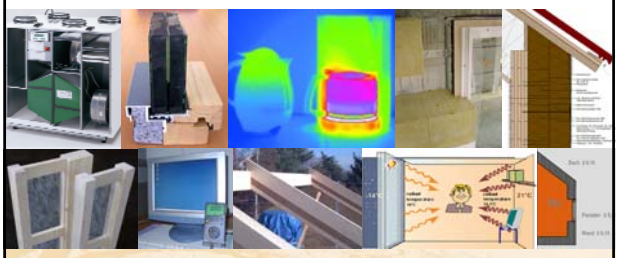
holzbaulehrstuhl
Universität Innsbruck

Passive House Principles

Asst. -Prof. DI Dr. techn. Anton Kraler
University of Innsbruck / Timber Engineering Unit



Workshop 1 – 2011 Wood Structures Symposium

1893: Research ship 'Fram' was a Passive House (!)

The first fully functioning Passive House was actually a polar ship and not a house:
the **Fram** of *Fridtof Nansen* (1893).

He writes:

"... The sides of the ship were lined with tarred felt, then came a space with cork padding, next a deal panelling, then a thick layer of felt, next air-tight linoleum, and last of all an inner panelling. The ceiling of the saloon and cabins . . . gave a total thickness of about 15 inches. ...The skylight which was most exposed to the cold was protected by three panes of glass one within the other, and in various other ways. ... The *Fram* is a comfortable abode. Whether the thermometer stands at 22° above zero or at 22° below it, we have no fire in the stove. The ventilation is excellent, especially since we rigged up the air sail, which sends a whole winter's cold in through the ventilator; yet in spite of this we sit here warm and comfortable, with only a lamp burning. I am thinking of having the stove removed altogether; it is only in the way." (from Nansen: „In **Farthest North**", Brockhaus, 1897)

1991: Passive House Darmstadt Kranichstein

- Four private clients formed the 'Developers Society Passive House' and commissioned the architects professor Bott/Ridder/Westermeyer with the planning of a row of houses with four flats, each with 156m² of living space.
- The building was provided with a highly precise data measurement acquisition system to examine the achievement of the objectives.
- A detailed report with technical data can be found here:

  http://www.passivhaustagung.de/Kran/Frist_Passive_House_Kranichstein.en.html

and in **Passipedia**

What is a Passive House?

This is the precise definiton of a passive house:

„A passive house is a building in which thermal comfort is solely guaranteed by re-heating (or re-cooling) the volume of fresh air that is required for satisfactory air quality – without using circulation air."

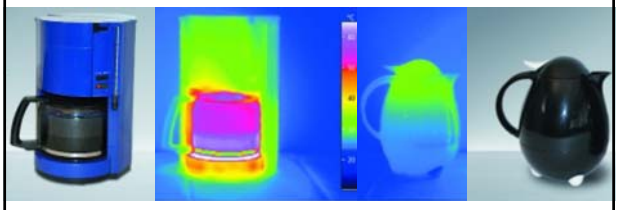
What is the Passive House Standard?

- A building standard, which is **energy efficient, comfortable, economic** and **environmentally friendly** at the same time.
  The Passive House is not a brand, it is a building concept which is open to all – and which has proved itself in practice.
- The Passive House is the leading standard in energy saving in buildings worldwide: The energy saving for heating amounts to over 75 % in comparison with the legally prescribed building standards. The heating costs are very small – high energy prices make no difference to residents of Passive Houses.
- Passive Houses achieve this enormous energy conservation through the use of special energy efficient building elements and ventilation techniques.

Not only is Comfort not impaired, it is measurably improved.

Principle of Passive Houses

What is passive about a Passive House?



ACTIVE

Keep warm by energy

Maintaining the heat by energy input

→

Keep warm by efficiency

Maintaining the heat using a insulated flask

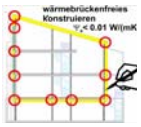
PASSIVE

What's so special about a Passive House?

