Training Workshop on High Performance Buildings

Session 1: Passive House Fundamentals / Refresher

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Speaker: Edward Lowes, Passive House Institute
Overview

- What is a Passive House?
- Passive House in Numbers
- The first Passive Houses
- Step-by-step retrofit
- PER: Primary Energy Renewable
- The role of the Passive House Institute
- Basic Passive Principles
  - Insulation
  - Thermal bridges
  - Windows
  - Ventilation
  - Airtightness
- Results and Examples
- Policy Uptake Examples
What is a Passive House?

A building with an annual heating demand less 15 kWh/(m²a)
With an overall energy consumption less 60 kWh_{PER}/(m²a).
The Efficiency Revolution

≥ 90% Reduction of Heating Energy Demand

Average existing buildings: fossile fuel

200 kWh/(m²a)  15 kWh/(m²a)

Energy efficient
Comfortable
Affordable
Sustainable

≥ 90%
## Passive House – in numbers

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Classic</th>
<th>Plus</th>
<th>Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating demand ≤</td>
<td>15</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>Heating load ≤</td>
<td>-</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Cooling demand ≤</td>
<td>15 + dehumidification allowance</td>
<td>climate dependent</td>
<td>15 + dehumidification allowance</td>
</tr>
<tr>
<td>Cooling load ≤</td>
<td>-</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Airtightness ≤</td>
<td>0.6</td>
<td></td>
<td>ACH&lt;sub&gt;50&lt;/sub&gt;</td>
</tr>
<tr>
<td>Primary energy ≤</td>
<td>60</td>
<td></td>
<td>renewable energy rating Classic</td>
</tr>
</tbody>
</table>

The complete Passive House criteria is available in the [website](https://www.passivhaus.org) of the Passive House Institute.
# Passive House – in numbers

<table>
<thead>
<tr>
<th>Criteria</th>
<th>≤</th>
<th>25</th>
<th>-</th>
<th>kBTU/(ft².yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating demand</td>
<td>≤</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Heating load</td>
<td>≤</td>
<td>-</td>
<td>-</td>
<td>W/m²</td>
</tr>
<tr>
<td>Cooling demand</td>
<td>≤</td>
<td>25</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cooling load</td>
<td>≤</td>
<td>-</td>
<td>-</td>
<td>W/m²</td>
</tr>
<tr>
<td>Airtightness</td>
<td>≤</td>
<td>1.0</td>
<td>-</td>
<td>ACH₅₀</td>
</tr>
<tr>
<td>Primary energy</td>
<td>≤</td>
<td>-</td>
<td>-</td>
<td>renewable energy rating</td>
</tr>
</tbody>
</table>

The complete Passive House criteria is available in the [website](https://www.passivhaus-institute.org) of the Passive House Institute.
1988: Research
1989: Research & Design
1990: Construction
1991: Four families move in
2016: Still performing

Superinsulated, airtight, high-quality windows, heat recovery ventilation
The building served also as a research project monitored in detail for many years.
Still performing as predicted ¼ century later

1st Passive House
Darmstadt

PHPP 10.5 kWh/(m²a)
3.3 kBTU/(ft².yr)

Heating 8.5 kWh/(m²a)
Passive Houses in Europe

CEPHEUS

Heating energy demand kWh/(m²a)

Building stock
Low-energy house
CEPHEUS Passive Houses

Average: 16.6 kWh/(m²yr)

Source: © PHI

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The Passive House concept...

Energy demand for heating kWh/(m²a)

- Building stock Belgiersiedlung
- Passive House Settlements
  - Wiesbaden
  - Stuttgart
  - Hanover

Average measured: 158 kWh/(m²a)

Passive House: no „Performance-Gap“...
Design – it’s too late to try to implement the concept on the building site if you don’t have a well-planned and well-documented design.

