The principle: optimal all-round thermal insulation.

Each structural component has a crucial effect.

Whether roof, external wall or cellar – good thermal quality of the individual components is always the safest and most sustainable way to avoid heat loss. All opaque elements of the building envelope should be thermal insulated so well that their thermal transmittance (U-value) is less or equal 0.15 W/(m^{2}K). In other words: for every degree temperature change and every square meter outer surface not more than max. 0.15 W heating energy must be lost. Usually, the major heat losers for most homes are edges and corners, connections and penetrations. It is therefore essential to ensure optimum insulation of these areas – as gapless as possible so that thermal bridges don't have the slightest chance.

To the point:

Recommended U-values for the building envelope.

External wall	U-value	≤	0.10 W/(m^{2}K)
Roof/ceilings/floors	U-value	≤	0.10 W/(m^{2}K)
Floor above cellar	U-value	≤	0.15 W/(m^{2}K)
PHPP-value*)	Ψ	≤	0.01 W/(m^{2}K)

**) PHPP = Passive House Planning Package offered by the Passivhausinstitut in Darmstadt/Germany*

Detached house Akazienweg, Bruck/Waasen, Austria
Planner: Plöderl.Architektur.Urbanismus.PAUAT Architekten

The facade: higher benefit from insulation than from masonry.

For economic reasons, the load-bearing masonry should only fulfil the static minimum requirements. Heat protection is primarily provided by thermal insulation. Facade and external walls can do more for a home than merely be its "visiting card": they can save a lot of energy if insulated well. And what is more: with a suitable orientation, the facade can be equipped with a system for producing renewable energy, e.g. a photovoltaic unit.

One external wall is not like the other.

This does not only apply to the visual but also to the technical design. Depending on the budget, intended use and desired form of the house, a matching design variant can be chosen. Here a brief overview:

• The ventilated facade as universal solution.
Here, we have a functional separation between a load-carrying, a heat- and sound-insulating and a water-draining layer, including an air gap between insulation and cladding. This separation optimally fulfils the physical demands made on the structure of an external wall. The ventilated facade lends itself to various designs. Whether wood, stone, glass, metal or ceramics: the facade can be clad with all weather-resistant materials. The load-bearing inner envelope makes it possible to install low-cost insulation materials (e.g. ISOVER mineral wool) and thus to achieve passive house standard.

• Cavity walls: always with a heat-insulated cavity.
This variant also assures good separation of the functions support, heat insulation and waterproofing. The use of hydrophobic core insulation made of glass wool provides durable, reliable as well as economical protection of the building.

• External thermal insulation composite systems (ETICS): for jointless facade insulation.
The advantages of systems based on mineral wool insulation boards are above all their non-flammability and the high diffusibility that promotes the rapid reverse drying of damp walls.

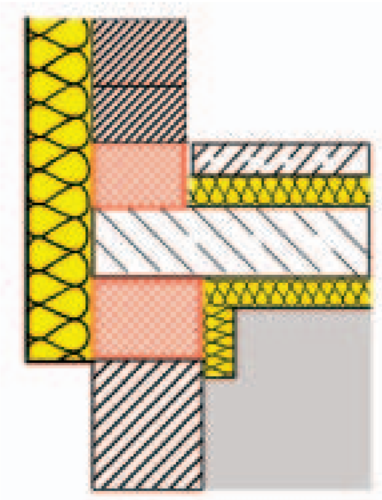
Timber construction
Good to know:
Compared to solid construction, timber construction offers the great advantage that a major part of the insulation can be fitted between the wooden frames and does not need to be additionally installed from outside. Consequence: lower wall thickness, higher degree of prefabrication, shorter construction times and lower building costs.

Filling the wood-frame construction tightly with ISOVER glass wool

The devil's in the detail: flaws in walls, ceilings and cellars.

Junctions are the weakest spots.

Penetrations of the building envelope by utility pipes, windows and doors are unavoidable. For this reason, thermal bridges can never be fully excluded. It is therefore indispensable to reduce these energy wasters to a minimum. For: The higher the thermal insulation quality of the building, the stronger the proportionate effect of a structural weakness on the total heat loss.



Critical area: where the outer wall meets the cellar.

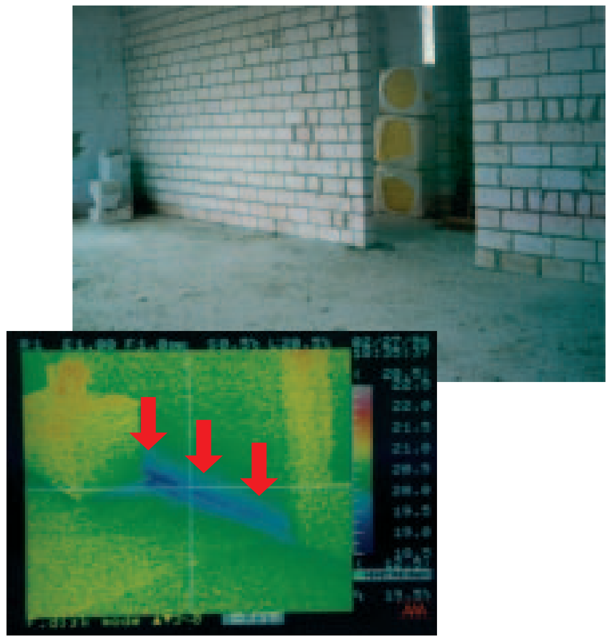
Especially with solidly built houses heat must be prevented from escaping through the brickwork or into the ground via highly heat-conductive concrete elements. Quite frequently, the cellar floor is insulated but the insulation layer interrupted in the area of the outer wall or of the foundations. This problem can be remedied by sufficient wall base insulation and should already be considered in the planning stage.

Likewise: partition wall meets insulated floor.

Where solid partition walls meet floors with room-side insulation, thermal separation by means of low heat-conducting building materials is necessary. The negative example on the right provides the proof: the job seems to have been executed with reasonable care and skill, but thermographic imaging clearly shows the thermal bridge. Refurbishment is done by additionally insulating the flanking building components.

For more security: decouple the foundation.

To prevent that heat is transmitted via the foundation or the ice wall, the foundation should be decoupled from the bottom slab. Even if the overlying insulation layer takes care of thermal insulation, greatest possible security can only be achieved by thermal separation.



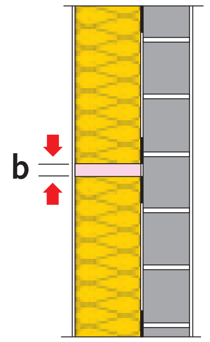
Typical weak spot because a well heat-conducting inner wall of the ground floor rises directly from the cold cellar floor. (Source: Niedrig Energie Institut Germany)

Cavities, insulation gaps and joints.

A closed, not too big cavity has only little energetic impact. By contrast, gaps and joints in the thermal insulation of a house cause considerable heat loss.

No need to worry about closed cavities.

Cavities located in the insulation layer are always airtight although they are not insulated. With cavities below 5 mm width, this lack of insulation does not cause any problems. As long as the cavities are non-communicating, no remedial measures need to be taken. Not so with cavities of more than 5 mm width.

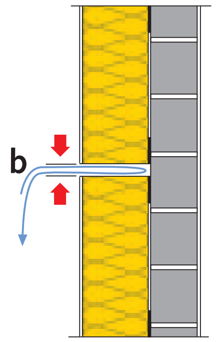


Cavities are airtight, but insulation is missing.

Their thermal bridge effect is so strong that they should best be filled with mineral wool. But don't use mortar as this would even reinforce the thermal bridge effect. Also watch out for communicating cavities: they can render an insulating layer nearly ineffective.

Insulation gaps ruin the energy balance.

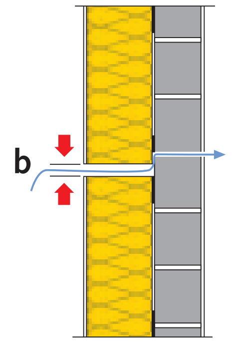
As gaps in the insulation are closed on only one side, they allow air flows on the other. This results in considerable heat loss. Thus a gap of 10 mm can reduce the insulating effect of a 300 mm thick composite thermal insulation system down to that of an insulation layer of just 90 mm thickness.



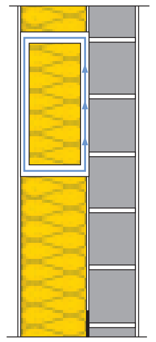
Insulation gaps are open on one side.

Joints are fatal.

Joints which are open on both sides have only little flow resistance. In a system that is otherwise completely closed, the heat loss multiplies many times over. It is therefore absolutely necessary to locate and completely eliminate them. Otherwise the building will be draughty and prone to structural damage.



A joint is open on both sides and makes the house leaky.



Communicating cavities considerably increase convection, thus being able to render the insulation nearly ineffective.