The five basic principles

1. Exceptionally high level of thermal insulation
2. Well-insulated window frames triple low-e panes
3. Thermal-bridge-free construction
4. Airtight building envelope
5. Comfort ventilation with highly efficient heat recovery



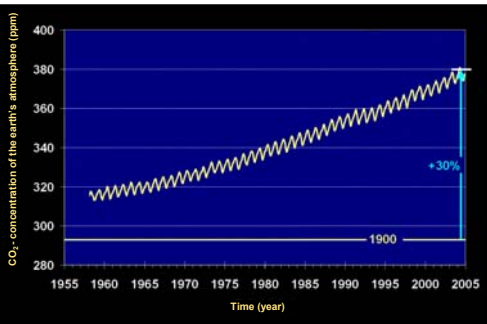



Why should we build Passive Houses?

Energy efficiency will be the key to survival of humanity

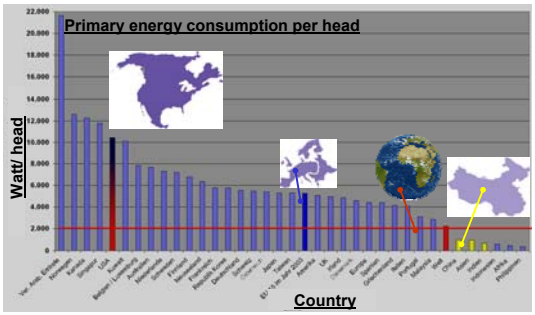
(Sir Norman Foster)

CO_2 - concentration of the earth's atmosphere



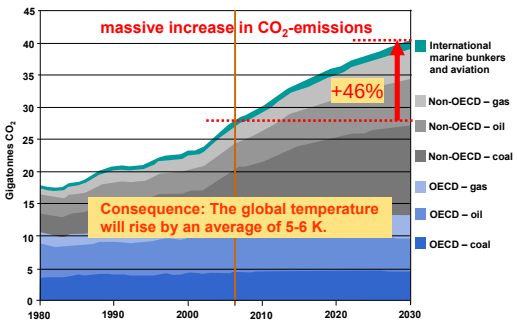
Source: C.D. Keeling, T.P. Whorf, and the Carbon Dioxide Research Group Scripps Institution of Oceanography (SIO) University of California

Primary energy consumption per head



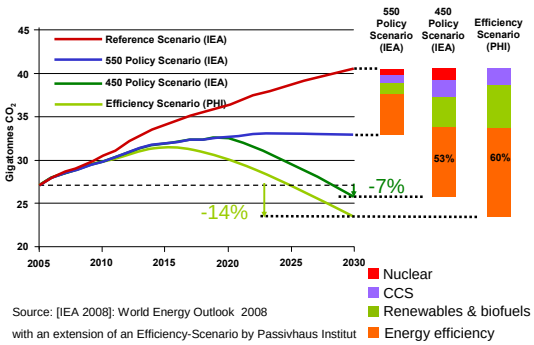
Source for data: International Energy Agency Agence Internationale de l'Energie

IEA-scenario for "business as usual"



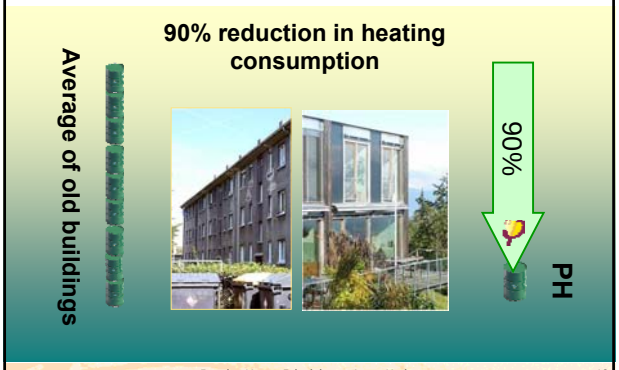
Source: [IEA 2008]: World Energy Outlook 2008

Scenarios for CO_2-reduction:

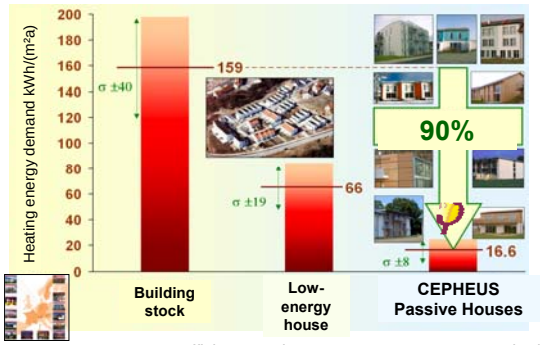


Source: [IEA 2008]: World Energy Outlook 2008
with an extension of an Efficiency-Scenario by Passivhaus Institut