Want to know more? Check more features of PHPP and DesignPH here. 
EnerPHit Retrofit Plan to prevent „lock-in“

www.europhit.eu
Renewable Primary Energy Demand: Heating, DHW, auxiliary and appliances

Renewable energy generation
\[ \text{[kWh}_{\text{PER}}/(\text{m}^2_{\text{projected}} \times \text{a})] \]

- **Classic**
  - \( \geq 60 \)

- **Plus**
  - \( \geq 120 \)

- **Premium**
  - \( \leq 30 \)

Renewable primary energy demand
\[ \text{[kWh}_{\text{PER}}/(\text{m}^2_{\text{TFA}} \times \text{a})] \]

- \( \leq 45 \)
- \( \leq 60 \)

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Primary Energy Rating: From PE to PER

Energy supply structure worldwide is transitioning from fossil fuels to renewables

Consequence: (non-renewable) PE factors change

PE = non-renewable primary energy

PER = renewable primary energy
Founded in 1996 as an independent institute to bridge the gap between researchers and building professionals

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Quality is the Key to Success

Software tools PHPP and designPH including LCCa

Passive House: 1.8 Mio m² TFA already built

passivehouse-designer.org

passivehouse-components.org

passivehouse-trades.org

passivehouse.com
It’s a team sport!

Networking & knowledge transfer:
International Passive House Days,
Passipedia, Forum, Newsletter,
technical panel etc.

www.passivehouse-international.org

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Passive House – well defined open standard

The Passive House is open to all

▪ No patents
▪ Not trademarked
▪ All criteria and rules are published
▪ Everybody may build Passive Houses

Passive House is not arbitrary

▪ Passive House has a functional, climate-independent definition
▪ Criteria are well-defined and publically available
▪ Quality is key: Independent quality assurance and certification available
▪ When Passive House is offered, Passive House has to be delivered!

Common International Passive House definition

A Passive House is a building in which thermal comfort can be guaranteed by post-heating or post-cooling the fresh-air mass flow required for good indoor air quality.

▪ Climate-independent
▪ Concept and strategy to find adapted and affordable solutions
Passive House – a global optimum?

- PH not cost-optimum
- Functional PH with HRV, small win
- PH with heating & cooling < 15 kWh/(m²a) each
- Functional PH with HRV
Basic Principles of Passive House and Certification Criteria

1. Thermal insulation:
   \[ U \leq 0.15 \text{ W/}(\text{m}^2\text{K}) \]
   \[ U_w \leq 0.8 \text{ W/}(\text{m}^2\text{K}) \]

2. Avoid thermal bridge effects:
   \[ \psi_a \leq 0.01 \text{ W/}(\text{mK}) \]

3. Triple-pane glazings:
   \[ U_g \leq 0.8 \text{ W/}(\text{m}^2\text{K}) \]
   \[ g = 0.50\ldots0.55 \]

4. Airtight envelope: \[ n_{50} \leq 0.6 \text{ /h} \]

5. Mechanical ventilation system with heat recovery:
   \[ \eta \geq 75\% \]

   - Outdoor air
   - Exhaust air
   - Extract air
   - Supply air

Heat energy demand \( \leq 15 \text{ kWh/}(\text{m}^2\text{a}) \)
Cooling energy demand \( \leq 15 \text{ kWh/}(\text{m}^2\text{a}) \)

or maximum heating/cooling load \( \leq 10 \text{ W/m}^2 \)

Airtightness \( \leq 0.6 \text{ /h} \)

Primary energy demand (all) \( \leq 120 \text{ kWh/}(\text{m}^2\text{a}) \)

or Primary energy renewable (PER) \( \leq 60 \text{ kWh/}(\text{m}^2\text{a}) \)

Frequency of overheating in summer \( \leq 10\% \)
Essential #1 – Thermal insulation

Before: 290 kWh/(m²a)  
After: 17 kWh/(m²a)

Refurbishment project Tevesstraße FF/M; Client: ABG Frankfurt Holding; Architects: faktor10, Darmstadt  
Scientific Monitoring: Passivhaus Institut, Darmstadt  
Financial support: Hessisches Ministerium für Wirtschaft, Verkehr und Landesentwicklung, Wiesbaden
Essential #1 – Thermal insulation

Typical values PH in cool-temperate climates (e.g. Armenia)

- **Roof**: 0.20 W/(m²K) for 15-20 cm
- **Exterior wall**: 0.28 W/(m²K) for 12-16 cm
- **Floor slab**: 0.35 W/(m²K) for 8-12 cm
- **Roof**: ≤ 0.15 W/(m²K) for 30-40 cm
- **Exterior wall**: ≤ 0.15 W/(m²K) for 24-30 cm
- **Floor slab**: ≤ 0.25 W/(m²K) for 15-30 cm

© PHI
Typical values PH in temperate climates (e.g. Mediterranean):

