LIVING WITH PASSIVE HOUSE

CASE STUDIES OF THE HUMAN EXPERIENCE

Richard Pedranti, AIA

September 30, 2017

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## Presentation Outline

<table>
<thead>
<tr>
<th>THEORY</th>
<th>PRACTICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. RPA 5 Passive House Principles</td>
<td></td>
</tr>
<tr>
<td>2. RPA 5 human Passive House principles</td>
<td></td>
</tr>
<tr>
<td>3. Case studies from our early Passive House work</td>
<td></td>
</tr>
</tbody>
</table>
LIVING WITH PASSIVE HOUSE

CASE STUDIES OF THE HUMAN EXPERIENCE
5 Passive House principles
5 Passive House principles
Passive House principles

1. SOLAR ORIENTATION
5 Passive House principles

1. SOLAR ORIENTATION
2. HIGH INSULATION
5 Passive House principles

1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
5 Passive House principles

1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
4. AIR TIGHT CONSTRUCTION
5 Passive House principles

1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
4. AIR TIGHT CONSTRUCTION
5. BALANCED VENTILATION
WINTER COMFORT SURVEY

RESULTS

50%
Report they struggle to feel warm and comfortable in during the winter months.

70%
Report that some or all walls in their homes are cold to touch.

43%
Report that rooms are avoided or unused because they are uncomfortably cold.
WINTER COMFORT SURVEY

WHY ARE WE UNCOMFORTABLE?

What factors are responsible when homes feel uncomfortable in the winter months?

- Drafty Openings: 51%
- Poor Insulation: 50%
- Old Home: 42%
- Heating Cost: 37%
- Old Heating System: 13%
- Need System Maintenance: 7%
How Do We Stay Warm?

What steps are taken to stay comfortable in homes other than turning up the thermostat?

- Blankets/Outerwear: 58%
- Fireplace/Stove: 39%
- Space Heaters: 35%
- Stay in warm rooms: 27%
- Heated Floors/Other: 13%
WINTER COMFORT SURVEY

FAMILIAL STRIFE

How regularly does balancing heating costs with keeping home warm during cold months cause disagreements with a spouse, partner, roommate(s) or children living in home?

- Continuously: 3%
- Frequently: 7%
- Sometimes: 31%
- Rarely: 29%
- Never: 21%
- Self-Debate: 8%
- No Self-Debate: 4%

67%

Of homeowners say that deciding how to keep their home comfortable during the winter have caused disagreements between family or roommates.

This is not just causing physical discomfort but emotional discomfort as well.

202 people living in detached homes, townhouses and row homes in areas that experience a winter season completed the survey.
5 Passive House principles
5 Passive House principles

1. Solar Orientation
2. High Insulation
3. High Performance Windows
4. Air Tight Enclosure
5. Balanced Ventilation w/ Heat Recovery
5 Human Passive House principles

1. Solar Orientation
2. High Insulation
3. High Performance Windows
4. Air Tight Enclosure
5. Balanced Ventilation w/ Heat Recovery
5 Human Passive House principles

Thermal comfort is the condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation.

5 Human Passive House principles

1. COMFORT
2. AIR QUALITY

1. Solar Orientation
2. High Insulation
3. High Performance Windows
4. Air Tight Enclosure
5. Balanced Ventilation w/ Heat Recovery
5 Human Passive House principles

1. COMFORT
2. AIR QUALITY
3. SOUND AND DAYLIGHT

Solar Orientation
2. High Insulation
3. High Performance Windows
4. Air Tight Enclosure
5. Balanced Ventilation w/ Heat Recovery
5 Human Passive House principles

1. COMFORT
2. AIR QUALITY
3. SOUND AND DAYLIGHT
4. SIMPLICITY

Solar Orientation
High Insulation
High Performance Windows
Air Tight Enclosure
Balanced Ventilation w/ Heat Recovery
“Increasing the insulation, window, and airtightness values to these levels is not only quite expensive, but very architecturally constraining”

“The Passive House (Passivhaus) Standard – A comparison to other cold climate low energy housing”, John Straub 2010
Quantitative
1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
4. AIR TIGHT CONSTRUCTION
5. BALANCED VENTILATION

Experience
1. COMFORT
2. AIR QUALITY
3. SOUND AND DAYLIGHT
4. SIMPLICITY
5. BEAUTIFUL PHYSICS
The art of optimizing BOTH “sides” is where successful Passive House design separates itself from simply achieving energy efficiency.

