PASSIVE HOUSE IN STUDENT HOUSING

WILLIAMS + WHEATON COLLEGE
PHIUS NAPHC 2018

ARCHITECTURE | PLANNING
INTERIOR DESIGN | VDC
BRANDED ENVIRONMENTS
SGA
WHO WE ARE

JACOB HIGGINBOTTOM
DIRECTOR OF HIGHER EDUCATION STUDIO

ANDREW STEINGISER
PROJECT ARCHITECT, CPHC

MICHAEL PULASKI
PHIUS AND ENERGY CONSULTANT

EXPERTS IN DESIGN FOR
• HIGHER EDUCATION FACILITIES
• CORPORATE OFFICE BUILDINGS
• CORPORATE INTERIORS
• CUTTING EDGE VIRTUAL DESIGN STUDIO
PROJECT CONTEXTS
IN 2017 SGA WAS HIRED TO:

WILLIAMS COLLEGE GARFIELD HOUSE

- Design 40 beds of student housing with aggressive energy performance EUI 28.
- Assist in decision to renovate existing 1850 residence hall or demolish and build new.
- Considered “deep energy retrofit”
- Design a project that feels like a “home” and not a residence hall.
- PHIUS was brought in by consulting team as a metric for consideration to advance college energy performance standards.
- Certify the project with USGBC as LEED GOLD
- Design a building contextual with surrounding residential neighborhood
- Integrate the building with the surrounding landscape.
PROJECT CONTEXTS
IN 2017 SGA WAS HIRED TO:

WHEATON COLLEGE RESIDENCE HALL

• Provide the maximum number of beds allowed by budget.
• Design a contextual solution fitting in the lower campus 1950’s architecture.
• Decide fate of existing dorm at the site to renovate or demolish.
• Design a PHIUS certified building for maximum energy savings.
• No LEED certification pursued.
• Create a building that completes the quadrangle of first year student housing and offers a sense of community to this part of campus.
• Integrate a multi-purpose space for first year student orientation and gatherings.
• Design a brick clad building to fit in with surrounding buildings.
WILLIAMS COLLEGE GARFIELD HOUSE

- Wood framed construction with HardiPlank siding
- Traditional contextual design
- 2.5 story 40 bed residence hall
- Scheduled occupancy fall 2019
- Suite style living arrangement (6 students/group/bath)
- No active cooling

<table>
<thead>
<tr>
<th>Building area</th>
<th>Construction cost</th>
<th>Cost/SF</th>
<th>Total beds</th>
<th>Area /Student</th>
<th>Cost/ Bed</th>
<th>Design EUI</th>
</tr>
</thead>
<tbody>
<tr>
<td>16,500 gsf</td>
<td>$9.5M</td>
<td>$575.00</td>
<td>40</td>
<td>413 SF/bed</td>
<td>$237,500</td>
<td>28.2</td>
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</tbody>
</table>

WHEATON COLLEGE RESIDENCE HALL

- Steel frame/ precast plank construction & brick veneer
- Modern contextual design (1950’s campus)
- 3.5 story 178 bed residence hall
- Scheduled occupancy fall 2019
- Wing style living arrangement (30 students/Wing/bath)
- Cooling provided

<table>
<thead>
<tr>
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<th>Design EUI</th>
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</thead>
<tbody>
<tr>
<td>45,000 gsf</td>
<td>$21.5M</td>
<td>$466.00</td>
<td>178</td>
<td>253 SF/bed</td>
<td>$120,800</td>
<td>26.6</td>
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</table>
PROJECT SITES

- Suburban site
- Orientation predetermined
- Expressed connections to nature

WILLIAMS

WHEATON

NORTH
PLAN LAYOUTS

WILLIAMS COLLEGE
GARFIELD HOUSE
Suite style arrangement 6 students/bath

WHEATON COLLEGE
RESIDENCE HALL
Double loaded corridors with central lounge/toilet core
EXPRESSED CONNECTION TO NATURE
WHEATON

EXPRESSED CONNECTION TO NATURE

SGA COMMUNICATING. COLLABORATING. CREATING

NAPHC 2018 9/22/18 | 9
PASSIVE HOUSE DESIGN COMPONENTS - ROOMS

Phase change materials in the walls and ceilings mitigate heat on hot days

Electric radiant heat source can be located off the floor to free floor space – only one per room required

Operable windows provide fresh air for student comfort

WILLIAMS COLLEGE
PASSIVE HOUSE DESIGN COMPONENTS - ROOMS

WHEATON COLLEGE

Single
145 sf

Double
190 sf

16' - 0"

9' - 1 1/2"

11' - 10 1/2"

D - Surface mounted downlight

C - Wall mount up / down light

GWB – 7'-9"

valance unit

SINGLE RCP

EXP

9' - 0"

valance unit

DOUBLE RCP

EXP

9' - 0"