Passive House concept



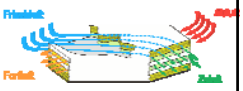
Comparison of consumption



CEPHEUS = Cost Efficient Passive Houses as European Standard

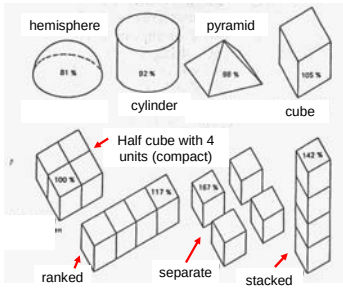
Passive house construction fundamentals

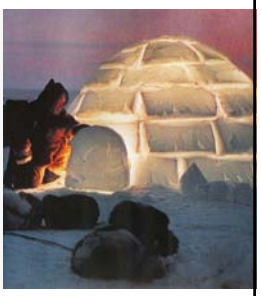
1. Good thermal insulation and compactness
2. Thermal-bridge-free construction
3. Well-insulated window frames with triple low-e panes
4. Airtight building envelope
5. Comfort ventilation with highly efficient heat recovery
6. Comfortable, even during the summer
7. Cost-effective and efficient building technology
8. Household energy saving systems
9. Quality-certified passive houses



Shape / Design of the building: A / V - Ratio

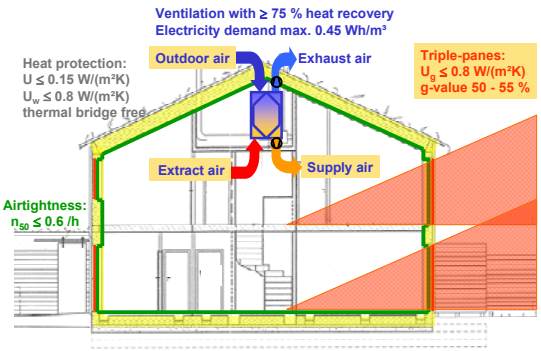
Surface, without floor area but with the same Volume (%)



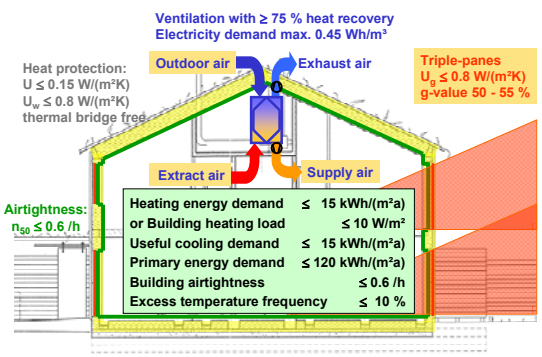


• More compact building: $A_{(Area)} / V_{(Volume)} < 0.6$ m-1

Passive House components

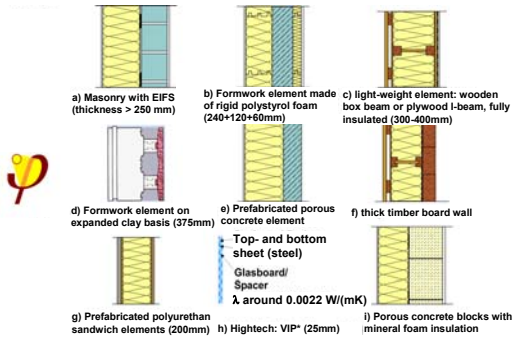


Passive House criteria

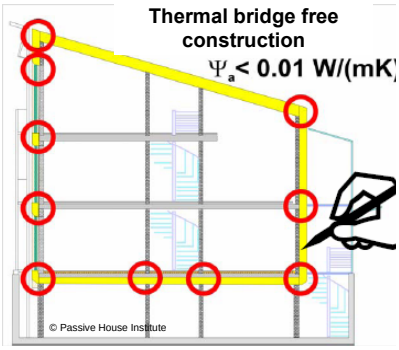


Passive House-suitable external wall constructions

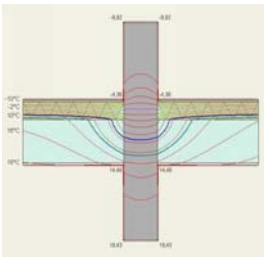
U ≤ 0.15 W/(m²K)