- **Roof** ~ 4.5 W/(m²K)
- **Exterior wall** ~ 4.5 W/(m²K)
- **Floor slab** ~ 4.5 W/(m²K)

**No insulation**

- **Roof** ≤ 0.55 W/(m²K)
- **Exterior wall** ≤ 0.55 W/(m²K)
- **Floor slab** ≤ 0.55 W/(m²K)

- **5 – 20 cm**
  - **Roof**
  - **Floor slab**

- **5 -20 cm**
  - **Exterior wall**

© PHI
Essential #1 – Thermal insulation

Typical values PH in hot climates (e.g. North Africa):

No insulation

Roof ~ 4.5 W/(m²K)

Exterior wall ~ 4.5 W/(m²K)

Floor slab ~ 4.5 W/(m²K)

Conventional building

Passive House

15 - 20 cm

Roof ≤ 0.25 W/(m²K)

20-25 cm

Exterior wall ≤ 0.25 W/(m²K)

Floor slab ≤ 0.25 W/(m²K)
Essential #2 – Thermal bridges

Thermal-bridge-free design:

\[ \Psi_e \leq 0.01 \text{ W/(mK)} \]

Avoid / optimize weak points in the insulation layer.

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Essential #2 – Thermal bridges
### Essential #3 – Appropriate windows

<table>
<thead>
<tr>
<th>Glazing</th>
<th>Single</th>
<th>Double</th>
<th>Double, low-e</th>
<th>Triple, low-e</th>
<th>Future: vacuum/multi-foil</th>
</tr>
</thead>
</table>

- **Winter**: Let the sunshine in

#### Energy Balance

<table>
<thead>
<tr>
<th>Annual energy balance kWh/m²</th>
<th>Losses</th>
<th>Passive solar heat gains</th>
<th>Net-losses</th>
<th>Net-gains!</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Essential #3 – Appropriate windows

- Suitable window size & orientation
  (Also important in winter)

- Exterior shading
  fixed elements and/or blinds
  → daylight redirection
Essential #4 – Controlled ventilation

High air quality: 30 m³/h per person [DIN 1946]

Division into zones:
High air quality in every room: Supply, transfer and extraction – each with suitable airflow rate.
Essential #4 – Controlled ventilation

Reduce ventilation heat losses with highly efficient heat / energy recovery!
Essential #5 – Airtightness

- energy saving
- more comfort: no drafts
- improved sound insulation
- avoid humidity related damage to the construction
- important for controlled ventilation to work effectively

\[ n_{50} \text{ max. } 0.60 \text{ h}^{-1} \]
Essential #5 – Airtightness
Results: Heating

Building stock:

- Air: 21°C
- Surface: 9°C
- Outside: -12°C

Passive House:

- Air: 21°C
- Surface: >17°C
- Outside: -12°C
- Small re heater, ~1 kW

Heating system, ~10 kW, with radiators under windows to compensate cold drafts
Results: Cooling

Building stock:

- Inside: 25°C, 65% r.h.
- Outside: 35°C, 80% r.h.

Passive House:

- Inside: 25°C, 50% r.h.
- Outside: 35°C, 80% r.h.
- Cooling/dehumidification through supply air
Sustainable Supply Strategies

Biomass + solar thermal
Biomasse + Solarthermie
Sustainable Supply Strategies

Electricity + Heat pump
Strom + Wärmezepumpe
Passive House: From a research project ...

... to an international journey
From single family to larger projects

- Offices,
- Apartment buildings

2015, TFA = 14.824 m²
Office building, Frankfurt
ID: 4524

2015, TFA = 8.488 m²
Student residence, Vienna
ID: 4452
... hotels, schools, supermarkets, archives ...
... in various climate zones

Changxing - hot & humid
Urumqi, - cold & dry
ZhuoZhou - moderate
Qingdao - warm & humid
... in the Black Sea region

Holiday villa, EnerPHit Retrofit in Bansko, BG
EKSA art, SolAir Architects, HES Bulgaria Ltd.
ID: 2087

Kindergarten, Passive House in Calarasi, Moldovia
Axis Mundi S.R.L. / RoA RONGEN ARCHITEKTEN PartG mbB
ID: 5361

Administration building, Passive House in Anatolia, Turkey
Gaziantep Metropolitan Municipality
ID: 4976

Apartment building, PH Low-energy building in Volos, Greece
ID: 4992

Single-family house, Passive House Plus in Romania
ID: 4893
This Soviet era school in Latvia was retrofit to the EnerPHit standard in 2014.