EXP : exposed underside of slab ceiling, painted white

Recessed Curved Valance Cover

RCP

PASSIVE HOUSE DESIGN COMPONENTS - ROOMS

WHEATON COLLEGE

SGA COMMUNICATING. COLLABORATING. CREATING

WHEATON COLLEGE | RESIDENCE HALL | 11

02.14.18
ENVELOPE

ROOF: R-60
WALLS: R-38
SLAB: R-20
THERMAL MASS
PHASE CHANGING MATERIAL

WILLIAMS

ROOF: R-50
WALLS: R-32
SLAB: R-20
FLEX SPACE OUTSIDE PH

WHEATON
GLAZING AND SHADING

WINDOWS:
U 0.17
SHGC 0.369 -0.558

WINDOW/WALL:  30%

WILLIAMS

WINDOWS:
U 0.2
SHGC 0.37

CURTAINWALL:
U 0.18
SHGC 0.25

WINDOW/WALL:  31%

WHEATON
WOOD VS. STEEL - WHEATON COLLEGE

WOOD:
- MORE COMPACT STRUCTURE
- POTENTIALLY FASTER CONSTRUCTION
- LESS LEAD TIME THAN STEEL
- HIGHER CAVITY EFFECTIVE R-VALUE
- LESS POTENTIAL FOR STRUCTURAL THERMAL BRIDGES
- RENEWABLE RESOURCE

STEEL+COMPOSITE DECK:
- LONGER SPANS
- BUILT IN FIRE RATING AT FLOORS
- LESS RELIEVING ANGLES REQUIRED FOR BRICK
- RECYCLED CONTENT
- GREATER PERCEIVED DURABILITY
WOOD VS. STEEL – WILLIAMS VS. WHEATON

WILLIAMS:
• NO ADDITIONAL STRUCTURE BEYOND WOOD STUDS
• MORE FLEXIBLE STRUCTURE/OPENINGS CAN BE FIELD MODIFIED
• THERMALLY BROKEN Z-GIRTS ONLY PENETRATION IN RAINSCREEN

WHEATON:
• NEED TO COORDINATE STEEL COLUMNS IN PLAN WITH PARTITIONS
• COMPLICATED SLAB EDGE DETAIL WITH UPSET STEEL FOR HEADROOM
• STEEL/PLANK NEED TO BE CLOSELY COORDINATED, INCLUDING WITH HVAC FOR ALL PENETRATIONS
• THERMALLY BROKEN BRICK TIES, RELIEVING ANGLES AND Z-GIRTS
Williams College Garfield Residence
Passive House Design Features

- 30% Window to Wall Ratio
- South Exterior Shading
- Passive Solar Design
- PV to offset Electric Heating Demand
- R60 Roof
- Triple Glazed Windows with Fiberglass Frame U-0.17
- R38 Walls
- R20 Underslab
ERV Efficiency 84%
- Swegon Unit
- Must be AHRI/ PHI Certified

Intermittent Bathroom Vent
- Saves 400 CFM of Exhaust = 4% site EUI savings

Balanced Ventilation Design
- Limit Exhaust only systems (Trash room)

Laundry Rooms
- Through wall make up air

Use Demand Control Ventilation in Living Room
Williams College Garfield Residence

Drainwater Heat Recovery

Reduces DHW Heating Energy by ~20-30%
Williams College Garfield Residence
55 kW PV Array
48,000 kwh/year
Williams College Garfield Residence

Energy Analysis - Energy Use Intensity Breakdown by Design Case

ASHRAE 90.1 2007 Baseline

Target EUI: 28

Proposed Design

Proposed Design (with PV)

54.7

28.2

20.9
Passive House Analysis
Williams College Garfield Residence

Passive House Model Results

Heating demand: 4.76 kBtu/ft² yr

Cooling demand: 0.74 kBtu/ft² yr

Heating load: 4.43 Btu/hr ft²

Cooling load: 1.64 Btu/hr ft²

Source energy: 6,022 kWh/Person yr
Williams College Garfield Residence
Energy Recovery Ventilation Unit Efficiency

Current Assumption: 84%

Alternative Assumption: 75%

31% Increase
16% Increase
12.7% Increase
Williams College Garfield Residence

Ventilation Analysis

Current Assumption: Continuous 2300 cfm + Kitchen 400 cfm

Alternative Assumption: Continuous 3000 cfm + Kitchen 400 cfm

- Heating demand: 6.38 kBtu/ft²yr
- Cooling demand: 0.26 kBtu/ft²yr
- Heating load: 4.03 Btu/hr ft²
- Cooling load: 1.22 Btu/hr ft²
- Source energy: 5,125 kWh/Person yr
- Site energy: 17.07 kBtu/ft²yr