Connection outer wall (timber construction) to cellar floor above unheated cellar

A. Cellar base (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.021
2. Concrete 2300	0.200	2.300	0.087
3. XPS insulation, 2-layered	0.240	0.039	6.154
4. Exterior plaster	0.025	1.000	0.036
Total sum of thermal resistances			6.298
Thermal surface resistances			0.170
U-value of the construction			U = 0.15 W/(m²K)

B. Outer wall, timber construction (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Composite wood panel	0.015	0.240	0.062
4. Glass wool felt	0.320	0.035	9.143
5. Wood fibreboard, e.g. MDF	0.016	0.070	0.228
6. Cladding, ventilated	–	–	–
Total sum of thermal resistances			10.922
Thermal surface resistances			0.170
U-value of the construction in the compartments between rafters			U = 0.09 W/(m²K)
U-value of the construction with wooden parts			U = 0.10 W/(m²K)

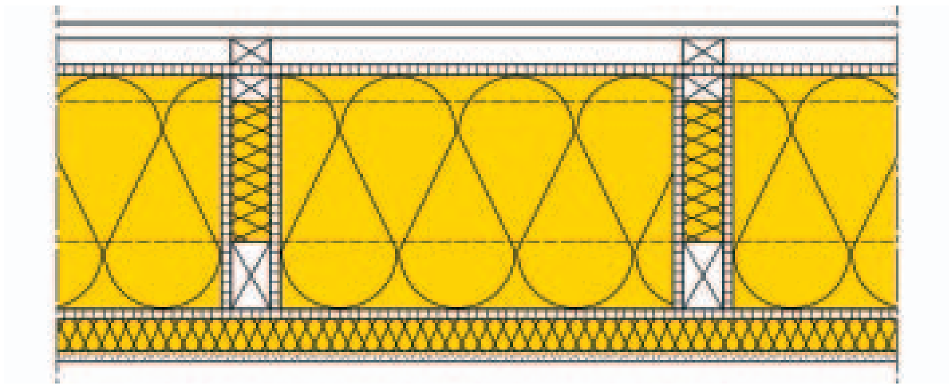
C. Cellar floor (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Cement screed	0.050	1.400	0.035
2. Mineral wool impact sound insulation	0.025	0.035	0.714
3. Composite wood panel	0.015	0.240	0.062
4. Mineral wool insulation	0.120	0.035	3.429
5. Concrete 2300, 1 % reinforcement	0.160	2..300	0.069
Total sum of thermal resistances			4.303
Thermal surface resistances			0.210
U-value of the construction			U = 0.22 W/(m²K)

ψ-value[1] = -0.181 W/(mK); f-value[2] = 0.940; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

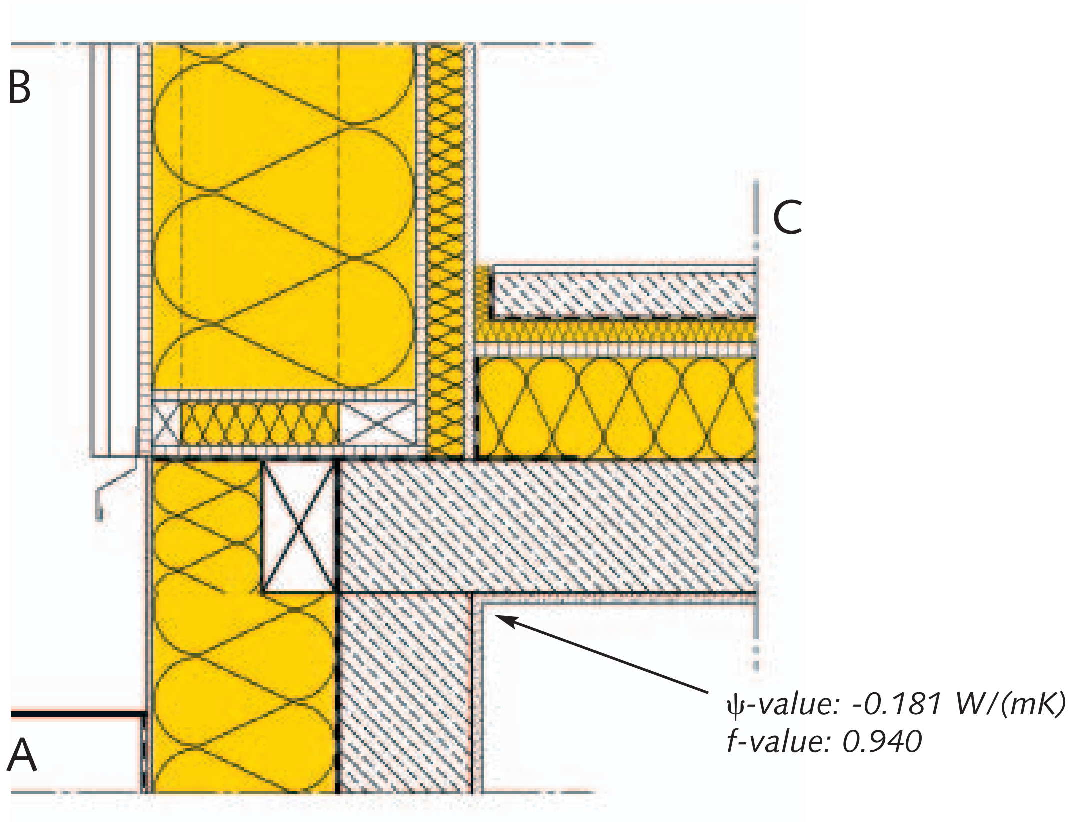
[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

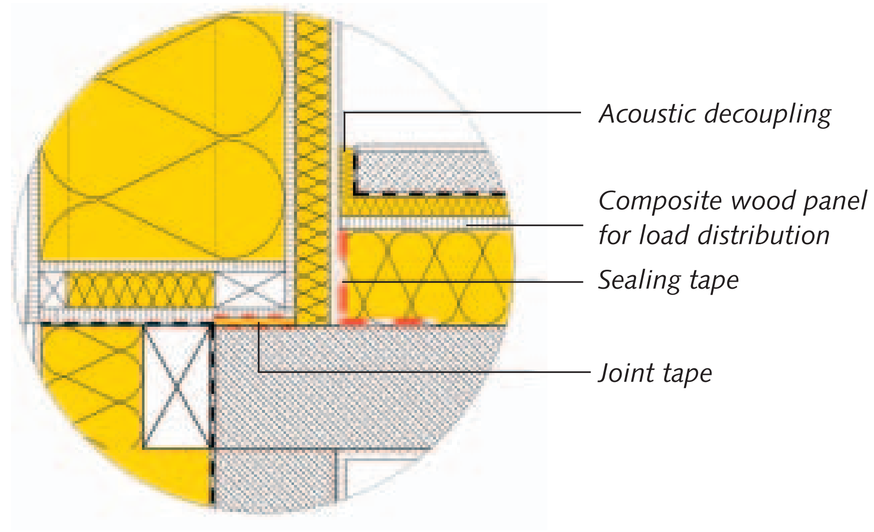


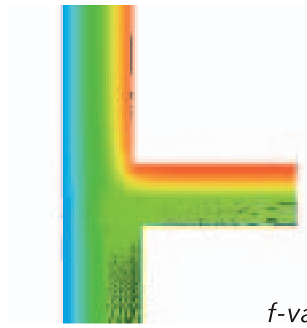
High thermal insulation and airtightness.

The solution shown below produces a thermal bridge optimized, airtight connection to a box rafter external wall with a ventilated cladding.

Outer wall: Sound reduction index Rw = 52 dB
Fire-resistance rating acc. to EN 13501-2, REI 30







f-value

Connection terrace door to cellar floor above unheated cellar

A. Cellar floor (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Cement screed	0.050	1.400	0.035
2. Mineral wool impact sound insulation	0.045	0.035	1.286
3. Concrete 2300, 1 % reinforcement	0.160	2.300	0.069
4. Mineral wool insulation	0.220	0.035	6.286
5. Plaster coat	0.015	0.700	0.021
Total sum of thermal resistances			7.697
Thermal surface resistances			0.210
U-value of the construction			U = 0.13 W/(m²K)

B. Cellar wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Concrete 2300, 1 % reinforcement	0.220	2.300	0.095
2. Moisture sealing	–	–	–
3. Perimeter insulation XPS	0.160	0.039	4.102
Total sum of thermal resistances			4.197
Thermal surface resistances			0.130
U-value of the construction			U = 0.23 W/(m²K)

Additional interior insulation of the floor connection d = 0.09 m , height = 0.50 m