1. SOLAR ORIENTATION
2. HIGH INSULATION
3. HIGH PERFORMANCE WINDOWS
4. AIR TIGHT CONSTRUCTION
5. BALANCED VENTILATION

1. COMFORT
2. AIR QUALITY
3. SOUND AND DAYLIGHT
4. SIMPLICITY
5. BEAUTY
Scrantan Passive House

Keffer Passive House

Soeder Passive House
WALL-SLAB DETAIL

1. WATER CONTROL LAYER
2. PAINTED WOOD CLADDING
3. 3/4" FURRING AND AIR SPACE
4. SIGA MAJVEST WRB
5. FIBERBOARD SHEATHING
6. 1 1/4" PSL
7. SCREENED CLADDING VENT
8. PARGED FIBER-CEMENT
9. 2" EPS FROST WING
10. GRADE
11. AIR & VAPOR CONTROL LAYER
12. 11 7/8" DENSE PACK CELLULOSE INSULATION
13. 11 7/8" TIJ
14. OSB | SEAMS TAPED WITH Siga WIGLUV
15. 1 1/2" MINERAL WOOL INSULATION
16. STRUCTURAL 2X4" STUD WALL
17. 5/8" GYPSUMBOARD
18. INTERIOR FINISH
19. 2X4" PLATE
20. 6" POURED CONCRETE SLAB
21. 10 MIL POLY
22. FLOORING
23. 8" PERLITE
24. 12" EPS INSULATION
25. THERMAL CONTROL LAYER
26. 8" COMPACTED #28 STONE
27. UNDISTURBED SOIL

R=78
WALL ASSEMBLY

Super-insulated Passive House wall

CLIMATE ZONES 5 AND 6

A proven Passive House wall assembly
Has a high R-value
Uses conventional building technology
Has an excellent vapor profile
All 4 control layers are continuous
Cellulose is hygroscopic
Cellulose is inexpensive
Cellulose has low embodied energy
The primary air seal is rigid and protected
Has a service cavity
Is thermal bridge free
Vent space at cladding allows for drying

CONTROL LAYERS

- T: THERMAL - CELLULOSE / ROCKWOOL
- W: WATER - SOLITEX MENTO
- A: AIR - HUBER ZIP SHEATHING
- V: VAPOR - HUBER ZIP SHEATHING

R=61
WINDOW SILL DETAIL

1. WINDOW JAMB BEYOND
2. UNDER SILL PROFILE BY INTUS
3. SPRAY FOAM OR FOAM TAPE
4. 3M 8067 TAPE
5. METAL WINDOW SILL
6. EPS INSULATION
7. COR O VENT
8. SIGA WIGLUV | SIGA MAJVEST WRB
9. 3/4" WINDOW JAMB EXTENSION
10. THERMAL CONTROL LAYER
11. 3/4" FURRING AND AIR SPACE
12. SIGA MAJVEST WRB
13. WINDOW INSTALLATION CLIP
14. VYCOR
15. 1 1/4" #12 WOOD SCREWS
16. 1 1/4" TIMBERSTRAND
17. 11 7/8" TJI VERTICAL
18. DENSE PACK CELLULOSE
19. OSB | SEAMS TAPE WITH SIGA WIGLUV
20. MINERAL WOOL INSULATION IN SERVICE CAVITY
21. 3 1/2" STRUCTURAL STUD WALL @ 24" O.C.
22. PAINTED GYPSUM BOARD (INTERIOR FINISH)

R=6.7
# Mechanical Systems

## Scranton Passive House
- **Ventilation:** EV200 RENWAIRE
- **Heating / Cooling:** MITSUBISHI MUZ 9000
- **Hot Water:** GE GEOSPRING HWHP

## Keffer Passive House
- **Ventilation:** ZEHNDER CA 350
- **Heating / Cooling:** 2 MITSUBISHI MUZ 12000
- **Hot Water:** NYLE GEYSER HWHP & MARATHON ELECTRIC WH

## Soeder Passive House
- **Ventilation:** ZEHNDER CA 350
- **Heating / Cooling:** 2 MITSUBISHI MUZ 12000
- **Hot Water:** GE GEOSPRING HWHP

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“Once we decided to build a house, the only sensible thing to do in the 21st century is to build a house that uses the least energy possible.”