16% Increase
8% Increase
8% Increase
Williams College Garfield Residence
Phase Change Material Study

THERMAL SIMULATION MODEL RESULTS

Second Floor/West Dorm Room (Operative temperature)

Cost: ~$3/sf

Peak Cooling Temp Reduction 10F

PCM Mats
• 16” wide x 48” long
• 24” wide x 48” long
• Class A Fire Rated
• Salt Hydrate
• 25 Year Longevity Warranty
• Standard Melt/Freeze Temps

55°F | 65°F | 71°F | 73°F | 78°F | 84°F
Williams College Garfield Residence
Passive House Cost Analysis
Wheaton College – Dormitory

High Performance Envelope Systems

- High Performance Triple Glazed Windows
  - U-value: 0.18
- High Performance Triple Glazed Curtainwall
  - U-value: 0.17
- Roof
  - R-value: 50
- Walls
  - R-value: 32
- Commons/multi-purpose center not included in PH envelope
- Airtight Construction
  - Infiltration rate: 0.05 CFM/SF
- Optimized Exterior Shading
Wheaton College – Dormitory

High Performance HVAC Systems

- Rooftop PV Capacity Estimate ~80kw
- 4 pipe Valance Units
- Condensing Boilers: Hot water
- Dry Cooler/WSHP: Cooling
- High Efficiency Energy Recovery Ventilation 84% Efficiency
- Drainwater Heat Recovery Reduces DHW energy use by 20-30%
- Continuous Air Barrier & Continuous Insulation Enclosed thermal envelope

Drainwater Heat Recovery
- Hot used water
- Pre-heated water
- Cold water
- Cooled used water
Wheaton College – Dormitory
HVAC System Selection

Primary Energy

<table>
<thead>
<tr>
<th>kWh/person/yr</th>
<th>Central Plant</th>
<th>Distribution</th>
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<tbody>
<tr>
<td>Option 1A</td>
<td>Geothermal</td>
<td>Valance Unit</td>
</tr>
<tr>
<td>Option 1B</td>
<td>Geothermal</td>
<td>FCU</td>
</tr>
<tr>
<td>Option 2A</td>
<td>VRF</td>
<td>VRF</td>
</tr>
<tr>
<td>Option 3A</td>
<td>Geothermal (back up boiler)</td>
<td>Valance Unit</td>
</tr>
<tr>
<td>Option 3B</td>
<td>Geothermal (back up boiler)</td>
<td>FCU</td>
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<tr>
<td>Option 4</td>
<td>Air-to-Water Heat Pump (Boiler)</td>
<td>Valance Unit</td>
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<tr>
<td>Option 4A</td>
<td>Air-to-Water Heat Pump (Boiler)</td>
<td>FCU</td>
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<tr>
<td>Option 4B</td>
<td>Air-to-Water Heat Pump (Steam)</td>
<td>Valance Unit</td>
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<tr>
<td>Option 4C</td>
<td>Air-to-Water Heat Pump (Steam)</td>
<td>FCU</td>
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</tbody>
</table>
Wheaton College – Dormitory

Energy Use Intensity Breakdown by Design Case

ENERGY USE BREAKDOWN BY DESIGN CASE

ASHRAE 90.1 2013 - Code

- Plug loads
- Lighting
- Appliances
- Fans
- DHW
- Cooling
- Heating

Proposed Design Case

78.0 kBtus/yr

66% Energy Savings

26.6 kBtus/yr
ENERGY COST BREAKDOWN BY DESIGN CASE

ASHRAE 90.1 2013 - Code

- Plug loads
- Lighting
- Appliances
- Fans
- DHW
- Cooling
- Heating

Proposed Design Case

$69,500

50% Energy Cost Savings

$35,000

$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-

$10,000
$20,000
$30,000
$40,000
$50,000
$60,000
$70,000
$80,000

- Heating

- Fans

- DHW

- Cooling

- Appliances

- Lighting

- Plug loads
Wheaton College – Dormitory

Energy Use Intensity Breakdown by End Use

76% Heating Energy Savings

51% Domestic Hot Water Savings

 kbtsf/yr

ASHRAE 90.1 2013 - Code
Proposed Design Case

Heating
Cooling
DHW
Fans
Appliances
Lighting
Plug loads
Wheaton College – Dormitory

Site Energy Comparison (EUI)

BUILDING ENERGY USE INTENSITY (EUI) COMPARISON

ASHRAE 90.1 2013 - Baseline
Proposed Design Case
Williams College
URI
Bowdoin
Framingham State

kBtu/sf·yr

66% savings
Wheaton College – Dormitory

Site Energy Comparison (Per Person)

