Secrets to Passive House Design

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The Largest Source of Global Warming Pollution Is the Burning of Fossil Fuels

Data: U.S. Department of Energy/CDIAC
PASSIVE HOUSE

U.S.A. vs The World

Comparing CO2 Emissions

Data Source: Netherlands Environmental Assessment Agency
### CO\textsubscript{2} Emissions

#### Annual Per Capita CO\textsubscript{2} Emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>CO\textsubscript{2} Emissions (Metric Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>16.2</td>
</tr>
<tr>
<td>Canada</td>
<td>15.1</td>
</tr>
<tr>
<td>Russia</td>
<td>11.9</td>
</tr>
<tr>
<td>Japan</td>
<td>9.6</td>
</tr>
<tr>
<td>Germany</td>
<td>8.9</td>
</tr>
<tr>
<td>China</td>
<td>7.5</td>
</tr>
<tr>
<td>UK</td>
<td>6.5</td>
</tr>
<tr>
<td>Median</td>
<td>4.9</td>
</tr>
<tr>
<td>France</td>
<td>4.7</td>
</tr>
<tr>
<td>Mexico</td>
<td>3.6</td>
</tr>
<tr>
<td>India</td>
<td>1.7</td>
</tr>
</tbody>
</table>

U.S. CO$_2$ Emissions

Buildings’ Big Impact

- 44.6% Buildings
- 34.3% Transport
- 21.1% Industry

Data Source: US EIA, Architecture 2030
Annual Site Energy Usage

Building Energy Use

Data Source: IG Passivhaus Österreich
Energy Use Distribution

Typical Passive House Multifamily

- 57% Plug Loads/Appliances
- 43% Building Operations

- 22% Hot Water
- 10% Heating/Cooling
- 6% Lighting
- 5% HRVs, Elev., Etc.

Data Source: PHPP
We Need **Ambition**
We Need **Scale**
PASSIVE HOUSE

What is it?

1. A Science-Based Building Philosophy
2. A Means to Hit the Target
PASSIVE HOUSE

Model Matches Performance

Predictable Results


80% Reduction
Health and Happiness

Relative Performance between:
PHIUS Passive House,
ENERGY STAR®,
Conventional buildings (US D.O.E.)

Healthful Environment

Comfort

Ultra-Efficient

Building Durability

Legend:
- PHIUS Passive House
- Energy Star
- Conventional Building
PASSIVE HOUSE

Cost Comparative

Proposed PHFA Project
2015-2016 Construction Cost (Projected)

PASSIVE HOUSE (Total=59)
CONVENTIONAL (Total=120)

Data Source: PHFA
**PASSIVE HOUSE**

**Verification Page**

Sample results from Passive House Planning Package (PHPP)

<table>
<thead>
<tr>
<th>Specific building demands with reference to the treated floor area</th>
<th>Treated floor area 12816 ft²</th>
<th>Requirements</th>
<th>Fulfilled?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space heating</strong></td>
<td></td>
<td>106% of 4.75 kBTU/(ft²·yr)</td>
<td>no</td>
</tr>
<tr>
<td>Heating demand</td>
<td>5.05 kBTU/(ft²·yr)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heating load</td>
<td>4.11 BTU/(hr·ft²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Space cooling</strong></td>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Overall specific space cooling demand</td>
<td>kBTU/(ft²·yr)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cooling Load</td>
<td>BTU/(hr·ft²)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Frequency of overheating (&gt;77 °F)</td>
<td>4.3 %</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Primary energy</strong></td>
<td></td>
<td>125% of 38.0 kBTU/(ft²·yr)</td>
<td>no</td>
</tr>
<tr>
<td>Heating, cooling, dehumidification, DHW, aux. electricity, lighting, electr. appliances</td>
<td>47.7 kBTU/(ft²·yr)</td>
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<td></td>
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<tr>
<td>DHW, space heating and aux. electricity</td>
<td>25.8 kBTU/(ft²·yr)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Specific primary energy reduction through solar electricity</td>
<td>kBTU/(ft²·yr)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Airtightness</strong></td>
<td></td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Pressurization test result n₅₀</td>
<td>0.6 1/h</td>
<td>0.6 1/h</td>
<td></td>
</tr>
</tbody>
</table>

* empty field: data missing; ^: no requirement

**Passive House?** no
Energy Modeling

PHPP Sheets

VERIFICATION  ENVELOPE  VENTILATION  HEATING  COOLING

DHW+DISTRIB.  SOLAR  PLUG LOADS  PASSIVE GAIN  MECHANICAL
PASSIVE HOUSE
Organizations

North American Passive House Network
Passive House Institute
International Passive House Association
PASSIVE HOUSE CANADA
PASSIVE HOUSE ALLIANCE UNITED STATES
PHIUS
PASSIVE HOUSE

