High Performance Residential Buildings: Next Step Homes and Passive House

Emerging Technologies Showcase
May 21, 2014

Welcome. Today’s webinar is being recorded and will be posted at:
- www.E3Tnw.org
- www.ConduitNW.org
GoToWebinar Logistics

- Minimize or maximize control panel
- Phone lines are muted
- Please use question pane to ask questions during Q & A or if you have any technical issues

NOTE: Today’s presentation is being recorded and will be available at [http://e3tnw.org/Webinars](http://e3tnw.org/Webinars) within 48 hours
High Performance Residential Buildings

**Next Step Homes**
Charlie Stephens – Northwest Energy Efficiency Alliance (NEEA)

**Passive House**
Katrin Klingenberg – Passive House

**Energy Codes of Washington State**
Gary Nordeen – WSU Energy Program
Technology doesn’t always work as intended, or work the same everywhere. And good things can almost always be done poorly.
Ductless Heat Pump Systems

Maximum power is 770W

Cycling here to about 460W

Average power is about 280W

Note that cycling worsens when outdoor temp rises above about 43F
DHP w/ Short-cycling, Corrected

Maximum power is 820W

Initially cycling to about 430W, every 19 minutes

Average power is about 390W

Note that after the firmware change, cycling goes to 1 to 3 hours, at 130W

The following month’s energy use, under largely the same outdoor conditions, was 29 kWh
Domestic Hot Water

Air Generate ATI-66 in the garage

Typical compressor power signature

6-person household that does a lot of laundry, but because it’s a HPWH, will use a lot less energy than a 2-person household with the electric resistance tank

Lots of hot water draws going on this day; they never run out
Domestic Hot Water

Air Generate ATI-66 in a colder garage

Lower garage temperature lowers performance of the HPWH

4-person household that does a lot of laundry

Lots of water draws this day

This unit was replaced due to a refrigerant leak, cutting run time and energy use a lot
Ventilation

Lifebreath 195 ECM

Delivered air temperature is pretty comfortable

But very warm air being sent outside, due both to less efficient heat exchange and motors than found in better-performing systems

But, run continuously at 27W, will use about 230 kWh per year (not bad)
Ventilation

Zehnder CA 350

Run continuously at 43W, will use about 300 kWh per year (not bad)

Homeowner is learning to program the system, will use less energy during some hours now
Ventilation

Zehnder CA 350 on a timer; **not a good way to control an HRV**

But, run intermittently at 17W, will use about 60 kWh per year

If this were not a 1-person household, it would be under-ventilating at this flow rate, but homeowner probably received no information on the system or how to operate it
Ventilation

Zehnder CA 350 with factory controls

2-degree difference between outgoing and incoming air streams – very efficient

Run continuously at 50W, will use about 420 kWh per year

Certainly over-ventilating at times, at this flow rate (110 cfm, 2-person household, 1,644 sq ft, 3 BR, 2 bath)
Some Pitfalls

This spa in a Montana project will likely use as much as the electric resistance water heater annually.

Not installed when the house was built, so not modeled for annual energy use.
Some Pitfalls

Standby energy consumption can be shocking:

- 2-stage ASHP system uses 95W in standby (about 600 kWh/yr)
- New Trane “connected” furnaces and air handlers seem to use 81W in standby (720 kWh/yr)
- Every 5W of standby power equates to 44 kWh per year
Some Pitfalls

Exhaust fans can significantly depressurize a relatively air-tight home:

• Two-speed range hood fan (300 and 600 cfm) in a Montana project depressurized the house to minus 39 Pa, even with a dampered 8” make-up air duct delivering to the range.

• Combined exhaust fans, including the dryer, depressurized one ventilation study home to minus 44 Pa.
Condensing on-demand natural gas water heater w/ 1-gallon electric resistance buffer tank

1,600 Watt demand when on

1-person household

Will likely use more than 1,300 kWh per year
System Design and Spec Matters

- Room-by-room heat loss and heat gain analysis (especially heat gain) is critical to knowing whether or not the specified heating/cooling system will meet occupant comfort expectations.
- High performance, high quality, relatively contractor-proof systems cost more, but are critical.
- Simplicity is VERY important.
- Planning for maintenance is VERY important.
- Occupant education and homeowner manuals are VERY important.
Introduction to Passive Building

Katrin Klingenberg, Executive Director
katrin@passivehouse.us
Outline and Objectives