Declan Mulhall, homeowner
**Scranton Passive House**

**PROJECT INFORMATION**
- **LOCATION**: SCRANTON, PA
- **SIZE**: 2,153 SQFT.
- **CLIMATE ZONE**: 5/6 COLD
- **HERS**: 28
- **CONSTRUCTION**: COMPLETE 2015
- **COST (EXTRA COST)**: $156/SQFT.
- **MODELING TOOLS**: PHPP / REMRATE
- **MONITORING**: RPA PHIOT
- **PV TO NET ZERO**: 5KW

**RPA PH GEOMETRY**
- ENVELOPE AREA TO TFA: 3
- SURFACE AREA TO VOLUME: 32
- ENVELOPE AREA TO GLAZING: 14%
- SOUTH GLAZING: 47%
- ENCLOSURE R-VALUE: 36.2

**PASSIVE HOUSE METRICS**
- **ANNUAL HEAT DEMAND**: 4.52 KBTU/(FT²YR)
- **HEAT LOAD**: 2.75 KBTU/(FT²YR)
- **PRIMARY ENERGY**: 31.5 KBTU/(FT²YR)
- **AIR TIGHTNESS**: 0.47ACH@50PA
- **TREATED FLOOR AREA**: 1,750 SQFT.

**CONSTRUCTION SPECS**
- **FLOOR**: R=76 SLAB ON GRADE
- **WALLS**: R=61 2X4 WALL PLUS TJI
- **ROOF**: R=91 ENERGY TRUSS
- **WINDOWS**: R=7 INTUS EFORTE

**MECHANICAL SYSTEMS**
- **VENTILATION**: RENEWAIRE ERV
- **HEATING AND COOLING**: MITSUBISHI ASHP
- **DOMESTIC HOT WATER**: GE HWHP

**Glazing Solar Gains and Losses by Orientation**

**Operating Expense**

<table>
<thead>
<tr>
<th>Cost Per Year</th>
<th>Passive House</th>
<th>Typical House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>$102</td>
<td>$1,056 yr</td>
</tr>
<tr>
<td>Cooling</td>
<td>$66</td>
<td>$88 mo</td>
</tr>
<tr>
<td>Hot Water</td>
<td>$177</td>
<td>$233 mo</td>
</tr>
<tr>
<td>Plug Loads</td>
<td>$711</td>
<td>$2,90 day</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$1,066 yr</strong></td>
<td><strong>$2,800 yr</strong></td>
</tr>
</tbody>
</table>

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Electric Usage Chart

- **kWh per Month Average**: 560 kWh
- **$ per Month Average**: $67

### kWh (Average Daily Use)

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>18</td>
</tr>
<tr>
<td>2016</td>
<td>32</td>
<td>28</td>
<td>20</td>
<td>18</td>
<td>15</td>
<td>9</td>
<td>13</td>
<td>14</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>2017</td>
<td>28</td>
<td>24</td>
<td>22</td>
<td>17</td>
<td>14</td>
<td>11</td>
<td>17</td>
<td>14</td>
<td>14</td>
<td>16</td>
<td>19</td>
<td>14</td>
</tr>
</tbody>
</table>

- **Year Average**:
SCRANTON PASSIVE HOUSE

The #112 PHIUS certified Passive House in North America

Declan Mulhall
and
Christie Karpiak
SCRANTON PASSIVE HOUSE

“It is beautifully designed, warm/cool, cheap to run, silent, and comfy.”

Declan Mulhall, Homeowner
“The thick front and side doors are finicky, and the sliding door is a total pain in the ass.”