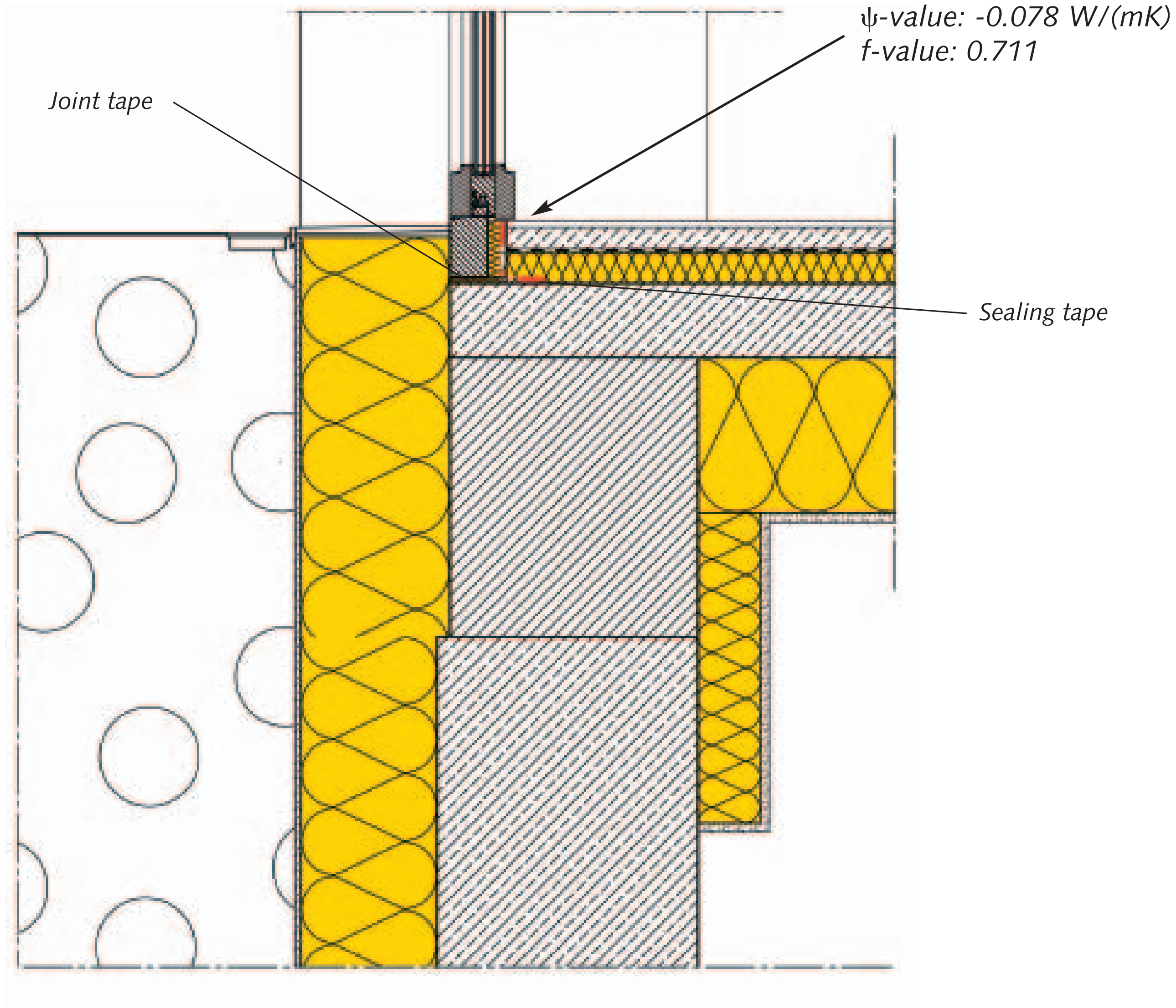
ψ-value[1)] = -0.078 W/(mK); f-value[2)] = 0.711

[1)] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

[2)] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Thermal bridge optimized terrace connection.

Thermal bridging can be reliably prevented when overlapping the window frame with thermally insulating materials and combining this with highly heat-insulating offset blocks and optimized insulation on the underside of the cellar floor.



Multi-Comfort House

Connection of outer wall (timber construction) to slab on the ground

A. Outer wall, timber construction (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Composite wood panel	0.015	0.240	0.062
4. Glass wool felt	0.320	0.035	9.143
5. Wood fibreboard, e.g. MDF	0.016	0.100	0.160
6. Cladding, ventilated	–	–	–
Total sum of thermal resistances			10.854
Thermal surface resistances			0.170
U-value without wooden parts			U = 0.09 W/(m²K)
U-value of the construction with wooden parts			U = 0.10 W/(m²K)

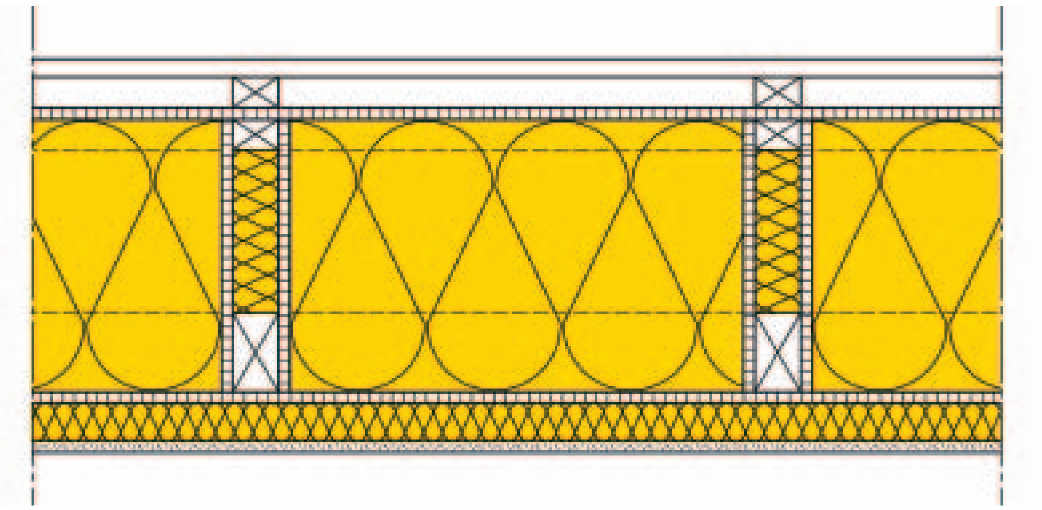
B. Base slab (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Cement screed	0.050	1.400	0.035
2. Mineral wool impact sound insulation	0.030	0.035	0.857
3. Moisture sealing	–	–	–
4. Concrete 2300, 1 % reinforcement	0.300	2.300	0.130
5. Separation layer	–	–	–
6. XPS insulation, 2-layered	0.240	0.039	6.153
7. Foundation course	–	–	–
Total sum of thermal resistances			7.175
Thermal surface resistances			0.210
U-value of the construction			U = 0.15 W/(m²K)

ψ-value[1] = -0.082 W/(mK); f-value[2] = 0.944; minimal surface temperature ϑsi = 18.6 °C; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

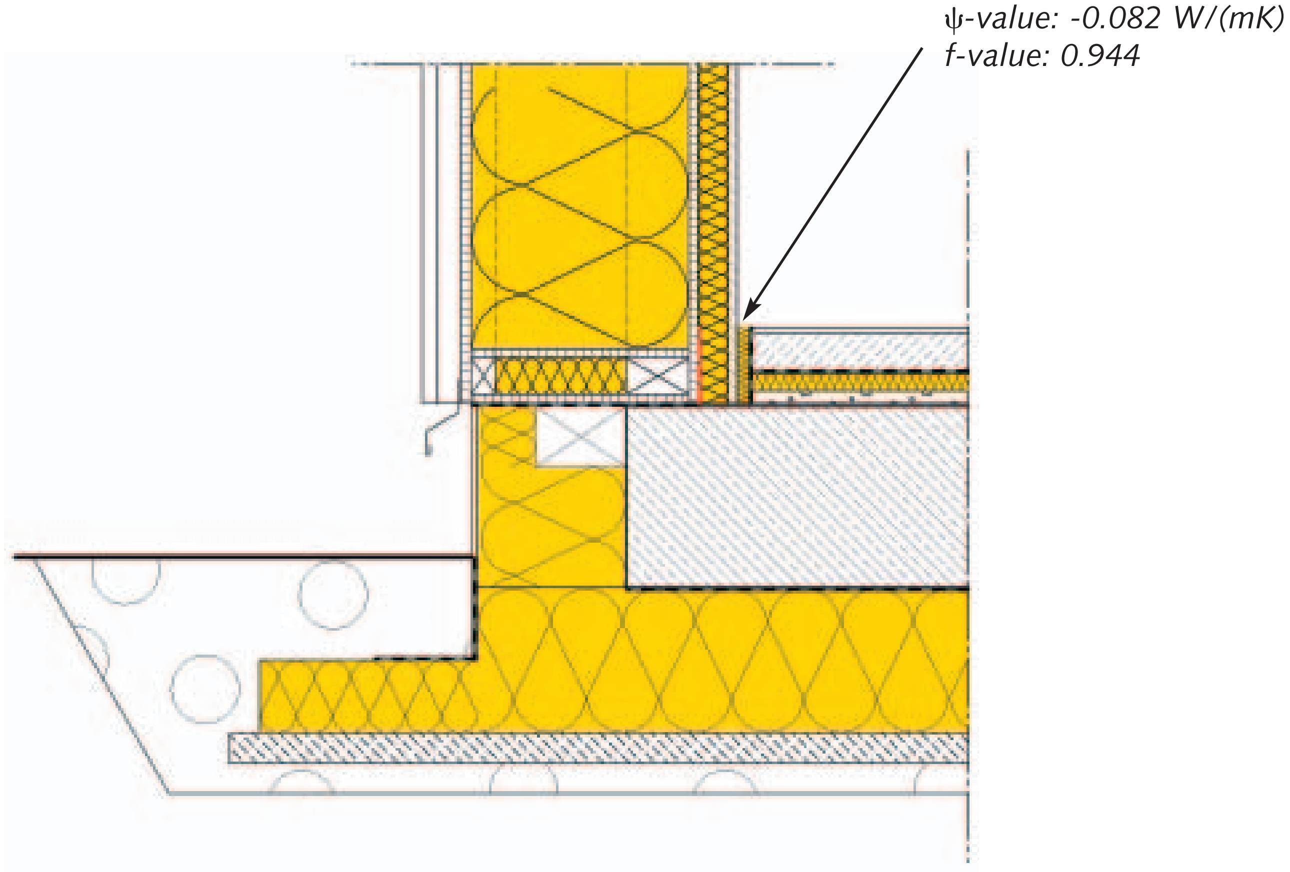
[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

