & must be acceptable to all parties.

• Best multi-family systems tend to be right-sized, industry standard, simple controls, easy / low-tech maintenance, and availability/accessibility to replacement parts.

• Humidity control is a challenge, especially when dwelling units are small and “right-size” equipment is not readily / economically available.

• The U.S. Department of Energy estimates that mini-split air conditioners cost about 30 percent more than central systems based on cooling capacity.

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
ENERGY CONSUMPTION

Do not forget the internal loads will affect the overall energy use of the facility:

- Appliances: Energy Star: Dishwasher, Washer, Dryer, Refrigerator/Freezer
- Lighting: LED
- Plug Loads:
- Domestic Hot Water: Individual vs Central
- Elevator: Machine & Drive, Controls, Lighting & Standby Energy

Source: http://www.naturaltools.com
ENERGY MODELING

PASSIVHAUS (PHI) : PHPP
PHIUS+ : WUFI

Regardless of the certification selected the following needs to be considered during the design phase.

• Run preliminary models utilizing differing envelope conditions, building shape & orientation, glazing & insulation for discussions during design concepts.

• Run pre-final models while adding internal loads, mechanical equipment, ventilation and infiltration scenarios.

• Run final models indicating accepted design approach.

• Do not forget to run a “Hygrothermal” study model in mixed climate conditions.

Lesson Learned: Changing building elements during construction can critically affect the energy model and possibly affect final certification. The final design & construction techniques need to be resolved during the design process. “Integrated Design”.

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
Local building codes and referenced standards affect the design process as codes have not caught up to the affects of Passive House design.

- Most affected where ventilation requirements between, IMC, ASHRAE 90.1 & 90.2 ASHRAE 62.1 & 62.2 and other Energy Standards requirements

When Energy Star requirements are added, you must consider utilization of the “Prescriptive” or “Performance” method.

Enterprise Green Communities, or other sustainable initiatives, will add additional overlaps that must be considered.

**Lesson Learned:** Perform your code and standards research very early in the process. Contact your code officials when running into conflicts.
Testing/Verification

Passive House Testing Includes:
- Envelope blower door testing
- Duct blaster (leakage) testing
- Ventilation system balancing
- Final blower door testing
- Systems equipment commissioning & verification

Preliminary Blower Door Test
Test envelope prior to insulation in drywall for a better sense of issues with the air barrier continuity

Final Blower Door Test
Two locations: Community Room + Roof Deck
Final result: 0.56 ACH50
THE COST OF PASSIVE HOUSE

• 5% additional to construction contract resulting from Passive House products, strategies, etc

• Analyzing change orders was difficult because General Contractor absorbed some Passive House related costs as part of a contingency or at a loss

• The following components made up the 5% additional cost:
  • $400K  Mechanical
  • $117K  Air tightness/sealing
  • $110K  Windows
  • $40K   Continuous Insulation (Wall + Roof)
  • $32K   Miscellaneous
  • $26K   Exterior Doors
  • $22K   Continuous Underslab Insulation

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
BUT THIS IS A PHIUS CONFERENCE!

What if this project was certified under PHIUS+ 2015? What, if any, are difference in Envelope, Systems, Construction?

PASSIVHAUS (PHI) Criteria
Primary Energy: 38 kBTU/sf/year
Annual Heat/Cool. Demand: 4.75 kBTU/sf/year
Peak Heat Load: 3.14 BTU/sf hr.
Peak Cooling Load: 2.54 BTU/sf hr.
Ventilation: 75% efficiency & < or = 0.76 W/CFM

PHIUS+ 2015 Criteria
Primary Energy: \(<\) or = 6200 kWh/yr/person
Annual Heat Demand: 1.0 – 12.0 kBTU/sf/year
Annual Cooling Demand: 1.0 – 21.4 kBTU/sf/year
Peak Heat Load: 0.8 – 5.4 BTU/sf hr.
Peak Cooling Load: 1.8 – 8.9 BTU/sf hr.
Ventilation: 53% - 95% efficiency & 0.27 – 2.23 W/CFM

PHIUS+ Criteria is climate specific and provides for differences in location climate throughout North America.

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
1. Converted Model From PHPP To WUFI Passive
   • (Thank You Lisa White, James Ortega and PHIUS+ Team)
2. Reconciled Issues With PHIUS 2015+ Requirements
   • Building Source Energy Exceeds Allowable Source Energy
3. Identified Best Way To Meet PHIUS 2015+ Requirements
   • Required Adding 100 kW PV System
4. Identified Reductions In Envelope Components To Meet Minimum Requirements

ACHIEVING AFFORDABILITY IN MULTIFAMILY PASSIVE HOUSE
SOURCE ENERGY WAS GREATER

• WHAT WAS THE CAUSE?
  • Sq/ft per resident; When you get over the 500 SF/person threshold, it’s difficult to meet the source energy requirements

• HOW DO WE RESOLVE IT?
  • By Adding a 100 kW PV system

• What if you can’t accommodate the 100 kW PV system in the Project (Physically or Financially)?