Science Based

Passive House is Building Physics

Thermal Energy
- Continuous Insulation
- Air Tight Envelope
- Thermal Bridge Free Details
- Adv. Plug Load Management

Light
- High Performance Windows & Doors
- Solar Shades
- Large Openings

Air
- Cont. Fresh Air
- Heat Recovery Ventilation
PASSIVE HOUSE

Magic of the Heat Pump
**PASSIVE HOUSE**

**Magic of the Heat Pump**

- **INSIDE**
  - Warm Liquid
  - Hot Vapor
  - Cool Vapor
  - Evaporator Coil
  - Compressor

- **OUTSIDE**
  - Cold Liquid/Mist
  - Condenser Coil
  - Expansion Valve

**Phase Change**
- Vapor to Liquid
- Liquid to Vapor
PASSIVE HOUSE

Optimizing The
Parts

1: WALLS
2: AIR SEALING
3: THERMAL BREAKS
4: WINDOWS
5: HVAC
6: HOT WATER
1. WALLS
WALLS

Moisture Drive

Exterior and Interior Risk Sources

Exterior
- Moisture from snow and rain
- Humidity

Interior
- Laundry
- Bathing
- Cooking
- Dishwashing
- Breathing
WALLS

Moisture Drive Theory

Moisture drive seeking equilibrium
Moisture Drive Theory

Moisture drive seeking equilibrium

Wall assemblies are where moisture equilibrium is maintained
WALLS

Moisture Drive Theory

Moisture drive seeking equilibrium

Wall assemblies are where moisture equilibrium is maintained
WALLS

Evolution of a Wall

Understanding the ideal wall

Basic 2x4  Basic 2x6  Code Compliant  Hybrid Wall  Ideal Wall
WALLS

Ideal Wall

Steel studs

- Gypsum Board
- 2x6 Studs
- Sheathing
- Air Barrier
- 6" Mineral Wool
- Fiberglass Clips
- Furring
- Exterior Cladding
WALLS

Ideal Wall with Rockwool
Ideal Wall with EIFS

Exterior Insulation Finishing System
WALLS

Ideal Wall with Cork
2. AIR SEALING
AIR SEALING

Taped Sheathing
Barrier Integrated Sheathing

Zip System® Sheathing
DENSelement
AIR SEALING

Fluid Applied Barriers
AIR SEALING

Fabric Building Wrap
AIR SEALING

Smart Membranes

When internal barrier system is needed.
AIR SEALING

Blower Door Testing
3. THERMAL BREAKS
THERMAL BREAKS

Thermal Bridge Awareness

Understand Psi Values
Utilize Software

Ψ = 0.191 BTU/(h·ft·F)

*F
Temperature

Photo Courtesy of HTFlux
THERMAL BREAKS

Masonry Shelf Angle

Photo Courtesy of Armatherm

Nicholson Kovalchick Architects / nkarch.com
THERMAL BREAKS

Steel-to-Steel
THERMAL BREAKS

Steel-to-Steel
4. WINDOWS
1: Windows should be energy neutral
2: Minimize heat gains in summer
3: Maximize heat gains in winter
Window Strategies

Minimize mullions to improve performance

More Mullions

More Glass

VS
**Triple Glazing**

**Low-E Coatings**

**Insulating Glass Argon, Krypton filled cavities**

**Spacers**

**Airtightness Gasket Seals**

**Insulation Thermal Breaks**

**WINDOWs**

**Window Section**

Anatomy of a high-performance window
Shading Strategies

Decks and Overhangs
Shading Strategies

Mechanical Louvers

Photo Courtesy of Hammer & Hand
Shading Strategies

Exterior Shades
Shading Strategies

Exterior Shades
Shading Strategies

Deciduous Trees
East Façade Strategies

Free Heat Energy from Morning Sun
East Façade Strategies

Mid-Day Sun

Deep Recessed Windows

Vertical Fins Shade Midday Sun
South Façade Strategies

Summer

- Deciduous Trees (Summer)
- Deep Recessed Windows
- Overhangs, Brise Soleil, and/or Decks
- Long & Low Horizontal Windows
- High Radiation Exposure
South Façade Strategies

Winter

Deciduous Trees (Winter)

- High Radiation Exposure
- Long & Low Horizontal Windows
- Overhangs, Brise Soleil, and/or Decks
- Deep Recessed Windows
West Façade Strategies

Mid-Day Sun
Winter

Deciduous Trees (Winter)

Overheating Risk with Windows

Vertical Fins

Narrow Vertical Windows

Deep Recessed Windows
West Façade Strategies

Mid-Day Sun
Summer

Overheating Risk with Windows

Vertical Fins

Narrow Vertical Windows

Deep Recessed Windows

Deciduous Trees (Summer)
North Façade Strategies

North façade will lose more heat than it will gain.