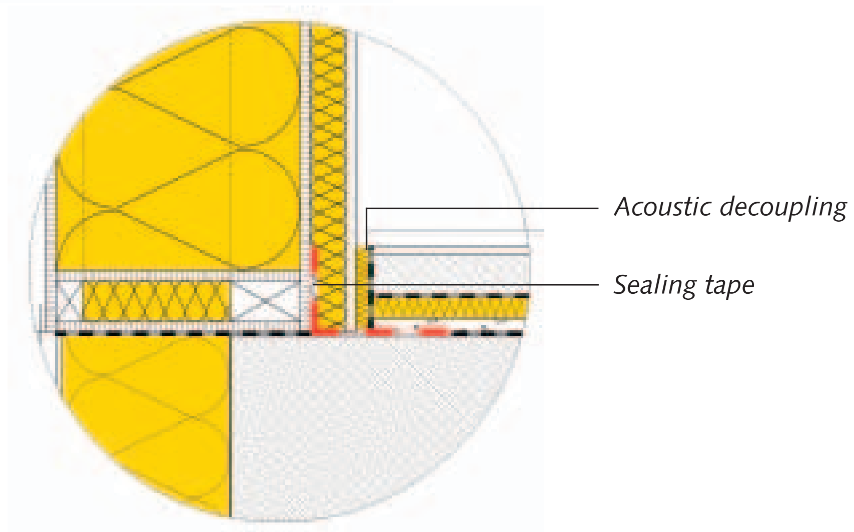


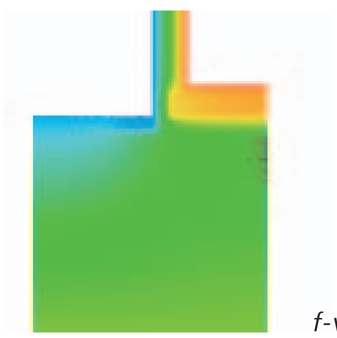
Connection of outer wall to slab on the ground.

When connecting the ventilated outer wall with the base slab, the ice wall considerably contributes to reducing heat loss via the ground.

Outer wall: Sound reduction index Rw = 52 dB
Fire-resistance rating acc. to EN 13501-2, REI 30







Outer wall (timber construction) with ETICS based on mineral wool to basement floor above unheated cellar

A. Cellar base (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^{2}K/W
1. Interior plaster	0.015	0.700	0.021
2. Concrete 2300	0.200	2.300	0.087
3. XPS insulation, 2-layered	0.240	0.039	6.153
4. Exterior plaster	0.025	1.000	0.036
Total sum of thermal resistances			6.297
Thermal surface resistances			0.170
U-value of the construction			U = 0.15 W/(m^{2}K)

B. Outer wall, timber construction (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^{2}K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Climatic membrane Vario KM	–	–	–
4. Composite wood panel	0.015	0.240	0.062
5. Glass wool felt	0.200	0.035	5.714
6. Wood fibreboard, e.g. MDF	0.016	0.100	0.168
7. Mineral wool plaster baseboard	0.140	0.035	4.000
8. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			11.458
Thermal surface resistances			0.170
U-value of the construction in the compartments between rafters			U = 0.08 W/(m^{2}K)
U-value of the construction with wooden parts			U = 0.09 W/(m^{2}K)

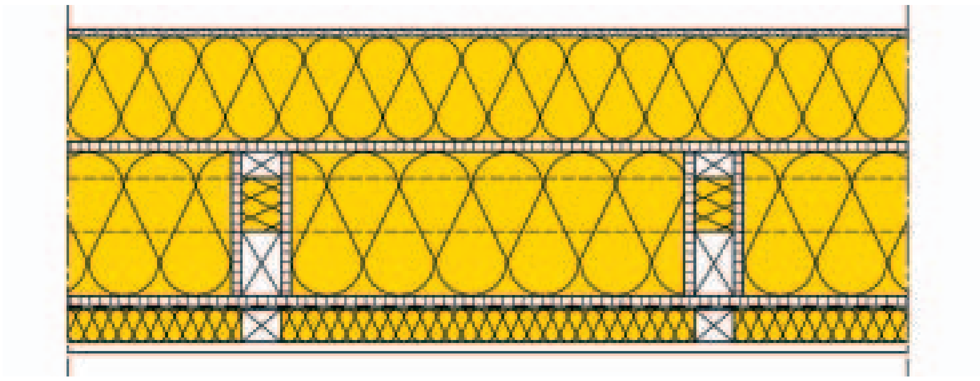
C. Cellar floor (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^{2}K/W
1. Wooden floor, frame-mounted	0.024	0.240	0.100
2. Glass wool between bolsters	0.040	0.035	1.143
3. Mineral wool insulation	0.200	0.035	5.714
4. Concrete 2300, 1 % reinforcement	0.160	2.300	0.069
Total sum of thermal resistances			7.026
Thermal surface resistances			0.21
U-value of the construction			U = 0.14 W/(m^{2}K)

ψ-value[1] = 0.033 W/(mK); f-value[2] = 0.944; minimal surface temperature ϑ_{si} = 18.6 °C; at 20°C indoors and -5°C outdoors.

1) The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

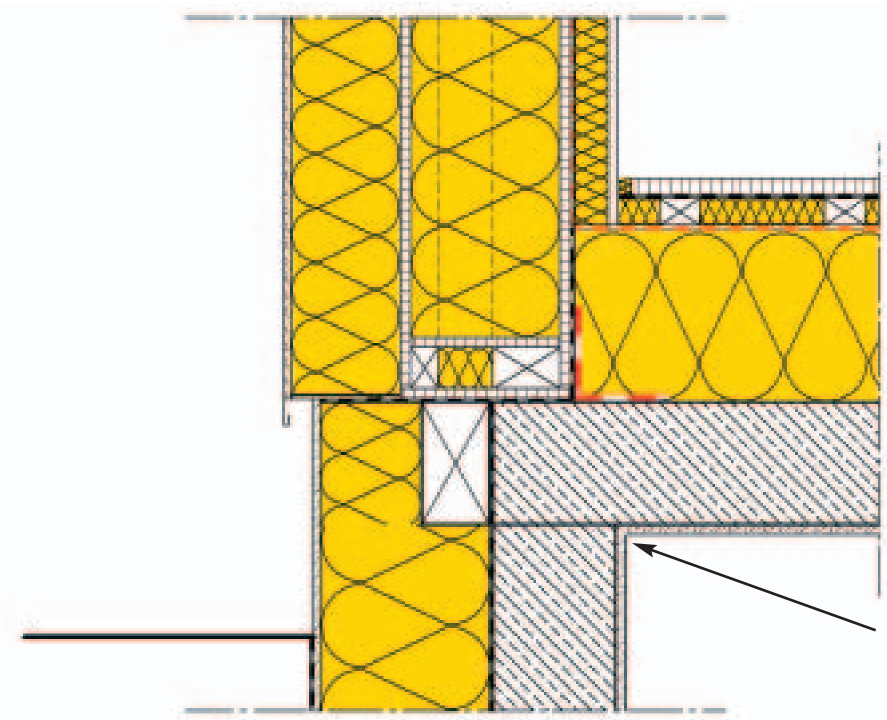
2) The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

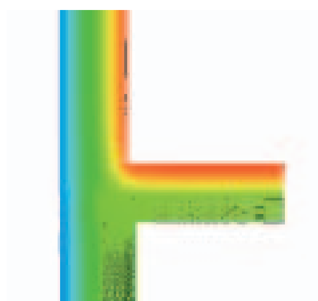


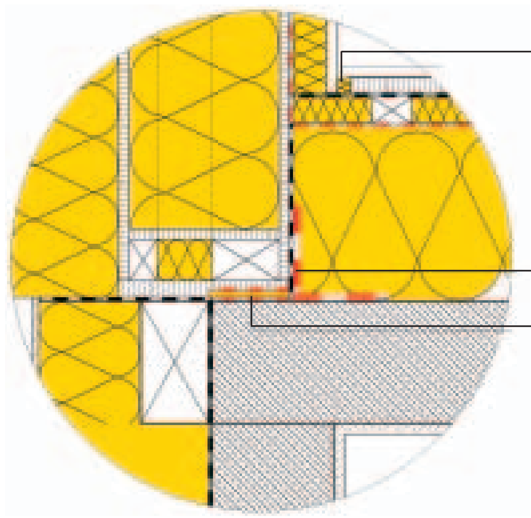
Thermal bridge free connection to the cellar floor.

The connection detail for an outer wall in timber construction – with externally installed mineral wool ETICS – has been optimized concerning thermal bridging. The wooden floor, which has been frame-mounted on the cellar floor, offers a particularly high-grade solution for heat and sound insulation combined with reliable air-tightness. The diffusion-capable external thermal insulation composite system based on mineral wool ensures the moisture balance of the wall construction.