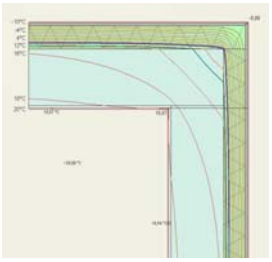


Thermal bridges



Constructive thermal bridge - distinction





Constructive thermal bridge

Geometric thermal bridge

Quelle: www.wikipedia.de

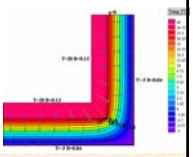
Thermal bridge free – Basic rules

Avoidance-rule

Pierce-through-rule

Connection-rule

Geometry-rule



Constructive thermal bridge

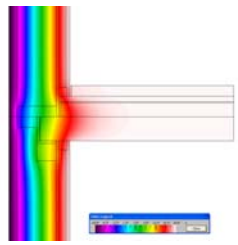


Bild: Herz & Lang

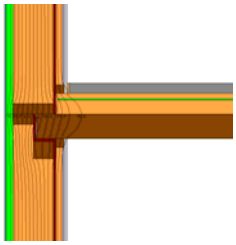
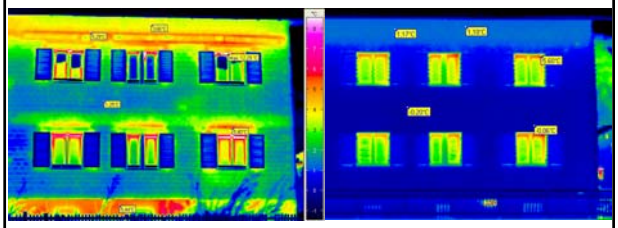


Bild: Herz & Lang

Thermal bridge

Infrared-thermography-images



without thermal insulation

with thermal insulation

Example: thermal insulation – building envelope

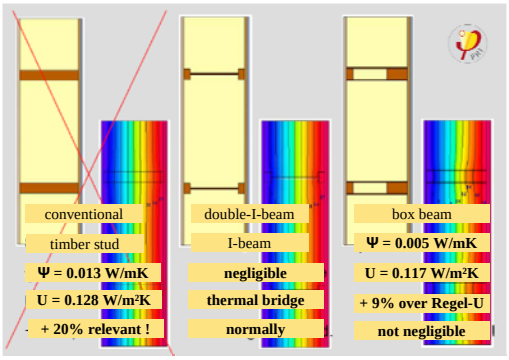
Thermal bridge free construction

Architect: Gerald Gaigg

Thermal bridge free construction

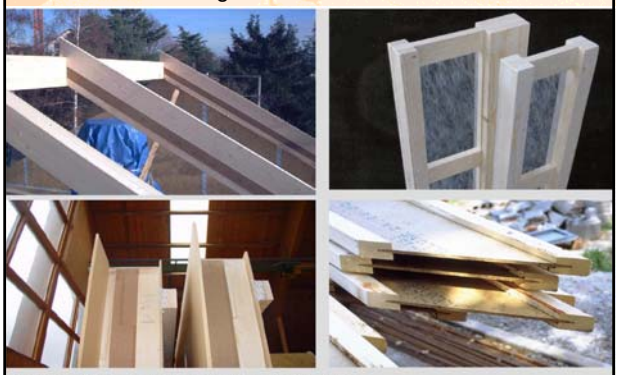
Architect: Gerald Gaigg

Thermal bridge free construction - exterior walls



Quelle: PHI. V. Sariri, J. Schnieders

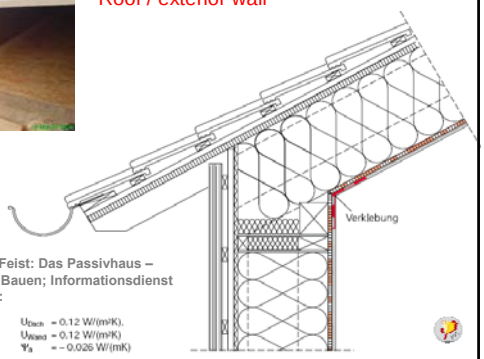
Thermal bridge free construction - materials