Declan Mulhall, homeowner
The high energy use days are on weekends and the dryer is the number 1 culprit. **Awful energy use from the dryer.** We don't hang dry enough.

*Christie Karpiak, homeowner*
“I still don't like the air registers. Hotel-esque, loud and annoying but only noticeable at night.”

Christie Karpiak
“The water heater is great, in my opinion. Definitely plenty of hot water on the efficient setting and no real problems from the cold air.”

Christie Karpiak
“No cooking odors.”

Christie Karpiak
SCRANTON PASSIVE HOUSE
1. OSB is not a reliable air barrier. 
See: “Is OSB Airtight” by Martin Holladay on GBA website.

2. Installing the Renewaire HRV and ductwork was challenging.

3. With carefully optimized design, it is possible to build an affordable Passive House in our region. $156/ sf
“It made sense to us to build a house that met the most advanced building and energy standards possible.”

Lynn Keffer, homeowner
## DATA

### Keffer Passive House

#### Project Information
- **Location**: Hawley, PA
- **Size**: 2,900 SQFT.
- **Climate Zone**: 5
- **HERS**: 32
- **Construction**: 2016
- **Cost**: $225 SQFT.
- **Modeling Tools**: PHPP / REMRATE
- **Monitoring**: PHIoT
- **PV to Net Zero**: 7KW

#### RPA PH Geometry
- **Envelope Area to TFA**: 3.5
- **Surface Area to Volume**: 34
- **Envelope Area to Glazing**: 15%
- **South Glazing**: 67%
- **Enclosure R-value**: 42.3

#### Passive House Metrics
- **Annual Heat Demand**: 4.65 KBTU/(FT2YR)
- **Heat Load**: 2.93 KBTU/(FT2YR)
- **Primary Energy**: 27.3 KBTU/(FT2YR)
- **Air Tightness**: 0.29ACH@50PA
- **Treated Floor Area**: 2,304 SQFT.

#### Construction Specs
- **Floor R-value**: 76
- **Walls R-value**: 62
- **Roof R-value**: 100
- **Windows R-value**: 7
- **Mechanical Systems**: Ventilation Zehnder ERV, Heating and Cooling Mitsubishi 12KBTU, Domestic Hot Water Nyles Geysir HWHP

### Projected Performance Information

![Diagram of GLAZING SOLAR GAINS AND LOSSES BY ORIENTATION](Image)

#### Operating Expense

<table>
<thead>
<tr>
<th>Cost Per Year</th>
<th>Passive House</th>
<th>Typical House</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>$112</td>
<td>$1,162 Year</td>
</tr>
<tr>
<td>Cooling</td>
<td>$73</td>
<td>$97 Month</td>
</tr>
<tr>
<td>Hot Water</td>
<td>$196</td>
<td>$233 Month</td>
</tr>
<tr>
<td>Plug Loads</td>
<td></td>
<td>$3.24 Day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$7.76 Day</td>
</tr>
</tbody>
</table>

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kWh per Month Average: 624 kWh
$ per Month Average: $74
KEFFER PASSIVE HOUSE

PHIUS certification

Passive House homeowners

Lyn and Tom Keffer
“The house is very comfortable.”

Lynn Keffer
“The passive house structure’s large south-facing windows provide lots of natural light.”

Lynn Keffer
“Whenever we arrive the inside air feels fresh, without musty odors.”

Lynn Keffer
“We have found that the house requires minimal maintenance.”

Lynn Keffer
“The house holds temperatures very well, so we don't have to constantly monitor a thermostat in response to changes in outdoor temperature.”

Lynn Keffer
“Amazingly, even with a few windows open the interior temperature doesn’t change much.”

Lynn Keffer
KEFFER PASSIVE HOUSE

“The house can be very quiet.”
Lynn Keffer
"The outdoor fireplace on the screened porch is great visually and it is wonderful on cooler nights in the summer, early fall, and late spring."

Tom Keffer
KEFFER PASSIVE HOUSE

LESSONS LEARNED

1. Humidity control is a problem
2. Windows / doors leak air
3. Nyles Geyser HWHP is noisy

Why its not certified
1. Washer not Energy Star
2. Hot water fails circulation test
“My wife and I wanted to build a new home that would suit us now and into retirement. I also wanted to achieve a high level of sustainability and take advantage of the latest building technology.”