Outer wall: Sound reduction index Rw = 51 dB
Fire-resistance rating acc. to EN 13501-2, REI 60







Ground floor with basement

A. Cellar base (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^2K/W
1. Interior plaster	0.015	0.700	0.021
2. Concrete 2300	0.200	2.300	0.087
3. XPS insulation, 2-layered	0.240	0.039	6.153
4. Exterior plaster	0.025	1.000	0.036
Total sum of thermal resistances			6.297
Thermal surface resistances			0.170
U-value of the construction			U = 0.15 $W/(m^2K)$

B. Outer wall, timber construction (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^2K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Climatic membrane Vario KM	–	–	–
4. Composite wood panel	0.015	0.240	0.062
5. Glass wool felt	0.200	0.035	5.714
6. Wood fibreboard, e.g. MDF	0.016	0.100	0.168
7. Mineral wool plaster baseboard	0.140	0.035	4.000
8. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			11.458
Thermal surface resistances			0.170
U-value of the construction in the compartments between rafters			U = 0.08 $W/(m^2K)$
U-value of the construction with wooden parts			U = 0.09 $W/(m^2K)$

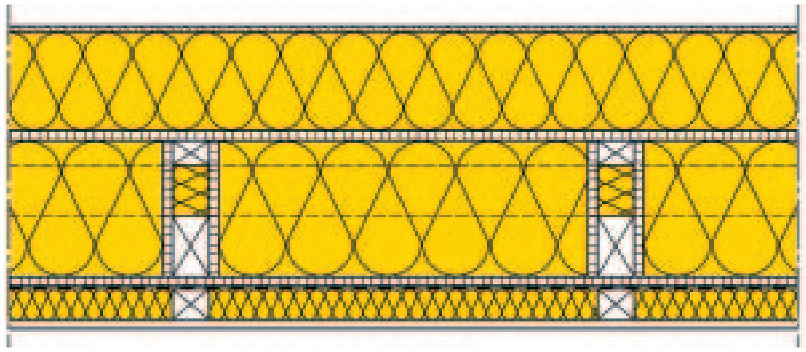
C. Cellar floor (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m^2K/W
1. Cement screed	0.050	1.400	0.035
2. Mineral wool impact sound insulation	0.025	0.035	0.714
3. Composite wood panel	0.015	0.240	0.062
4. Mineral wool insulation	0.120	0.035	3.429
5. Concrete 2300, 1 % reinforcement	0.160	2.300	0.069
Total sum of thermal resistances			4.309
Thermal surface resistances			0.21
U-value of the construction			U = 0.22 $W/(m^2K)$

ψ-value[1] = 0.033 W/(mK); f-value[2] = 0.944; minimal surface temperature ϑ_{si} = 18.6 °C; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

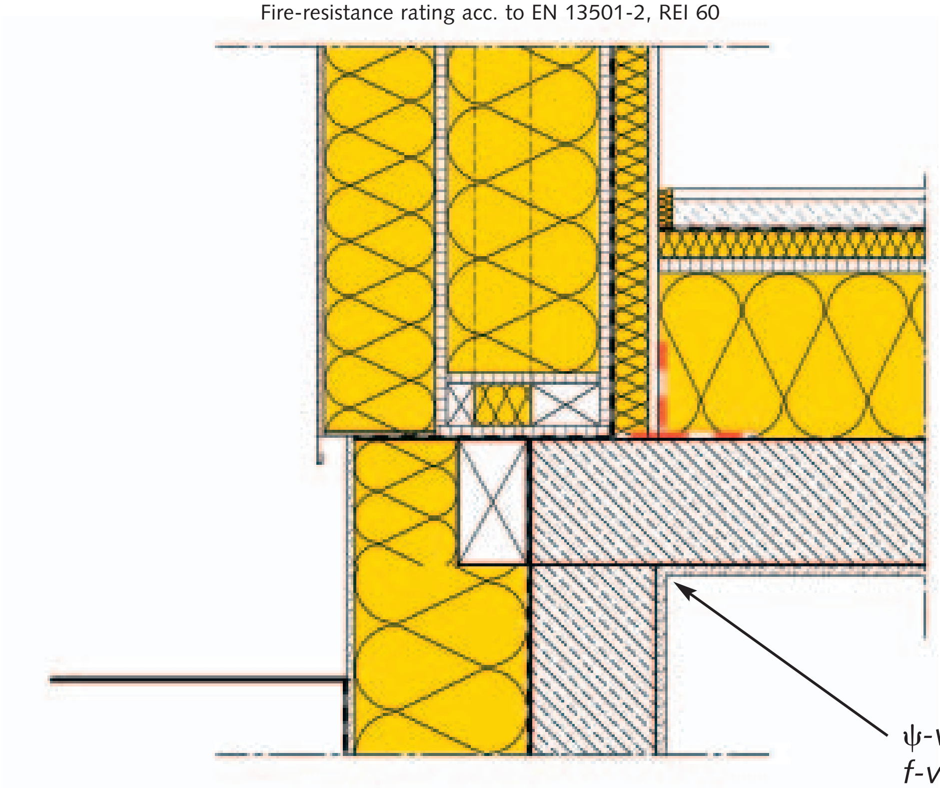
[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

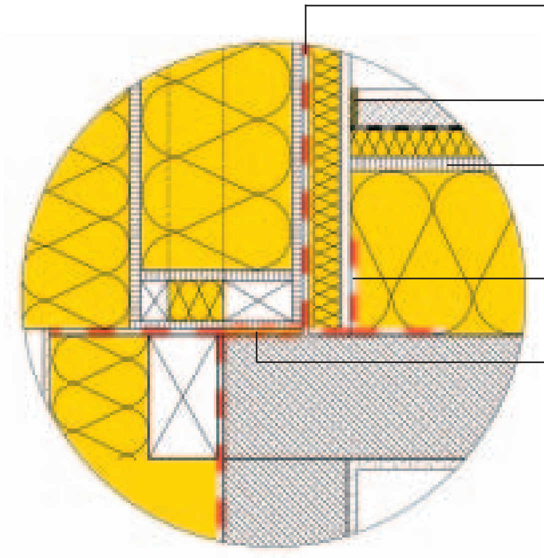


Safe. Airtight. High-grade.

The connection detail for an outer wall in timber construction – equipped with mineral wool based ETICS – has been optimized concerning thermal bridging. The floating cement screed installed on top of the cellar floor offers a particularly high-grade solution for heat and sound insulation combined with reliable airtightness. The diffusion-capable external thermal insulation composite system based on mineral wool ensures the moisture balance of the wall construction.

Outer wall: Sound reduction index Rw = 51 dB
Fire-resistance rating acc. to EN 13501-2, REI 60





Connection between massive outer wall insulated with mineral wool ETICS and slab on the ground with ice wall

A. Socle area outer wall (structure from the inside out)

Component layer	d in ml in W/(mK)	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.060
2. Sand-lime wall 1800	0.240	0.990	0.242
3. Moisture sealing	–	–	–
4. XPS insulation	0.080	0.037	2.162
5. XPS socle insulation	0.200	0.039	5.128
6. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			7.617
Thermal surface resistances			0.170
U-value of the construction			U = 0.13 W/(m²K)

B. Base slab (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Cement screed	0.050	1.400	0.035
2. Mineral wool impact sound insulation	0.030	0.035	0.857
3. Moisture sealing	–	–	–
4. Concrete 2300, 1 % reinforcement	0.300	2.300	0.130
5. Separation layer	–	–	–
6. XPS thermal insulation, 2-layered	0.240	0.038	6.316
7. Base course	–	–	–
Total sum of thermal resistances			7.338
Thermal surface resistances			0.210
U-value of the construction			U = 0.13 W/(m²K)

ψ-value[1] = -0.109 W/(mK); f-value[2] = 0.924; minimal surface temperature ϑsi = 18.1 °C; at 20°C indoors and -5°C outdoors.

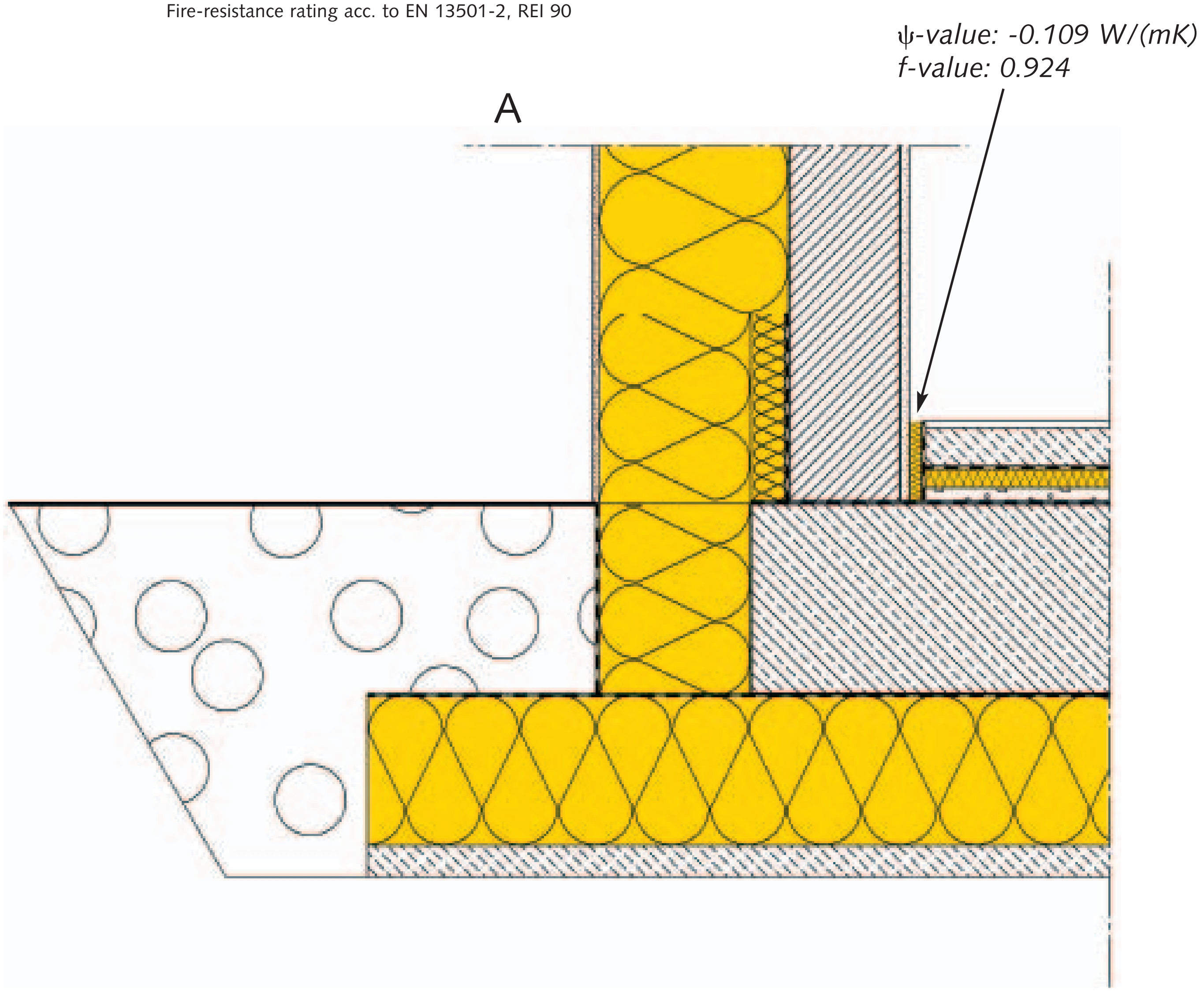
[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