Quelle: Foto rechts oben: Fa. Lignotrend, sonstige Fotos M. Ploss

Thermal bridge free construction

Roof / exterior wall

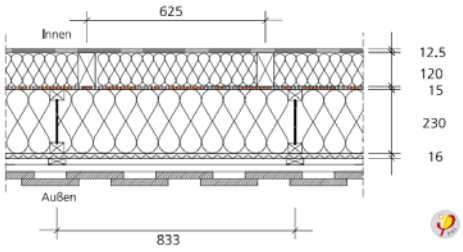


Quelle: Kaufmann, Feist: Das Passivhaus – Energie-Effizientes Bauen; Informationsdienst Holz (Herausgeber):

U_{Dach} = 0.12 W/(m²K),
U_{Wand} = 0.12 W/(m²K)
Ψ_a = – 0.026 W/(mK)

Thermal bridge free construction

Wood timber frame construction U-Value = 0,12 W/(m²K).

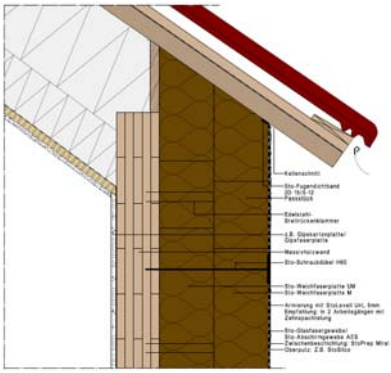


System Kölner Holzhaus (Architekt:Robert Laur)

Quelle: Kaufmann, Feist:: Das Passivhaus – Energie-Effizientes Bauen; Informationsdienst Holz (Herausgeber)

Thermal bridge free construction –

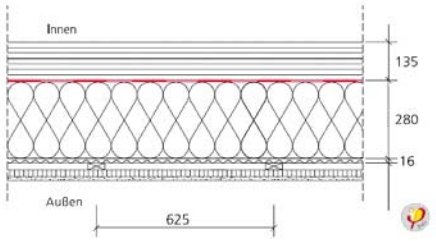
Roof / exterior walls
(cross laminated timber)



Quelle: www.sto.de

Thermal bridge free construction

Exterior wall (Cross-laminated-timber) U-Value = 0,12 W/(m²K).



Quelle: Kaufmann, Feist: Das Passivhaus – Energie-Effizientes Bauen;
Informationsdienst Holz (Herausgeber):

Thermal bridge free construction

Details exterior wall and roof

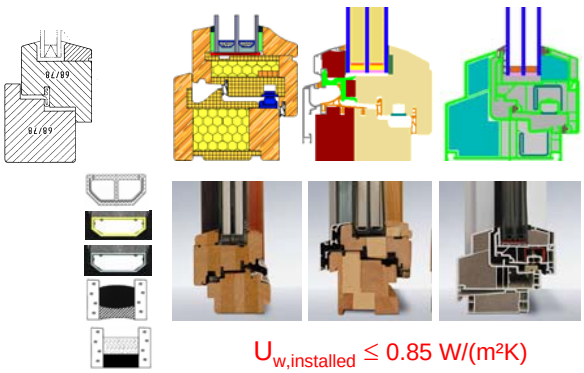
Thermal bridge free construction

Optimized building envelope

Thermal bridge free construction

Architect: Gerald Gaigg

Passive House windows



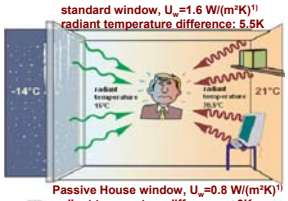
$U_{w,installed} \leq 0.85$ W/(m²K)

Radiant temperature asymmetry

Room with standard window and double low-e panes

- Low surface temperature of window
- Radiation temperature asymmetry too high
- Radiator below the window necessary

standard window, U_w=1.6 W/(m²K)[1)]
radiant temperature difference: 5.5K

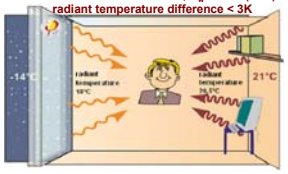


Room with Passive House window and triple-panes

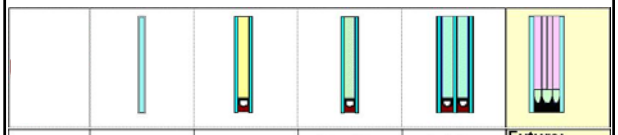
Surface temperature of window high

- Radiation temperature asymmetry small enough
- Radiator not necessary for comfort