• Passive Building Metrics/Energy Savings
• Economics
• Passive Building Principles/Technologies
• Conclusions
Passive building metrics/ Energy Savings
Passive House History starts here: 1973

1973
- First experimental Lo-Cal Homes in Urbana Illinois

1974-76
- Saskatchewan Conservation House, 30,000 Units built by ‘86

1974-76
- Kranichstein Passivhaus, 600 Certified European projects by 2014

1990-2014
- Smith House and BioHaus, 200 certified NA projects by end of 2014

2002-2014

© 2013 PHIUS
The Passive House Concept

Optimize the House...to the Heating/Cooling System

(Image Source: Manfred Brausem)
Passive Building Standard Philosophy

**Conservation, Systems Efficiency, Durability, Renewables**

- Treated Floor Area
- kWh / SQ Meter or SQFT & kBTU / SQ Meter or SQFT
- No site generation **BUT** solar thermal OK
- No Life Cycle Costs
- Primary Energy or Source Energy

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Energy Carrier</th>
<th>PE (non-regenerative)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kWh&lt;sub&gt;Prim&lt;/sub&gt;/kWh&lt;sub&gt;Final&lt;/sub&gt;</td>
</tr>
<tr>
<td>Fuel Source</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Oil</td>
<td>1.1</td>
</tr>
<tr>
<td>3</td>
<td>Natural Gas</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>LPG</td>
<td>1.1</td>
</tr>
<tr>
<td>5</td>
<td>Hard Coal</td>
<td>1.1</td>
</tr>
<tr>
<td>6</td>
<td>Wood</td>
<td>0.2</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Electricity-Mix</td>
<td>2.7</td>
</tr>
<tr>
<td>8</td>
<td>Electricity from Photovoltaics</td>
<td>0.7</td>
</tr>
<tr>
<td>District Heat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Hard Coal CGS 70% PHC</td>
<td>0.8</td>
</tr>
<tr>
<td>3</td>
<td>Hard Coal CGS 35% PHC</td>
<td>1.1</td>
</tr>
<tr>
<td>4</td>
<td>Hard Coal HS 0% PHC</td>
<td>1.5</td>
</tr>
<tr>
<td>Gas CGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Gas CGS 70% PHC</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>Gas CGS 35% PHC</td>
<td>1.1</td>
</tr>
<tr>
<td>7</td>
<td>Gas HS 0% PHC</td>
<td>1.5</td>
</tr>
<tr>
<td>Heating Oil-EL CGS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Oil CGS 70% PHC</td>
<td>0.8</td>
</tr>
<tr>
<td>9</td>
<td>Oil CGS 35% PHC</td>
<td>1.1</td>
</tr>
<tr>
<td>10</td>
<td>Oil HS 0% PHC</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Data Source: DIN V 4701-10/GEMIS 4.14

© 2013 PHIUS
### PHIUS+ Certificate Requirements: *Current Program (aligned w/ Europe)*

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Requirement Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Heat/Cooling Demand</td>
<td>≤4.75 kBTU/ft²yr (15 kWh/m²a)</td>
</tr>
<tr>
<td></td>
<td><strong>OR</strong></td>
</tr>
<tr>
<td>Peak Loads (heating/cooling)</td>
<td>≤3.17 BTU/hr.ft² or 0.93W/ft² (10 W/m²)</td>
</tr>
<tr>
<td>Primary Energy Demand</td>
<td>≤38 kBTU/ft²yr (120 kWh/m²a)</td>
</tr>
<tr>
<td>Airtightness</td>
<td>≤ 0.6 ACH₅₀</td>
</tr>
<tr>
<td>Ventilation</td>
<td>≥75% Recovery, ≥0.76 W/cfm</td>
</tr>
<tr>
<td>Thermal Envelope:</td>
<td>R min ≥ 38.5 hr. ft²°F/BTU, U ≤ 0.026 BTU/hr. ft²°F</td>
</tr>
<tr>
<td>Thermal-bridge Free</td>
<td>Ψ ≤0.006 BTU/hr. ft °F</td>
</tr>
<tr>
<td>Windows installed:</td>
<td>Uₜ.install ≤ 0.15 BTU/hr. ft² °F</td>
</tr>
<tr>
<td>SHGC</td>
<td>SHGC 0.5 – 0.55</td>
</tr>
</tbody>
</table>

© 2013 PHIUS
## PHIUS+ Standard Refinement Work: w/ Building Science Corp under BA Contract