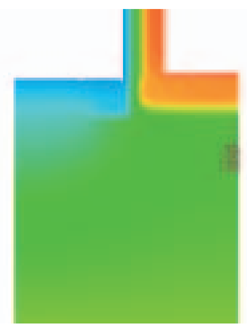
[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Thermal bridge optimized massive wall connection to slab on the ground.

When connecting the massive outer wall insulated with mineral wool ETICS to the base slab, the ice wall considerably contributes to reducing heat loss via the ground.

Outer wall: Sound reduction index Rw = 56 dB
Fire-resistance rating acc. to EN 13501-2, REI 90





f-value

Spend the winter behind passive house windows.

Never below 17°C.

With triple glazing and thermally insulated frames the passive house window is well able to resist the cold. And more than that. The solar gains that can be achieved by south-facing passive house windows exceed the heat loss through the windows – even in the winter months of Central Europe. Thanks to state-of-the-art glass quality, the temperatures measured on the surface of the panes are always close to inside air temperature.

Passive house windows

Triple glazing	approx. U_g 0.5-0.8 W/mK
Insulated window frames	approx. U_f 0.7 W/mK
Thermal insulation total window	$U_w < 0.8$ W/mK
Total energy transmittance (g-value)	$g \geq 0.5$

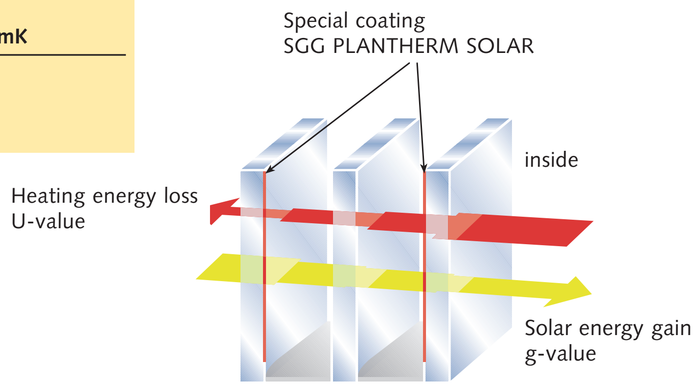
A gain for every room: properly positioned windows free of thermal bridges.

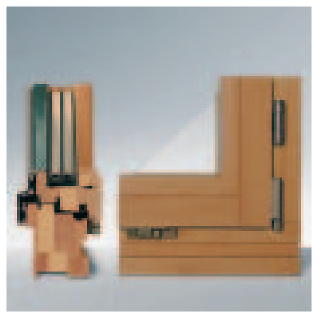
Under optimum installation conditions, passive house windows can contribute substantially to heating the building if positioned properly. Provided the following conditions are fulfilled:

- Install 80 % of the windows on the south side.
- Install the windows in the center of the insulated area.
- Cover the frame with an insulating wedge and install insulating layers below the windowsill.
- Provide an airtight seal of the perimeter joint between window frame and outer wall using environmentally friendly ISOVER VARIO FS1 or FS2 joint tape and joint filler.

Good to know:

1. Due to the higher glass weight, triple glazing requires frames with a better insulation.
2. In general, large-area window glazing with a small vent is more favourable in terms of energy and cost.





Passivhaus Institut Darmstadt, Germany

Saint-Gobain glass CLIMATOP SOLAR consists of the extra-white Saint-Gobain float glass DIAMANT and the special Saint-Gobain glass coating PLANITHERM SOLAR. The triple glazing features excellent thermal insulation as well as a high g-value that normally can only be achieved with double glazing. This special relation of U_g- and g-value makes Saint-Gobain glass CLIMATOP SOLAR the perfect choice for realizing energy-efficient buildings.

Always warmly recommended: Saint-Gobain Glass.

Especially in the dark autumn and winter months, triple thermal insulation glazing by Saint-Gobain shows itself at its best. With optimally designed buildings, the limited amount of sun energy is utilized so efficiently that the solar gains from outside can largely compensate the heat losses through the windows. And if the sun doesn't shine, this is also no problem as the high-tech insulating glass is of extremely low heat emissivity. This means that the special pane structure reduces the amount of heat radiated from the building. The major part of this heat is reflected by the infrared layers and radiated back into the home's interior.

"Heat-free" in summer.

Especially on hot days, the ISOVER Multi-Comfort House remains pleasantly cool. If the windows face south, their triple thermal insulation glazing allows less sun warmth to enter the house than with conventional windows. While in winter the low sun shines into the house filling it with warmth, much less radiation hits the windows when the summer sun is high in the sky. Structural sun protection, for example a sufficiently dimensioned roof overhang, can provide better shading from outside. Additional temporary shading is advantageous. With east/west windows, by contrast, temporary shading is a must.

VARIO FS1 and FS2 Joint tape

The all-decisive U-value.

Modern double-glazed windows can achieve U-values in the range of 1.0 to 1.8 (W/m²K) while the frames reach less favourable values of 1.5 to 2.0 (W/m²K). The requirements to be met by passive house windows are much more rigorous: they need to achieve U-values of 0.7 to 0.8 (W/m²K). This heat transition coefficient applies to the whole window though – and this includes the frame.

Window connection to lintel in timber construction

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Composite wood panel	0.015	0.240	0.062
4. Glass wool felt	0.320	0.035	9.143
5. Wood fibreboard, e.g. MDF	0.016	0.070	0.228
6. Cladding, ventilated	–	–	–
Total sum of thermal resistances			10.922
Thermal surface resistances			0.170
U-value of the construction			U = 0.09 W/(m²K)

ψ-value[1] = 0.003 W/(mK); f-value[2] = 0.864; minimal surface temperature ϑsi = 16.6 °C; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Window connection to windowsill in timber construction

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Gypsum plasterboard	0.015	0.250	0.060
2. Mineral wool insulation	0.050	0.035	1.429
3. Composite wood panel	0.015	0.240	0.062
4. Glass wool felt	0.320	0.035	9.143
5. Wood fibreboard, e.g. MDF	0.016	0.070	0.228
6. Cladding, ventilated	–	–	–
Total sum of thermal resistances			10.922
Thermal surface resistances			0.170
U-value of the construction			U = 0.09 W/(m²K)

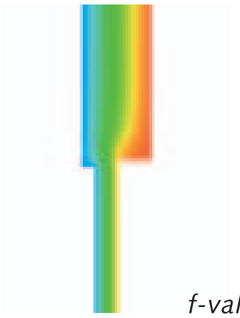
ψ-value[1] = 0.01 W/(mK); f-value[2] = 0.853; minimal surface temperature ϑsi = 16.3 °C; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Thermal bridge reduction.

A reduction of thermal bridging can be achieved in the lintel area by insulating the window frame.
When connecting the windowsill, the positioning of the frame in the insulation layer helps to reduce thermal bridge loss in connection with the special window frame.



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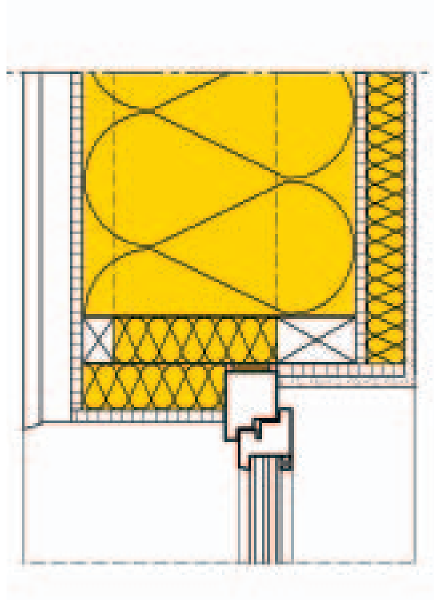

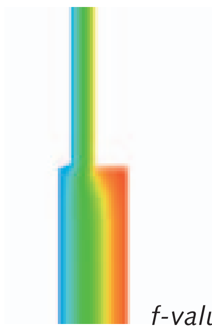

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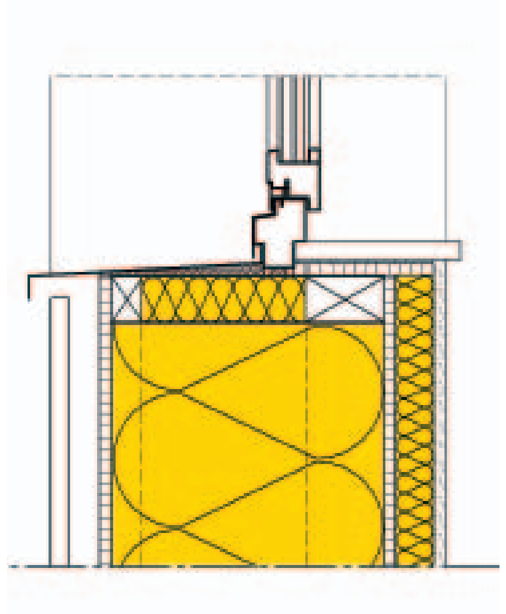


The Realization.