Passive House window, U_w=0.8 W/(m²K)[1)]
radiant temperature difference < 3K



Comparison of pane types



Panes	Single	Double	Double, low-e	Triple, low-e	Future: vacuum/ multi-foil
U_g-value (W/[m²K])	5,60	2,80	1,20	0,50	0,35
surf. temp	-1,8 °C	9,1 °C	15,3 °C	18,1 °C	18,6 °C
g-value	0,92	0,80	0,62	0,52	0,45

Example: Window installation with timber beam

Frame located in the insulation layer, in front of the masonry wall

Point fixing with metal brackets

Glued fleece for airtightness

Load bearing timber beam

Photo of insulation installation

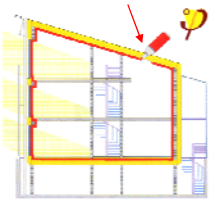
Example: MFH Hamburg, Wernst Immobilien

Airtightness

Basics of Airtightness

Include airtight shell in the planning stage

Pencil Rule

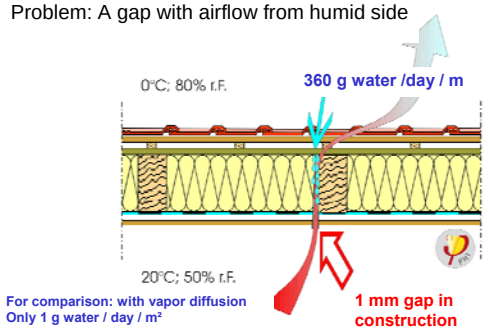


design **ONE** airtight layer all around the building

Quelle: holzbaulehrstuhl Innsbruck

Airtightness - why?

Problem: A gap with airflow from humid side



For comparison: with vapor diffusion Only 1 g water / day / m²

1 mm gap in construction

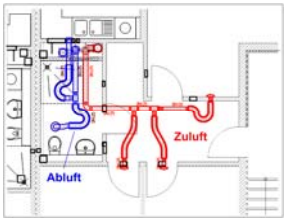
Airtightness - why?

Airtightness - why?

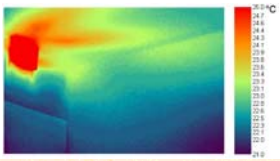
Advantages of Airtightness

- Avoidance of moisture-related building damage
- Avoiding drafts and cold feet
- Avoiding high infiltration heat losses
- Necessary for the use of an adjustable, requirement based ventilation system
- Necessary for efficient thermal insulation
- Improved sound insulation
- Improved inside air quality

Best indoor air quality



Example: Kassel Marbachhöhe
Design: innovatec / Otte
monitoring: PHI Pfluger / Feist

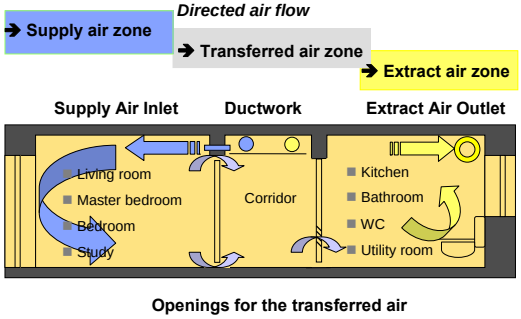


Role of the ventilation system in a Passive House

- **Main role:** Renewal of indoor air
  - Limit the air humidity / avoid mold growth
  - Avoid concentration and build-up of pollutants
  - Limit odor nuisance
- **Additional roles:** Conditioning of the indoor air:
  - Cleaning (filters)
  - Heating / Cooling
  - Humidification / Dehumidification (caution regarding hygiene)
- **Side effect:** Passive heat recovery
  - Reduction of ventilation heat losses
  - Increase in comfort due to higher supply air temperatures