<table>
<thead>
<tr>
<th>Category</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Heat/Cooling Demand</td>
<td>• &lt;6.34 kBTU/ft²yr (20 kWh/m²a) --OR--</td>
</tr>
<tr>
<td></td>
<td>• &lt; 4.75 BTU/hr.ft² or 1.39 W/ft² (15 W/m²)</td>
</tr>
<tr>
<td>Peak Heat Load</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>• ≤ 38 kBTU/ft²yr (120 kWh/m²a)</td>
</tr>
<tr>
<td>Primary Energy Demand</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>• ≤ 0.6ACH&lt;sub&gt;50&lt;/sub&gt; better ≤ 0.3ACH&lt;sub&gt;50&lt;/sub&gt;</td>
</tr>
<tr>
<td>Airtightness</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>• ≥85% Recovery, ≥0.76 W/cfm</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>• R min ≥ 45 hr. ft&lt;sup&gt;2&lt;/sup&gt;°F/BTU, U ≤ 0.022 BTU/hr. ft&lt;sup&gt;2&lt;/sup&gt;°F</td>
</tr>
<tr>
<td>Thermal Envelope:</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>• Ψ ≤ 0.006 BTU/ hr. ft °F</td>
</tr>
<tr>
<td>Thermal-bridge Free</td>
<td>Required</td>
</tr>
<tr>
<td></td>
<td>• U&lt;sub&gt;w-install&lt;/sub&gt; ≤ 0.14 BTU/hr. ft² °F</td>
</tr>
<tr>
<td>Windows installed:</td>
<td>Recommended</td>
</tr>
<tr>
<td></td>
<td>• South : ≥ 0.5, for all others ≤ 0.4</td>
</tr>
</tbody>
</table>

© 2013 PHIUS
U.S. building energy use accounts for **41%** of total U.S. energy use.
Worldwide Energy Demand: *Resources and Consumption*

Reference: Shell-Study (till 2005), Scenario with high efficiency and regenerative usage of energy

© 2013 PHIUS
Brought Forward by Architect Ed Mazria

The 2030 Challenge

### Passive Houses and Buildings
Economics
Note: Costs are for central Europe (Germany)

(Source: IEA Information Paper: Energy Efficiency requirements in Building Codes, Author Jens Laustsen)
National Renewable Energy Lab
Cost and Energy Optimization Tool BEopt

1600 ft² Passive Project in Pierre, South Dakota
Cost Benefit Calculator

<table>
<thead>
<tr>
<th>Cost of Home Options</th>
<th>Cost of Baseline Home</th>
<th>Cost to Upgrade to Passive House</th>
<th>Cost of Passive House</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>150,000</td>
<td>12%</td>
<td>168,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Cost, Baseline Home ($ per month)</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual Rate of increase in Energy Costs Projected</td>
<td>2%</td>
</tr>
<tr>
<td>Energy Reduction from Passive House Approach (%)</td>
<td>70%</td>
</tr>
</tbody>
</table>

Future Value of Energy Savings after Applying them to Extra Down Payment and Monthly Payments of the Passive Option

Year: 0 5 10 15 20 25 30

Areas below zero indicate that the extra down and monthly payments exceed the value of the energy savings to date.

When the value reaches zero, it's all gravy - and the energy savings each month will add up to a substantial sum!

INFORMATION PRESENTED BY:

© 2013 PHIUS
Passive building principles/Technologies
Passive Energy Balancing

Passive Principles and Metrics: Sweet Spot Between Conservation and Generation

- **Continuous Insulated Envelope**, airtight compact building shape, thermal-bridge-free
- **High Performance Windows & Doors**, optimal solar orientation, shading and modest window areas
- **Constant Fresh Air Supply** balanced mechanical ventilation system w/ heat/moisture recovery
- **Managing Internal Loads** efficient appliances, lighting and plumbing
- **Efficient Heating and Cooling Devices** minimize fossil fuel and electric energy consumption
- **Efficient Hot Water Generation** optimizes primary energy and carbon emissions
  - **Solar and Wind Energy** offset remaining energy consumption and carbon emissions

Solar and Wind Energy offset remaining energy consumption and carbon emissions

Passive Energy Balancing as Basis for Zero/Positive Energy

© 2013 PHIUS
Continuous Insulation

**Thermal Comfort Conditions for Passive**

Interior comfort conditions winter 68 °F, summer 77 °F, RH 40-60%

**Source:** ASHRAE Standard 55-2010 Thermal Environmental Conditions for Human Occupancy
Continuous Insulation
Cold Climate Thermal Comfort Winter