### PHIUS+ 2015 COMPARATIVE STUDY

<table>
<thead>
<tr>
<th>Source Energy (kBtu/ft² yr)</th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version As Designed</th>
<th>PHIUS+ 2015 Version Updated Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Demand (kBtu/ft²*yr)</td>
<td>3.89</td>
<td>2.21</td>
<td>5.28</td>
</tr>
<tr>
<td>Cooling Demand (kBtu/ft²*yr)</td>
<td>2.74</td>
<td>3.27</td>
<td>2.09</td>
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<tr>
<td>Heating Load (Btu/hr*ft²)</td>
<td>3.07</td>
<td>2.83</td>
<td>3.97</td>
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<tr>
<td>Cooling Load (Btu/hr*ft²)</td>
<td>1.93</td>
<td>2.65</td>
<td>2.11</td>
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<tr>
<td>Source Energy (kWh/person)</td>
<td>8,800</td>
<td>6,111</td>
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</tr>
<tr>
<td>Source Energy (kBtu/ft²*yr)</td>
<td>36.61</td>
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</tbody>
</table>
### PHIUS+ 2015 Comparative Study

<table>
<thead>
<tr>
<th>Opaque Components</th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version As Designed</th>
<th>PHIUS+ 2015 Version Updated Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls (R-Value)</td>
<td>30.9</td>
<td>30.9</td>
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<tr>
<td>Roof (R-Value)</td>
<td>62.3</td>
<td>62.3</td>
<td>48</td>
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<td>Wall to Ground (R-Value)</td>
<td>24.7</td>
<td>24.7</td>
<td>24.7</td>
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<tr>
<td>Slab (R-Value)</td>
<td>12</td>
<td>12</td>
<td>5</td>
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<tr>
<td>Floor to Garage (R-Value)</td>
<td>85.4</td>
<td>85.4</td>
<td>30.9</td>
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<tr>
<td>Exterior Doors (R-Value)</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Trash Chute Wall (R-Value)</td>
<td>15</td>
<td>15</td>
<td>15</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Transparent Components</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Windows - South (U-value)</td>
<td>0.1716</td>
<td>0.1716</td>
<td>0.36</td>
</tr>
<tr>
<td>Windows - South (SHGC)</td>
<td>0.49</td>
<td>0.49</td>
<td>0.32</td>
</tr>
<tr>
<td>Windows - East (U-value)</td>
<td>0.1648</td>
<td>0.1648</td>
<td>0.36</td>
</tr>
<tr>
<td>Windows - East (SHGC)</td>
<td>0.49</td>
<td>0.49</td>
<td>0.32</td>
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<tr>
<td>Windows - North (U-value)</td>
<td>0.1811</td>
<td>0.1811</td>
<td>0.36</td>
</tr>
<tr>
<td>Windows - North (SHGC)</td>
<td>0.49</td>
<td>0.49</td>
<td>0.32</td>
</tr>
<tr>
<td>Windows - West (U-value)</td>
<td>0.1742</td>
<td>0.1742</td>
<td>0.36</td>
</tr>
<tr>
<td>Windows - West (SHGC)</td>
<td>0.49</td>
<td>0.49</td>
<td>0.32</td>
</tr>
</tbody>
</table>

### Climate Specific Window Recommendations

![Climate Specific Window Recommendations](image.png)

**Achieving Affordability in Multifamily Passive House**
# PHIUS+ 2015 Comparative Study

## Direct Conversion from PHI to PHIUS+

<table>
<thead>
<tr>
<th>Heat Gains</th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version As Designed</th>
<th>PHIUS+ 2015 Version Updated Model to Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar: 196,867 kBTU/yr</td>
<td>1.748</td>
<td>1.748</td>
<td>1.748</td>
</tr>
<tr>
<td>Inner sources: 395,651 kBTU/yr</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Mechanical heating: 142,616 kBTU/yr</td>
<td>Ref Column Base (Btu/hr*ft°F) 1.748 Length (ft) 15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation: 250,491 kBTU/yr</td>
<td>C4 Column at Garage Ceiling (Btu/hr*ft°F) 0.016 Length (ft) 83.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Losses</td>
<td>0.244</td>
<td>0.244</td>
<td>0.244</td>
</tr>
<tr>
<td>Opaque building envelope: 264,602 kBTU/yr</td>
<td>Slab-Wall Connection (Btu/hr*ft°F) 0.244 Length (ft) 639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Windows &amp; Doors: 166,249 kBTU/yr</td>
<td>Length (ft) 639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural ventilation: 42,429 kBTU/yr</td>
<td>Length (ft) 639</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical ventilation: 250,491 kBTU/yr</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Adjusted PHIUS+ for Improvements