The building was constructed from concrete and the walls, roof and floor were insulated. A Passive House certified ventilation system with heat recovery was installed and the building was made airtight to the Passive House standard.

Additional heating to the building was provided by a ground source heat pump.
The results of the EnerPHit retrofit saw a significant reduction in heating demand for the building.

- Pre Retrofit: 278 kWh/(m²a)
- Post Retrofit: 25 kWh/(m²a)

This results in an overall reduction in heating for the building of **524,722 kWh** per year.

- This results in an annual reduction of **72.5 tonnes** of CO2 from the atmosphere
... at varying heights

2010
Freiburg, DE
Residential retrofit
16 floors
58 m

2017
New York, US
Student residents
26 floors

2012
Vienna, AT
Office building
23 floors
77 m

2018
Bilbao, ES
Residential
28 floors

© Lenz Ingenieur-Büro
© PHI
© Field Condicion & Pavel Bendov
© Varquitectos

© Lenzo
© PHI
© Varquitectos

... at varying heights
... at varying heights
... at different densities

Success due to good quality assurance process:

**PHPP**

Monitoring:
~ 900 000 ft²
~ 1 400 apartments

14.9 kWh/(m²a) || 4.7 kBTU/(ft².yr)
16.4 kWh/(m²a) || 5.2 kBTU/(ft².yr)

Source: [Peper 2016](#)
... at different densities

Bahnstadt Heidelberg

Railway City Gaobeidian
approx. 1.8 Mio m² TFA of certified Passive House projects worldwide

Open the map here.
Get inspired from projects worldwide

www.passivehouse-database.com
Public Awareness of the Benefits

The public is more often interested in the emotional and/or soft benefits of energy efficiency including:

1. High levels of comfort
2. Consistent fresh air throughout the building
3. Structural longevity: mould-free buildings with a highly reduced risk of moisture related damage
4. Extremely low heating/cooling costs; despite rising energy costs
5. Passive House buildings benefit regional manufacturers
Policy uptake

www.passivehouse-international.org

Passive House Legislation & Funding

In the following section you will find a list of cities and administrative districts that already stipulate the Passive House standard in their building regulations. This list is always growing. If you know of any further cities or regions that are implementing the Passive House Standard in their building regulations, please let us know by sending an email with a link to: info@passivehouse-international.org.

10 point plan
The Passive House Institute has also published a position paper with recommendations detailing how cities and communities can take their commitment forward in an effective way.

iPHA does not take any liability for the correctness of the information below.

AT | BE | DE | ES | LU | NO | US
Summing up of policy examples

→ **Frankfurt**: PH into the building code, starting 2007 all public buildings must be Passive Houses.

→ **Vancouver**: started by removing barriers through incentives and improving the building code, has resulted into the Center of Excellence and the inclusion of Passive House into the code of BC and other provincial governments

→ **Brussels**: dissemination, free consulting, exemplary projects, training programmes, energy fund and buildings to Brussel’s passive code.

→ **Luxembourg**: subsidies to buildings built to the Passive House standard

→ **Mexico**: concept for the gradual increase of requirements for energy efficiency, tools for the performance evaluation system
Europe Climate Policy

20-20-20 Goals of the European Commission

- Until 2020
  - 20% higher efficiency
  - -20% greenhouse gases (GHG) emissions
  - 20% share of renewables

Source: https://ec.europa.eu/clima/policies/strategies/2050/

2030 Climate & Energy Framework

Source: EU Commission, annual report

80% reduction of EU GHG emissions by 2050 (compared to 1990 values)

Source: https://ec.europa.eu/clima/policies/strategies/2050/
EU: Related directives and acts

Related Directives and Acts

- European Emissions Trading Scheme
- EU Energy-Efficiency Directive
- EU CHP Directive
- EU Buildings Directive (EPBD)
- EU Delegated Act
- EU Directive on Renewable Energy
- EU EcoDesign Directive

EU Energy Efficiency Directive

Gap

Source: European Commission 2011

EU EcoDesign Directive

Principles and criteria for ecological requirements on energy-using / energy-related products (ErP).