BUILDING ENERGY USE PER PERSON COMPARISON

kBtu/person-yr

ASHRAE 90.1 2013 - Baseline
Proposed Design Case
Williams College
URI
Bowdoin
Framingham State
Passive House Analysis
Wheaton College – Dormitory

Model Results Against PH Thresholds

- Heating demand: 2.19 kBtu/ft²yr
- Cooling demand: 2.1 kBtu/ft²yr
- Heating load: 4.1 Btu/hr ft²
- Cooling load: 3.12 Btu/hr ft²
- Source energy: 3,390 kWh/Person yr

All thresholds are met.
Wheaton College – Dormitory

Passive House Boundary

- Excluding First floor (flexible space)
- Separate metering: electric, chilled water, hot water, DHW
- Separate Ventilation (AHU)
- Separate Air Barrier
Wheaton College – Dormitory

Cost Analysis for Passive House

CONSTRUCTION COST

2.5% Premium
## WUFI Passive Model Inputs

### WUFI Passive Model Input Parameter

<table>
<thead>
<tr>
<th>Building Envelope</th>
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<tbody>
<tr>
<td>Roofs Construction</td>
<td>Assembly R-50 (U-0.02)</td>
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<tr>
<td>Walls (Above Grade)</td>
<td>Assembly R-32 (U-0.02)</td>
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<tr>
<td>Ground Floor</td>
<td>R-20 (U-0.05)</td>
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<tr>
<td>Building Shell Area Infiltration</td>
<td>0.05 CFM/SF @ 50 Pascal's (PASSIVE HOUSE LEVEL)</td>
</tr>
<tr>
<td>Glazing U-factor (Punch windows)</td>
<td>Assembly U-0.20</td>
</tr>
<tr>
<td>Glazing U-factor (Curtainwall)</td>
<td>Assembly U-0.17</td>
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<tr>
<td>Vertical Glazing SHGC (Punch windows)</td>
<td>0.378</td>
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<tr>
<td>Vertical Glazing SHGC (Curtainwall)</td>
<td>0.20</td>
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<tr>
<td>Shading Devices</td>
<td>Horizontal overhangs on SW and W facades</td>
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<thead>
<tr>
<th>HVAC (Air-Side)</th>
<th>Proposed Case</th>
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<tbody>
<tr>
<td>HVAC Systems</td>
<td>Campus steam (hot water), WSHP/Dry Cooler (chilled water), Valance unit (distribution)</td>
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<table>
<thead>
<tr>
<th>Outside Air System</th>
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<tbody>
<tr>
<td>Ventilation Supply Air / Exhaust Air</td>
<td>4060 CFM / 4060 CFM</td>
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<tr>
<td>Heat Recovery Device Type</td>
<td>Enthalpy Wheel 82% Effectiveness</td>
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<table>
<thead>
<tr>
<th>Domestic Water Heating</th>
<th>Proposed Case</th>
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<tbody>
<tr>
<td>Heater Fuel</td>
<td>Condensing Gas boiler (95% efficient)</td>
</tr>
<tr>
<td>HW Demands</td>
<td>12 gallons/person/day</td>
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<tr>
<td>HW controls</td>
<td>Low flow fixtures, drain water heat recovery on showers</td>
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<thead>
<tr>
<th>Lighting</th>
<th>Proposed Case</th>
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<tbody>
<tr>
<td>Lighting Power Density (LPD)</td>
<td>47682 kWh/yr (0.3 W/SF)</td>
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<table>
<thead>
<tr>
<th>Miscellaneous</th>
<th>Proposed Case</th>
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<tbody>
<tr>
<td>Miscellaneous equipment</td>
<td>52659 kWh/yr</td>
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<table>
<thead>
<tr>
<th>Photovoltaic Panels</th>
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<tbody>
<tr>
<td>Generation (potential)</td>
<td>139,000 kWh</td>
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Lessons Learned

Design Guidelines

- **Glazing** - <40% wall area for most cost effective PH design.
- **Overheating** – High SHGC glazing can cause overheating, use external shading cleverly.
- **Curtainwall** – Large glazed areas overheat quickly so limit to specific areas and provide shading.
- **Ventilation** – Align ventilation calcs with MEP early, as they greatly impact heating/cooling demand, energy.
- **ERVs** – specify systems with high efficiency 84%+ Efficiency (Sensible heat recovery)
- **Heating** – keep it simple. You don’t need much.
- **Cooling** – typically required, and can be a large energy consumer, so explore passive cooling (high thermal mass, phase change materials natural ventilation).
- **Domestic Hot Water (DHW)** – use drainwater heat recovery wherever possible.
- **Thermal Bridging** – eliminate thermal bridging concerns to the greatest extent possible, while using cost effective solutions.
THANK YOU.
NAPHC 2018