Cross ventilation principle with supply & extract air

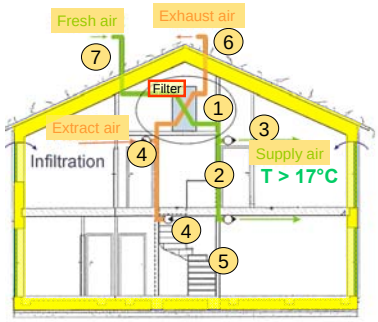
Concept:



Openings for the transferred air

Supply & extract air system with heat recovery (HRV)

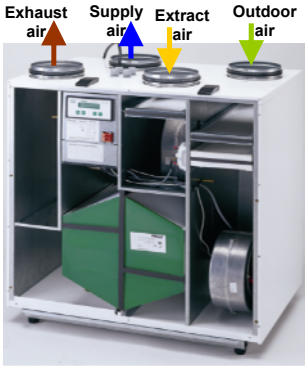
System concepts:



Characteristics:
- Centrally located ventilation unit with fans and heat recovery
- Supply and extract air in separate ducts

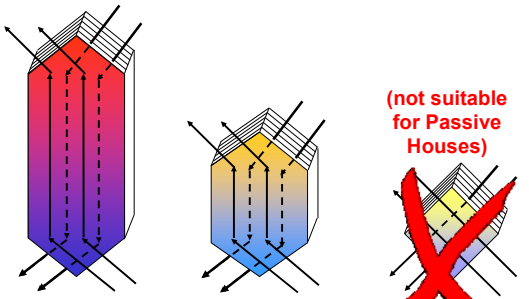
Main components :
1. Ventilation unit with fans, control, HR, filters
2. Ducting with silencers
3. Supply air inlets
4. Extract air outlets
5. Directed flow through the internal rooms, transfer openings in internal doors
6. Exhaust air outlet
7. Fresh air inlet

Components of central units



- Air to air heat exchanger with HR ≥ 75%
- DC motors
- Control: operating levels and air flow balancing
- Thermal insulation and airtightness
- Condensate drain
- Filter: Extract air + outdoor air
- Frost protection
- Summer bypass

System components: Air to air heat exchanger (HE)



Counter flow
70 -95 %

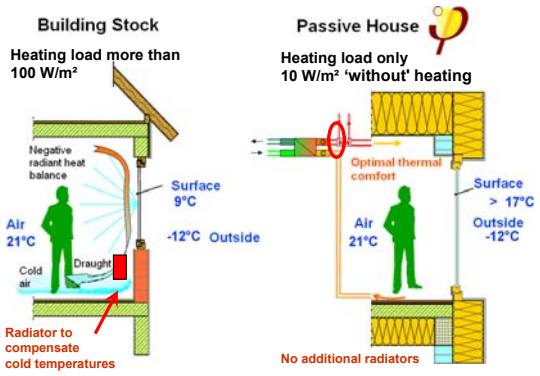
Cross counter flow
70 - 85 %

Cross flow
40 - 60 %

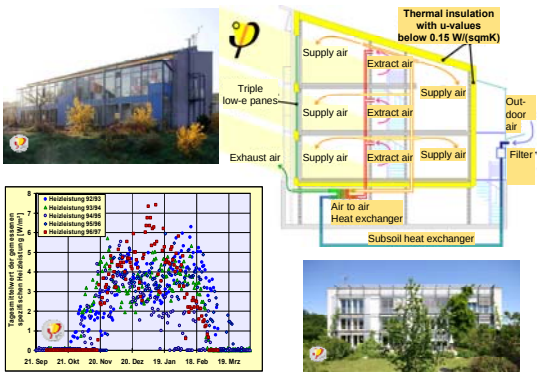
Special requirements of heating supply in Passive Houses

- **Extremely low annual space heat demand**
  Annual space heat demand ≤ 15 kWh/(m²a);
- **Dominance of DHW energy demand**
  DHW heat demand of 18-35 kWh/(m²a) is more important than space heating – efficient and cost-effective systems for DHW required
- **It does not matter how the heat is delivered into the rooms!**
  e.g.: radiators or surface heating systems or supply air heating
- **Very low heating load**
  The maximum heating load of 10 W/m² is approx. 3-5 times lower compared to average new buildings.