EPBD (2002), Recast 2010:


- From 31 Dec 2020 onwards, all new buildings are “Nearly zero energy buildings” (Art. 9)
  - For all public buildings this applies from 31 Dec 2018
  - Member states shall implement measures to increase the number of “Nearly Zero Energy Buildings”, and define targets (Art. 10)
- Member States are responsible for setting minimum requirements (Art. 4)
  - Have to meet at least cost optimum with respect to lifecycle costs (new buildings and building components)
- The commission is responsible for framework regulations (Art. 5)
  - “Delegated act” (Jan 2012)
  - Standardisation Mandate M 480 of the European Commission to the European Committee for Standardisation (CEN)
- Member States are responsible for the implementation
EPBD: The Nearly Zero Energy Building

Efficiency first!

- The Nearly Zero Energy Building is a “building that has a very high energy performance…”
- “The nearly zero or very low amount of energy required should to a very significant extent be covered by energy from renewable sources, including renewable energy produced on-site or nearby.” (Def Article 2, (2))
- Indicators for Energy Performance and Primary energy (Art 3, App. 1)
- No accounting of efficiency and renewables
- Minimum requirements for energy performance have to meet at least cost optimum with respect to lifecycle costs

“Cost-optimal level” - with respect to lifecycle
NZEB and Passive House: Cost optimum

EPBD:
“... requirements should be set with a view to achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the lifecycle of the building, ...”

NZEB:
Member States are responsible

Passive House: International prototype for NZEB

50 a without promotion
2.5% p.a. real interest rate
Energy price 9 Cent/kWh
Building Energy Performance Standards

Example Germany

Primary energy demand:
Heating, hot water, auxiliary electricity

Heat energy demand

Primary energy / Heating energy demand [kWh/(m²a)]

Useful floor space / living space

WSchV 77
WSchV 82
WSchV95
EnEV 02/04/07
EnEV09
EnEV14

Passive House Promotion by KfW

Passive House Pilot project

NZEB?

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Predictable Design needs Reliable Products

Product Certification

- Values for design
- Integrated in PHPP → directly available for energy balance - worldwide
- + component database

Make it Simple, Efficient, Cost-effective

© PHI
## Components in Different Climate Zones

The values of all certified components are available in the component database and in PHPP.

<table>
<thead>
<tr>
<th>Climate</th>
<th>No</th>
<th>Region</th>
<th>Wall- U-Value [W/(m²K)]</th>
<th>Window- U-Value (built.) [W/(m²K)]</th>
<th>Ventilation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>1</td>
<td>Arctic</td>
<td>0,09</td>
<td>0,45</td>
<td>HRV, hum recovery, frost prot.</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Cold</td>
<td>0,12</td>
<td>0,65</td>
<td>HRV, hum. recovery, frost prot.</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Cool temperate</td>
<td>0,15</td>
<td>0,85</td>
<td>HRV, frost protection</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Warm temperate</td>
<td>0,30</td>
<td>1,05</td>
<td>HRV</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Warm</td>
<td>0,50</td>
<td>1,25</td>
<td>---</td>
</tr>
<tr>
<td>Cooling</td>
<td>6</td>
<td>Hot</td>
<td>0,50</td>
<td>1,25</td>
<td>HRV, humidity rec in humid cl.</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Very hot</td>
<td>0,25</td>
<td>1,05</td>
<td>HRV, humidity rec in humid cl.</td>
</tr>
</tbody>
</table>
Component Database

Opaque building envelope
- Wall and construction systems
- Façade anchors
- Floor slabs
- ICF for roof parapets
- Flue systems
- Balcony connections
- Attic staircases

Building services
- Compact heat pump units
  - Ventilation systems (capacity < 600 m³/h)
  - Ventilation systems (capacity > 600 m³/h)
- Drain water heat recovery

www.componentdatabase.org

Explore the house and find the links or
- let the hotspots show up

Transparent building envelope
- Windows
- Roof windows
- Skylights
- Curtain wall systems
- Glass roofs
- Openable glass roof elements
- Shutters
- Entry doors
- Sliding doors
- Glazing
- Spacers

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Call for Papers

Application close 2nd March 2020

www.passivehouseconference.org
Online learning...

Welcome to our Passive House Online Platform!

www.elearning.passivehouse.com
Online resources...

www.passipedia.org
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