Window connection to lintel in massive construction

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.021
2. Sand-lime wall 1600	0.175	0.790	0.221
3. Glass wool plaster baseboard	0.280	0.035	8.000
4. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			8.267
Thermal surface resistances			0.170
U-value of the construction			U = 0.12 W/(m²K)

ψ-value[1] = 0.015 W/(mK); f-value[2] = 0.910; minimal surface temperature ϑsi = 17.8 °C; at 20°C indoors and -5°C outdoors.

1) The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

2) The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Window connection to window sill in massive construction

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.021
2. Sand-lime wall 1600	0.175	0.790	0.221
3. Glass wool plaster baseboard	0.280	0.035	8.000
4. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			8.267
Thermal surface resistances			0.170
U-value of the construction			U = 0.12 W/(m²K)

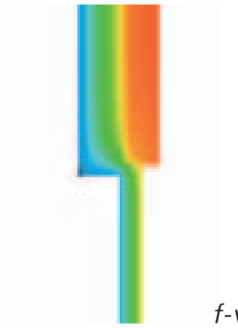
ψ-value[1] = 0.034 W/(mK); f-value[2] = 0.892; minimal surface temperature ϑsi = 17.6 °C; at 20°C indoors and -5°C outdoors.

1) The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

2) The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Thermal bridge reduction.

A reduction of thermal bridging can be achieved in the lintel area by insulating the window frame.
When connecting the windowsill, the positioning of the frame in the insulation layer helps to reduce thermal bridge loss in connection with the special window frame.



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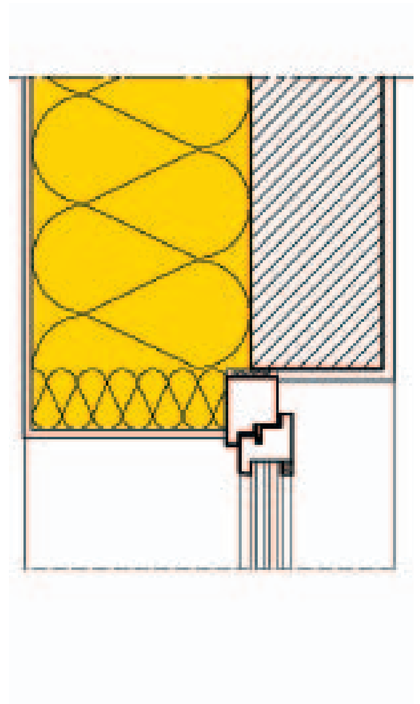

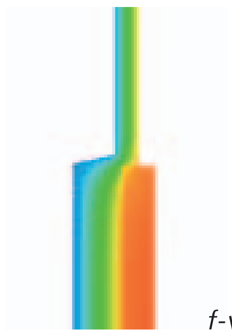

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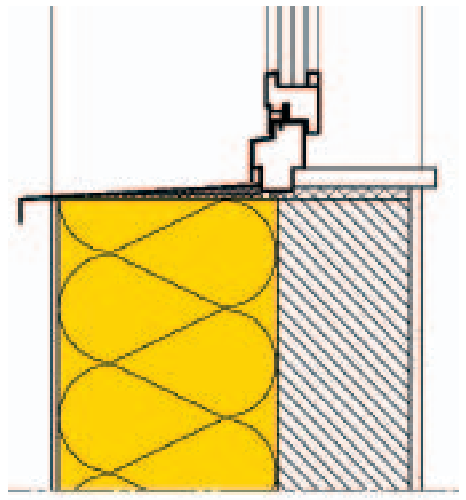


Spoilt and powered by th e sun.

The sun's energy potential is virtually inexhaustible: it is our most important energy supplier for the future. Day by day, the sun provides us with about eighty times the primary energy that is needed on earth. After deduction of the scattering loss to the atmosphere, an average of 1000 W per m² reach the earth's surface. This value is deemed to be the maximum possible irradiation on a cloudless day and at the same time serves as a base and reference value for all calculations.

Facade-integrated solar collectors, Pettenbach, Upper Austria

Window, facade and roof areas as power plants of passive living.

The highest solar gains for a building can still be generated with roof-mounted solar collectors. But also photovoltaic facades and window surfaces can considerably contribute to the positive energy balance of a passive home. Passive house adequate triple glazing allows solar radiation to enter the interior and take effect as passive heat gain. Roof areas are used for accommodating modern, highly efficient collectors. This is where the solar circuit in an ISOVER Multi-Comfort House starts. Sun collectors convert solar radiation into heat and transfer it to a carrier medium such as water, brine or air. Afterwards, the converted solar heat can be utilized for producing domestic hot water, but also for supporting the space heating.

Efficient all year round: the solar thermal system.

A cost-optimized system can cover about 40-60 % of the entire low-temperature heat demand in an ISOVER Multi-Comfort House. What does that mean in terms of domestic hot water supply? In summer, more than 90 % of the required hot water can be produced with solar energy. In the winter months and transitional periods, the supplied energy is always sufficient to preheat the domestic water.

To the point: Dimensioning of solar hot water systems.

Daily hot water demand (l)	Storage capacity (l)	Collector area*) Flat-plate collector SL (m²)	Collector area*) Flat-plate collector SS (m²)	Collector area*) Evacuated tube collector (m²)
100-200	300	6-8	5-6	4-5
200-300	500	8-11	6-8	5-6
300-500	800	12-15	9-12	7-8

*) Depending on deviation from south orientation, ideal roof pitch and climatic influences. SL: solar varnish coating, SS: selective absorber coating

Christophorus Haus, Stadl-Paura, Upper Austria

When using modern appliances with warm water supply instead of conventional washing machines and dishwashers, the available solar energy can, of course, be exploited even more efficiently. When dimensioning your home's solar system, you should always proceed from an average water consumption of 50 litres (45 °C) per person and day. The collector area required to cover this demand is normally between 1.2 m² and 1.5 m².

Solar heat storage pays off with large building projects.

For one- and two-family houses, partial space heating with solar energy based on hourly or daily storage of solar heat is of interest even today. But the complete heating of buildings via seasonal storage of solar energy, e.g. in heat buffers, is deemed economical only for large building projects – at least for the time being.

Efficient: solar systems for space heating.

The use of solar energy for indoor heating and for generating electricity is technically feasible and becoming more widespread. The economical and ecological benefits need to be assessed individually for each building though.

To the point:

Preconditions for a solar system to give its best.

- *A good collector does not guarantee a good solar system.*
- *All system components must be of high quality and perfectly matched.*
- *The angle of inclination for collectors to produce maximum energy is 45° on an annual average.*
- *In summer (April to September), an angle of 25° is ideal. In winter, modules with an angle of up to 70° or 90° produce the highest yield.*
- *South orientation of the modules is always recommendable although deviations up to 20° do not significantly reduce the yield.*
- *If possible, the solar system should be free of shading.*

Draught-free supply of fr esh air.

Healthy living – like in a health resort.

90 % of our breathing is done indoors.

Air is one of our most vital commodities, but modern man increasingly consumes it behind closed doors. These days, the population of Central Europe spends already as much as 90 % of their time indoors. Usually, indoor air quality is worse than outside the door. Above all, it contains too much humidity and is contaminated with pollutants, smells and the like. Remedial action is a steady exchange of air which fulfils the hygiene requirements for indoor air. Unfortunately, the air change rate cannot be dosed exactly by means of natural window ventilation. It strongly differs – depending on outdoor temperature, wind direction and individual airing habits. And just as bad: no possibility for heat recovery. Forced ventilation systems, by contrast, ensure a preselected, constant air change rate, recover heat from the exhaust air and take care of its distribution.

The Comfort Ventilation System controls heating and ventilation in one breath.