Heating load in building stock versus Passive House

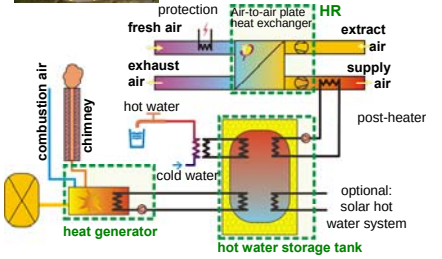


Heating load Darmstadt Kranichstein



Central-heating boiler: System design

Certified Passive House
Detached house
in Steinheim, Architect:
Sanwald.
Gas boiler technology +
supply-air heating coil
Foto: Wolfgang Sanwald



Passive House Planning Package (PHPP)

Recommended TOOL. Balance calc procedure

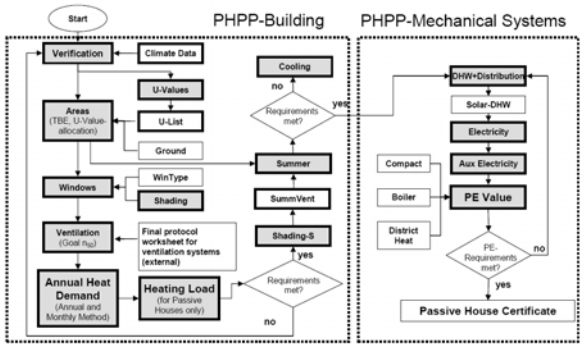
Calculates e.g.

- U-values of the building shell, including windows
- transmission losses to ambient air and ground
- ventilation and infiltration losses
- passive solar and internal gains, including shading
- household and auxiliary electricity demand
- heating load
- summer comfort

•Validated against measurements

Passive House Planning Package (PHPP)

Schematic: PHPP 2007



Certification of buildings


Certificate

Quality Approved Passive House

Goals:

- Quality assurance: good, functioning Passive Houses

Motivation:

- Second check, design assurance
- by neutral institution
- Increase in value through certificate

Method:

Check using four-eye-principle:

- PHPP, construction and mechanical services drawings
- Verification of execution: Airtightness test and ventilation adjustment protocol
- Optional: Consultancy, site visits, …

Certifiers:

- Authorised by PHI
- Act at their own responsibility

Useful design tools

- **Passive House Planning Package (PHPP)**

  Energy balance tool for energy evaluation, heating load and summer comfort (Can be ordered online)

- **PHLuft**

  Calculation tool for duct losses, subsoil heat exchanger (Free download. English version available soon)

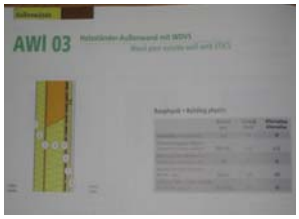
- **Literature with basics and design tools**

- **Certificates for Passive House components**

  (Free download)

www.passivehouse.com

Details for passive houses



Details for Passive Houses
A Catalogue of Ecologically Rated Constructions
National Design Specification for Wood Construction, SpringerWienNewYork, 2008

Examples of Passive Houses

Architekt: Gerald Gaigg

Examples of Passive Houses

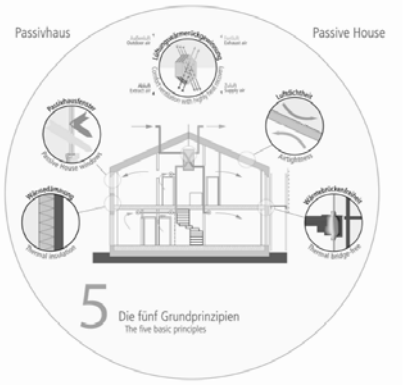
Examples of Passive Houses

Residential building Mühlweg, Vienna

Examples of Passive Houses

Refuge Schiestlhaus, Hochschwab Stmk.

Summary – The five basic principles



Passive House Institute – Structure & Offerings

Passive House Institute

Offices

Passive House Institute Darmstadt Since 1996

Passive House Institute Innsbruck Since 2010

R&D | Quality assurance | Building & Component certification | Expert training | International PH Conference

www.passivehouse.com

Network

International PASSIVE HOUSE Association Since 2010 1PHA

International Passive House network | Passipedia | Passive House promotion | International Passive House Days

www.passivehouse-international.org

Worldwide Affiliates