Shawn Soeder, homeowner
**PROJECT INFORMATION**

**LOCATION**
Bechtelsville, PA

**SIZE**
2,600 SQFT.

**CLIMATE ZONE**
5/6 COLD

**HERS**
30

**CONSTRUCTION COMPLETE**
2016

**COST**
$136/SQFT.

**MODELING TOOLS**
PHPP / REMRATE

**MONITORING**
PHIoT

**PV TO NET ZERO**
6KW TO 8

---

**RPA PH GEOMETRY**

<table>
<thead>
<tr>
<th>Envelope Area to TFA</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Area to Volume</td>
<td>32</td>
</tr>
<tr>
<td>Envelope Area to Glazing</td>
<td>14%</td>
</tr>
<tr>
<td>South Glazing</td>
<td>51%</td>
</tr>
<tr>
<td>Enclosure R-Value</td>
<td>38.5</td>
</tr>
</tbody>
</table>

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**PASSIVE HOUSE METRICS**

<table>
<thead>
<tr>
<th>Annual Heat Demand</th>
<th>4.75 KBTU/(FT²YR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Load</td>
<td>2.84 KBTU/(FT²YR)</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>34.5 KBTU/(FT²YR)</td>
</tr>
<tr>
<td>Air Tightness</td>
<td>0.22ACH@50PA</td>
</tr>
<tr>
<td>Treated Floor Area</td>
<td>2,440 SQFT.</td>
</tr>
</tbody>
</table>

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**CONSTRUCTION SPECS**

<table>
<thead>
<tr>
<th>Floor R-Value</th>
<th>42 CRAWL SPACE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall R-Value</td>
<td>60 2X4 WALL PLUS TJI</td>
</tr>
<tr>
<td>Roof R-Value</td>
<td>100 ENERGY TRUSS</td>
</tr>
<tr>
<td>Window R-Value</td>
<td>7 INTUS EFORTE</td>
</tr>
</tbody>
</table>

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**MECHANICAL SYSTEMS**

<table>
<thead>
<tr>
<th>Ventilation</th>
<th>ZEHNDER ERV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating and Cooling</td>
<td>12KBTU MITSUBISHI ASHP</td>
</tr>
<tr>
<td>Domestic Hot Water</td>
<td>GE HWHP</td>
</tr>
</tbody>
</table>

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**GLAZING SOLAR GAINS AND LOSSES BY ORIENTATION**

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**OPERATING EXPENSE**

- **Heating**: $169
- **Cooling**: $117
- **Hot Water**: $99
- **Plug Loads**: $862

---

**COST PER YEAR**

- **Passive House**: $1,406 YR, $117 MO, $3.90 DAY
- **Typical House**: $2,800 YR, $233 MO, $7.76 DAY
Electric Usage Chart

- kWh per Month Average: 930 kWh
- $ per Month Average: $112

Soeder Passive House
SOEDER PASSIVE HOUSE

The #143 PHIUS certified Passive House in North America

Passive House homeowners

JeanAnn and Shawn Soeder
"Our house has been extremely comfortable! Both my wife and I feel the main living spaces tend to be the right temperature and humidity through all the seasons. We do have one upstairs bedroom that tends to be too warm at times, and that takes some attention (door open during the day, sometimes use a fan)."

Shawn Soeder
“My favorite thing is the peace of mind that comes with a high performance building, knowing that we didn’t compromise when it comes to the environmental impact.”

Shawn Soeder
“JeanAnn doesn't like the ventless dryer”

Shawn Soeder
“We feel that we have cleaner air than a normal house. We don't smell odors within the house except, temporarily from cooking food.”

Shawn Soeder
Also, we haven't install the screens. I don't like how the screens fit into the Intus windows and this keeps us from opening them as often as we'd like.”

Shawn Soeder
1. PHIUS +

2. A Passive House Arduino based IoT monitoring system

3. Self build cost = $136 sf