Feels: comfortable!
Temperate glass and wall surfaces and no drafts

PH Example

- R 60

- R -9 Triple glazed

- 0º F

Glass Surface 62.4º F
Exterior Walls 67.1º F
Interior Walls 68º F

PH Comfort criteria:

- Air Temp • (68 º F)
- Relative Humidity • (40-60 % for PH)
- Air Velocity • (<19.7 ft/min)
- Radiant Condition • Max Delta T <7.2 º F (4 ºC)

RH:40-50%

© 2013 PHIUS
Continuous Insulation
Marine Climate *Thermal Comfort Winter*

Feels: **comfortable!**
Temperate glass and wall surfaces and *no drafts*

- **PH Example**
  - **Envelope**
    - *R45*
  - **Window**
    - *R 6-7 triple glazed*
  - **Outside Temp**
    - 24º F

- **PH Comfort criteria:**
  - **Air Temp**
    - (68 º F)
  - **Relative Humidity**
    - (40-60 % for PH)
  - **Air Velocity**
    - (<19.7 ft/min)
  - **Radiant Condition**
    - Max Delta T <7.2 º F (4 ºC)

© 2013 PHIUS
Continuous Insulation

Avoiding Thermal Bridging

Source: Building Science Corporation Newsletter #49: Aqua Tower and Infra Red by Fluke Corp

© 2013 PHIUS
High Performance Windows & Solar

Window Thermal Comfort

Left: conventional window frame thermograph of surface temperatures, right Passive House window thermograph surface temperatures

Mold at glass edge of double pane glazing unit

Continuous Air-tight/Wind-tight Layer

Red/Green Line

Factors affected by air tightness:

- Moisture Performance of wall
- Heat loss through leaks
- Comfort, no drafts!

Air-tight Layer: 0.6 ACH50!

RED LINE RULE

- Draw continuous air barrier
- Identify each air barrier component
- Identify connection between them

Wind tight Layer

© 2013 PHIUS
Continuous air barrier is applied to achieve...

...Air Leakage (@ 50 Pa) of less than 0.6 house volumes per hour!
1. Balanced Ventilation w/ Heat/Moisture Recovery and pre-conditioning

2. Dehumidification

3. Cooling

4. Heating

5. Domestic Hot Water
Micro-load Mechanical System

**Balanced Ventilation Delivery**

- Primary Role Balanced Ventilation: Healthy Indoor Air
- Secondary: Filtration of Contaminants
Micro-load Mechanical System

Highly Efficient Mechanical Systems

- Minimized
- Integrated with ventilation
- Point source
- Ducted
- Efficient appliances/hot water

© 2013 PHIUS
Conclusions

© 2013 PHIUS
Energy Savings:

- *reduced space conditioning energy load* (of new buildings) by approximately **90%, site energy by 75%**

Non-Energy Savings Benefits:

- *performance-based and verifiable building energy metric* established *based on global carbon reduction* needed to avert the climate crisis

- *economically feasible to society* to avert future costs of fossil fuels (peak oil)

- other benefits include *higher quality/durability of construction, resilience to power outages, increased comfort and health* of the inhabitants.
PHIUS+ Certifications/Uptake over last 10 Years in US and Canada

PHIUS+ Certified Projects

- Cumulative
- Each Year

2003: 1
2004: 1
2005: 2
2006: 2
2007: 3
2008: 3
2009: 7
2010: 16
2011: 30
2012: 53
2013: 74
Projected: 114

© 2013 PHIUS
Washington State Energy Code

Gary Nordeen
(360) 956-2042
energycode@energy.wsu.edu

Produced with funding from:

neea

WASHINGTON STATE UNIVERSITY
EXTENSION ENERGY PROGRAM
Washington State Energy Code

• One of the most efficient energy codes in the country
• The energy code obtains 20%-25% of all energy conservation savings in the state
• Residential compliance rates in Washington State are 97%+

* Cadmus study done for NEEA 2013
Legislative Mandate

• RCW 19.27A.160 Requires:

Residential and nonresidential construction permitted under the 2031 state energy code must achieve a seventy percent reduction in annual net energy consumption, using the adopted 2006 Washington state energy code as a baseline.
What does that mean?

• Every three year code cycle reduce target energy use by 8.75% compared to the 2006 WSEC.

• From 2006 to 2012 savings are approx:
  ➢ 30% residential occupancies
How the code works:

- Everyone follows the requirements of the base code.