No shading devices are necessary or recommended.
Off-Axis Orientation

Avoid 45 degree Angle off of South Axis

Hybrid shading solutions are difficult and expensive for controlling unwanted gains on southeast and southwest corners.
5. HVAC
Savings Offset Costs

Pursuing the Platonic Ideal
Conventional Approach

The conventional trickle vent approach is a fantasy.
Conventional Approach

Conventional, pressurized corridors cause leaks and create problems
HVAC

Conventional Approach

Exhaust penetrations leak conditioned air
Temperature Throttling

The conventional approach creates an inefficient surplus of heat that is slowly lost over time.
Thermal Comfort

The solution is even temperature consistency.

If the temperature difference between 4” AFF to 3’-6” AFF is greater than 3.6° F, a seated person will feel cold feet and drafts.

No cold feet or perceivable drafts.
HVAC

HRV: Heat Recovery

- Outside Air (Unconditioned)
- Filters
- Heat Exchanger
- Inside Air (Conditioned)
HRV: Oxygen Rich
HVAC

HRV: Filtered Fresh
HVAC

Heat Pump

Heating / Cooling

Photo Courtesy of Mitsubishi
HVAC

HRV Integration
HRV Solutions
Unit-by-Unit Through-Wall HRV
HVAC

Ventilation Solutions

Through-wall HRV

Photo Courtesy of Lunos
Ventilation Solutions

Unit-by-Unit Cassette HRV
Ventilation Solutions

Cassette HRV

Photo Courtesy of Panasonic
The only section of ductwork that needs to be insulated is the section that connects the HRV to the exterior wall, as the rest of the ductwork is on the sealed side of the HRV.
Ventilation Solutions

Floor-by-Floor Ventilation
HVAC

Ventilation Solutions

Floor-by-Floor Ventilation
Ventilation Solutions

Floor-by-Floor

HVAC

Nicholson Kovalchick Architects / nkarch.com
Ventilation Strategy
Floor-by-Floor HRV
Ventilation Solutions
Whole Building Ventilation

Photo Courtesy of Ventacity
Ventilation Solutions

Whole Building Cassette HRV
Ventilation Solutions

Floor-by-Floor Solutions: VRF
ELEVATOR

Elevator Strategy

Problem: Piston Effect
Elevator Strategy

Solution: Move elevator and vestibule outside the air barrier
Elevator Strategy

Solution: Create a double shaft
6. HOT WATER
Energy Use Distribution

Typical Passive House Multifamily

- **Plug Loads/Appliances**: 57%
- **Building Operations**: 43%
- **Hot Water**: 22%
- **HRVs, Elev., Etc.**: 5%
- **Heating/Cooling**: 10%
- **Lighting**: 6%

Data Source: PHPP
HOT WATER

Hot Water Strategy

Heat Pump H₂O Heaters:
Unit-by-Unit or Floor-by-Floor

Photo Courtesy of Stiebel Eltron
Hot Water Strategy

Heat Pump H₂O Heaters: Unit-by-Unit or Floor-by-Floor
HOT WATER

Hot Water Strategy

Heat Pump H₂O Heaters: Unit-by-Unit or Floor-by-Floor
HOT WATER

Hot Water Strategy

Electric on Demand: Unit-by-Unit

Photo Courtesy of Stiebel Eltron
Hot Water Strategy

Heat Pump H₂O Heaters: Unit-by-Unit or Floor-by-Floor
Laundry Strategy

Community Laundry
Laundry Strategy

Community Laundry Ideally Outside of Thermal / Air Tight Envelope
Clothes Drying

Heat Pump Dryer

Photo Courtesy of Bosch
Clothes Drying

Conventional Approach

- Dryer Exhaust
- Whole House or Laundry Room Exhaust
- Long Duct Run
- 2 Envelope Penetrations
Clothes Drying

Heat Pump Dryer

Drain Condensate

Heat Pump Dryer

Exhaust to HRV

Soffit Not Needed
APPLIANCES

Cooking

Induction Range with Recirculating Hood

Photo Courtesy of Bosch
Nicholson Kovalchick Architects / nkarch.com
Dishwashing

Dishwasher without heating coil
APPLIANCES

Strategy

Dishwasher without heating coil
APPLIANCES

Lighting

LEDs Reduce Energy Consumption and Interior Heat Gains
APPLIANCES

Refrigeration

Avoid through-door ice and water dispensers
Thank you.

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