<table>
<thead>
<tr>
<th>Heat Gains</th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version As Designed</th>
<th>PHIUS+ 2015 Version Updated Model to Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar: 150,457 kBTU/yr</td>
<td>1.1</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Inner sources: 405,927 kBTU/yr</td>
<td>Laundry Washer (kwh/use)</td>
<td>2.15</td>
<td>2.15</td>
</tr>
<tr>
<td>Mechanical heating: 249,307 kBTU/yr</td>
<td>Laundry Dryer (kwh/use)</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Mechanical ventilation: 221,832 kBTU/yr</td>
<td>Refrigerator (kwh/day*unit)</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Heat Losses</td>
<td>Misc (kwh/yr) 40,432</td>
<td>Elevators (kwh/yr) 2,683</td>
<td></td>
</tr>
<tr>
<td>Opaque building envelope: 308,726 kBTU/yr</td>
<td>Interior Lighting (kwh/yr)</td>
<td>60,148</td>
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</tr>
<tr>
<td>Windows &amp; Doors: 223,165 kBTU/yr</td>
<td>Exterior Lighting (kwh/yr)</td>
<td>5,405</td>
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<tr>
<td>Natural ventilation: 42,496 kBTU/yr</td>
<td>Garage Lighting (kwh/yr)</td>
<td>8,935</td>
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<tr>
<td>Mechanical ventilation: 221,832 kBTU/yr</td>
<td>Miscellaneous Loads (kwh/yr) 583</td>
<td>Plug Loads 6,336</td>
<td></td>
</tr>
</tbody>
</table>

## Internal Loads

| PHI Version | PHIUS+ 2015 Version As Designed | PHIUS+ 2015 Version Updated Model to Results |
| Dishwasher (kwh/use) 1.1 | Laundry Washer (kwh/use) 1.1 |
| Laundry Dryer (kwh/use) 2.15 | Refrigerator (kwh/day*unit) 1.0 |
| Misc (kwh/yr) 40,432 | Kitchen Cooktop (kwh/use) 0.25 |
| Interior Lighting (kwh/yr) | |
| Exterior Lighting (kwh/yr) 5,405 | |
| Garage Lighting (kwh/yr) 8,935 | |
| Elevators (kwh/yr) 2,683 | Miscellaneous Loads (kwh/yr) 583 |
| Plug Loads 6,336 | Small Appliances (kWh/yr) 7,200 |

## Achieving Affordability in Multifamily Passive House

![PHIUS+ 2015 Comparative Study Diagram]

![PHIUS+ 2015 Comparative Study Diagram]

![PHIUS+ 2015 Comparative Study Diagram]
### PHIUS+ 2015 COMPARE STUDY

#### DIRECT CONVERSION FROM PHI TO PHIUS+

![Energy Balance Diagram](image)

#### ADJUSTED PHIUS+ FOR UPGRADES

![Energy Balance Diagram](image)

### Ventilation

<table>
<thead>
<tr>
<th></th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version (As Designed)</th>
<th>PHIUS+ 2015 Version (Updated Model to Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Air due to persons (cfm)</td>
<td>2592</td>
<td>2322</td>
<td>2322</td>
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<tr>
<td>Total extract air demand (cfm)</td>
<td>3826</td>
<td>4545</td>
<td>4545</td>
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<tr>
<td>Volumetric requirements (cfm)</td>
<td>3439.74</td>
<td>4324.36</td>
<td>4324.36</td>
</tr>
<tr>
<td>Design air flow rate (cfm)</td>
<td>3826</td>
<td>4545</td>
<td>4545</td>
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<tr>
<td>Average air flow rate (cfm)</td>
<td>4644.3</td>
<td>5355.25</td>
<td>4614.25</td>
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<tr>
<td>Average air change rate (1/hr)</td>
<td>0.53</td>
<td>0.48</td>
<td>0.48</td>
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</table>

### Rooms Ventilation

<table>
<thead>
<tr>
<th></th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version (As Designed)</th>
<th>PHIUS+ 2015 Version (Updated Model to Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Air (cfm)</td>
<td>3826</td>
<td>4545</td>
<td>4545</td>
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<tr>
<td>Exhaust Air (cfm)</td>
<td>3826</td>
<td>3820</td>
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### Exhaust Ventilation

<table>
<thead>
<tr>
<th></th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version (As Designed)</th>
<th>PHIUS+ 2015 Version (Updated Model to Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Dryer (cfm)</td>
<td>125</td>
<td>125</td>
<td>125</td>
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<tr>
<td>Exhaust Dryer Run Time (min/yr)</td>
<td>325036.8</td>
<td>291178.8</td>
<td>291178.8</td>
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<tr>
<td>Other Exhaust Appliances (cfm)</td>
<td>741</td>
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<tr>
<td>Other Exhaust Appliances Run</td>
<td>525600</td>
<td>525600</td>
<td>525600</td>
</tr>
<tr>
<td>Time (min/yr)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Ventilation

<table>
<thead>
<tr>
<th></th>
<th>PHI Version</th>
<th>PHIUS+ 2015 Version (As Designed)</th>
<th>PHIUS+ 2015 Version (Updated Model to Results)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Air due to persons (cfm)</td>
<td>2592</td>
<td>2322</td>
<td>2322</td>
</tr>
<tr>
<td>Total extract air demand (cfm)</td>
<td>3826</td>
<td>4545</td>
<td>4545</td>
</tr>
</tbody>
</table>
The ERV efficiency is slightly higher because

1. The equipment is HVI / AHRI rated equipment
2. Doesn’t have to be de-rated if the equipment is not PHI approved
3. We can select a more efficient equipment