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>5 AND MARINE 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FENESTRATION U-FACTOR</strong>&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>SKYLIGHT U-FACTOR</strong></td>
<td>0.50</td>
</tr>
<tr>
<td><strong>GLAZED FENESTRATION SHGC</strong>&lt;sup&gt;b, e&lt;/sup&gt;</td>
<td>NR</td>
</tr>
<tr>
<td><strong>CEILING R-VALUE</strong>&lt;sup&gt;i&lt;/sup&gt;</td>
<td>49</td>
</tr>
<tr>
<td><strong>WOOD FRAME WALL</strong>&lt;sup&gt;g, k, l&lt;/sup&gt; <strong>R-VALUE</strong></td>
<td>21 int</td>
</tr>
<tr>
<td><strong>Mass Wall R-Value</strong>&lt;sup&gt;i&lt;/sup&gt;</td>
<td>21/21&lt;sup&gt;h&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>FLOOR R-VALUE</strong></td>
<td>30&lt;sup&gt;g&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>BELOW-GRADE WALL R-VALUE</strong></td>
<td>10/15/21 int + TB</td>
</tr>
<tr>
<td><strong>SLAB</strong>&lt;sup&gt;d&lt;/sup&gt; <strong>R-VALUE &amp; DEPTH</strong></td>
<td>10, 2 ft</td>
</tr>
</tbody>
</table>

E3T Energy Efficiency Emerging Technologies
All new houses and additions must:

- Pass an air leakage test (5 ACH$_{50}$)
  - Not too impressive but a good start
- Max duct leakage = 4CFM/ft$^2$
  - Tight ducts
- Intermediate framing
- Glazing U-.30
- Increased insulation levels
- Mechanical ventilation systems
Table 406.2 Energy Credits

- All new construction must develop credits from Table 406.2 based on size of dwelling unit.
<table>
<thead>
<tr>
<th>Description</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Houses &lt; 1500 ft²</td>
<td>0.5</td>
</tr>
<tr>
<td>• 300 ft² max. glazing</td>
<td></td>
</tr>
<tr>
<td>• Additions 750 ft²</td>
<td></td>
</tr>
<tr>
<td>Houses ≥ 1500 ft² – 5,000 ft²</td>
<td>1.5</td>
</tr>
<tr>
<td>Houses &gt; 5,000 ft²</td>
<td>2.5</td>
</tr>
</tbody>
</table>
### Table 406.2 Energy Credits

- **Improvements to building envelope**
  - Credits range from .5 to 2.0 credits
- **Tighter building with efficient ventilation**
  - Credits range from .5 to 1.5 credits
- **High Efficiency HVAC**
  - Credits range from .5 to 2.0 credits
- **Mini Split**
  - 1 credit
- **All HVAC equipment and ducts inside**
  - 1 credit
### Table 406.2 Energy Credits

- **Efficient water heating**
  - Credits range from .5 to 1.5 credits

- **Renewable electric energy**
  - Credits range from .5 to 3.0 credits
Questions?

Charlie Stephens  
Senior Engineer  
Northwest Energy Efficiency Alliance  
cstephens@neea.org  
503-688-5457

Gary Nordean  
Senior Building Science Specialist  
WSU Energy Program  
nordeeng@energy.wsu.edu  
360-956-2040

Katrin Klingenberg  
Executive Director  
Passive House  
katrin@passivehouse.us  
312-561-4588
High Performance Residential Buildings

- Firmware upgrade for ductless heat pumps
- High-efficiency Set-top boxes
- Reduce appliance standby loads
- Three-function heat pump: hot water, radiant floors, cooling

Date to be determined between June 6 and June 20

Information and registration at www.e3tnw.org/webinars

More information about emerging technologies:

E3T database: www.e3tnw.org
E3T Program: www.bpa.gov/energy/n/emerging_technology/
Conduit: www.ConduitNW.org
GoToWebinar Logistics for TAG Members

- Minimize or maximize control panel
- ComTAG members – choose “telephone” and dial using the info provided
- Mute your phone when not speaking
- Click on the hand icon when you want to ask a question
- Please use question pane to ask questions during Q & A or if you have any technical issues
Criteria

• How significant and reliable are the energy savings per unit?
• How great are the non-energy advantages for the end user for adopting this technology?
• How ready are the products(s) and providers to scale up for widespread use in the Pacific Northwest?
• How easy is it for the end user to change to the proposed technology?
• Considering all costs and all benefits, how good of a buy is this technology for the owner?