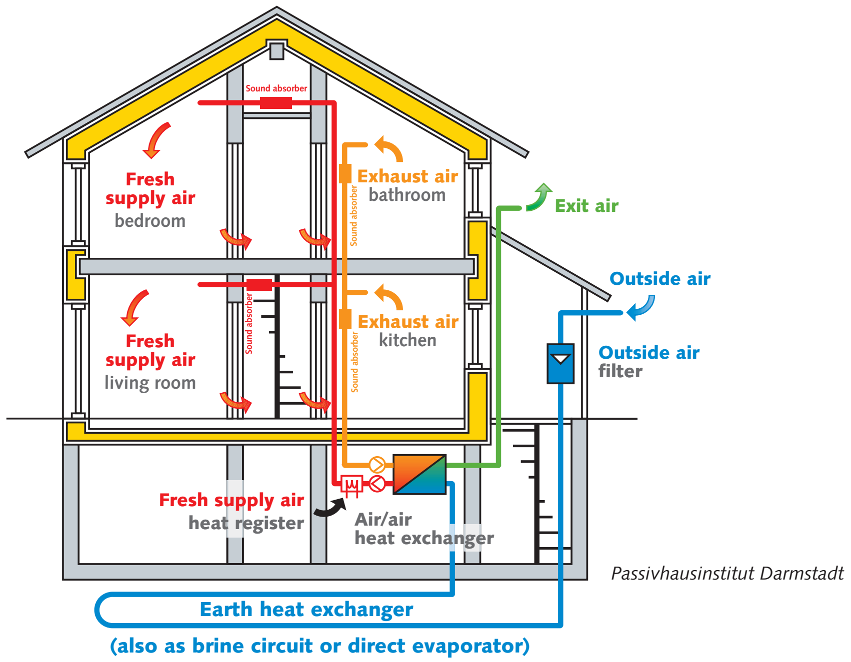
The ISOVER Multi-Comfort House doesn't need a boiler room. A compact ventilation unit the size of a fridge is totally sufficient to steadily supply all rooms with fresh air and heat while at the same time removing the consumed air. How does it work? The central unit comprises a heat exchanger, fans, filters and – if desired – air pre-heater, air cooler and air humidifier or dryer. Stale air from kitchen, bathroom and WC is removed via the exhaust air system. Before being routed outdoors, it gives off its heat in the heat exchanger, thus warming the incoming fresh air to near room temperature. Today, heat recovery rates of up to 90 % are possible.

Features of a passive house conforming ventilation system.

As it requires only little space, the ventilation unit can be accommodated in any storeroom or even in a cabinet.

- Performance: At a maximum air change rate of about 0.4 per hour required for hygienic reasons, the ventilation system can contribute via the fresh air max. 1.5 kW energy (when maintaining the max. supply air temperature of 51 °C) to a residential building of 140 m².
- Short wire lengths
- Pipe diameter – larger than 160 mm for main ducts, larger than 100 mm for branch ducts
- Acoustic insulation of the central unit and supply ducts by installing sound absorbers. A noise level of 20-25 dB(A) should not be exceeded for living space.
- Easy maintenance, e.g. when changing filters and cleaning the unit
- The system can be easily adapted to varying needs, e.g. switch off the incoming air fan when opening the windows, bypass for summer use.

In order to ensure the permanent exchange of air and heat even with closed doors, it is recommended that long-range nozzles are installed, preferably above the door frames.



Passivhausinstitut Darmstadt

Virtually soundless and economical.

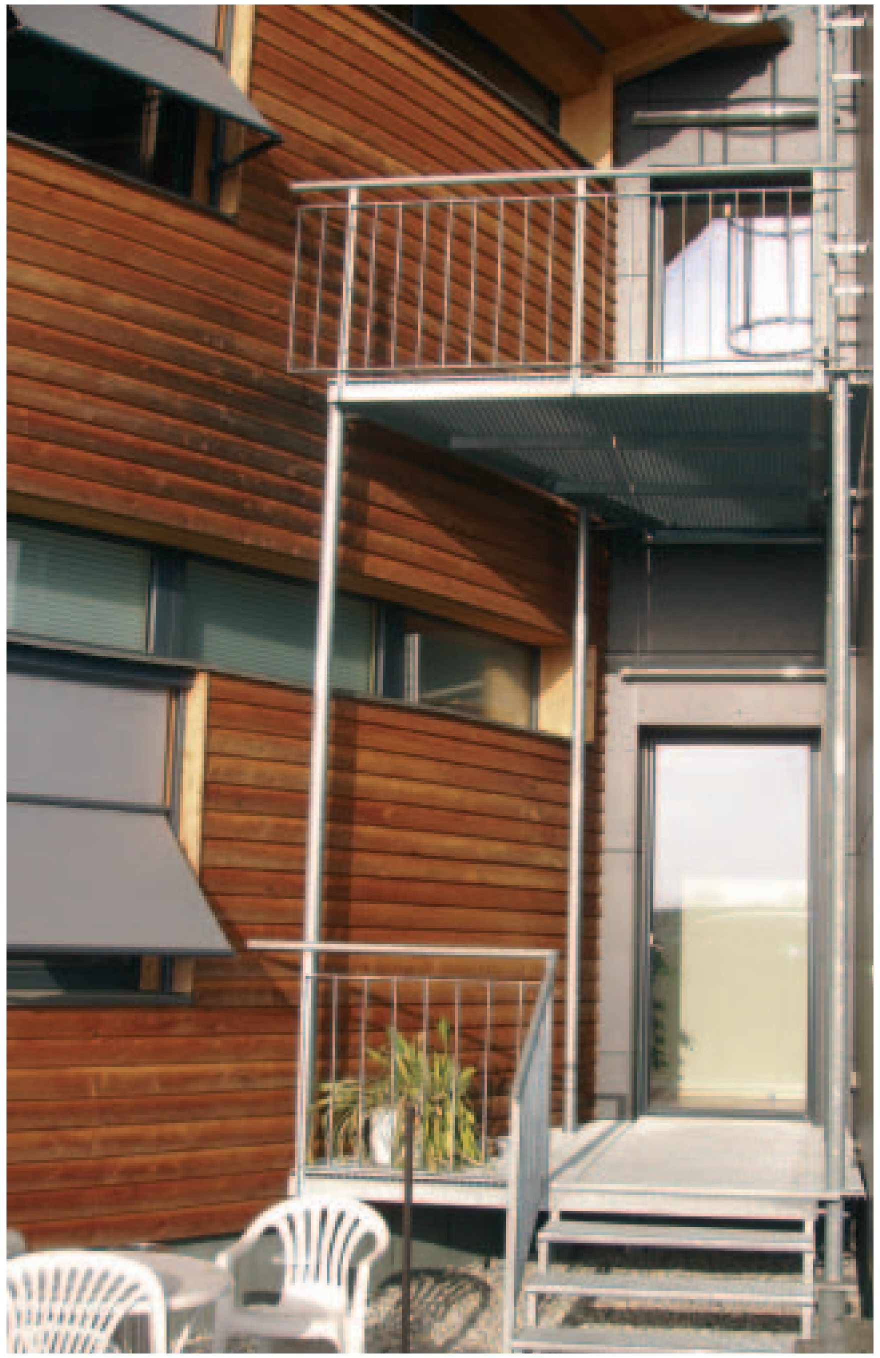
Sound absorbers built into supply and exhaust air ducts ensure that the ventilation system of the passive home quietly does its job at a sound level of 25dB (A). And very economical at that: the combined ventilation/heating system is able to cover the entire demand for domestic hot water and space heating while consuming only 1500 to 3000 kWh per year. An average four-person household needs almost twice as much electricity – without heating.

To the point:

Comfortable advantages for man and building.

- *Healthy fresh air – free of dirt, pollen, aerosols etc.*
- *Low air humidity helps prevent the intrusion of moisture, mould formation and structural damage*
- *No bad smells as the controlled air flow does not allow stale air to mix with fresh air*
- *No draughts*
- *No temperature fluctuations*
- *No airing required*
- *Window ventilation – only if desired*
- *Highly efficient heat recovery*
- *Low electricity consumption*
- *Easy maintenance*

With a little effort and ex pense also balcony and conservatory can be come part of your home.



Bracket-mounted or detached balconies are the simplest solution.

Where the air is good and no outside noise disturbs, balconies no doubt increase the quality of living. But if they are to be integrated as external elements into passive houses, they can in unfavourable circumstances considerably increase the heating demand. When connecting balconies, platforms, conservatories or other projecting elements to heated parts of the building, there is always the risk of a strong thermal bridge effect.

In the following cases, the heat loss is particularly high:

- if both building and balcony consist of a well heat-conducting material, e.g. concrete or steel
- if the structural connection has a large cross section because it needs to transmit static forces
- if both building components differ largely in temperature.

Christophorus Haus, Stadl-Paura
Correct solution: The balcony has been bracket-mounted in order to prevent thermal bridges.

View from the living room into the conservatory. Thanks to its passive house glazing, it is thermally separated from the passive house proper. Photo: Raimund Käser

To prevent this in the first place, balconies should be planned to be completely thermally separated. Bracket-mounted or detached solutions are attractive and don't cost a fortune. It's important though to consider both the balcony's positioning and its dimensions. One thing must be avoided by all means: shading of windows that contribute solar gains to the ISOVER Multi-Comfort House.

With a built-in conservatory the living room doors need to remain shut.

The conservatory is located outside the warm building envelope and therefore needs to "function" separately. This means: Heat escaping from inside the building in winter months must be just as much avoided as summer heat flowing from the conservatory inside the house. For this purpose, the following measures are required:

- Separate the conservatory from the interior by installing glass doors fit for passive houses.
- Provide efficient thermal insulation of all adjoining walls.

It goes without saying that the conservatory must not be heated in the cold season nor cooled in the hot summer months, but airing must be possible.

Photo: Niedrig Energie Institut (Low-Energy Institute), Detmold, Germany

Thermally separated, bracket-mounted balcony. Massive construction with plaster facade.

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.021
2. Sand-lime wall 1600	0.175	0.790	0.221
3. Glass wool plaster baseboard	0.280	0.035	8.000
4. Exterior plaster	0.025	1.000	0.025
Total sum of thermal resistances			8.267
Thermal surface resistances			0.170
U-value of the construction			U = 0.12 W/(m²K)

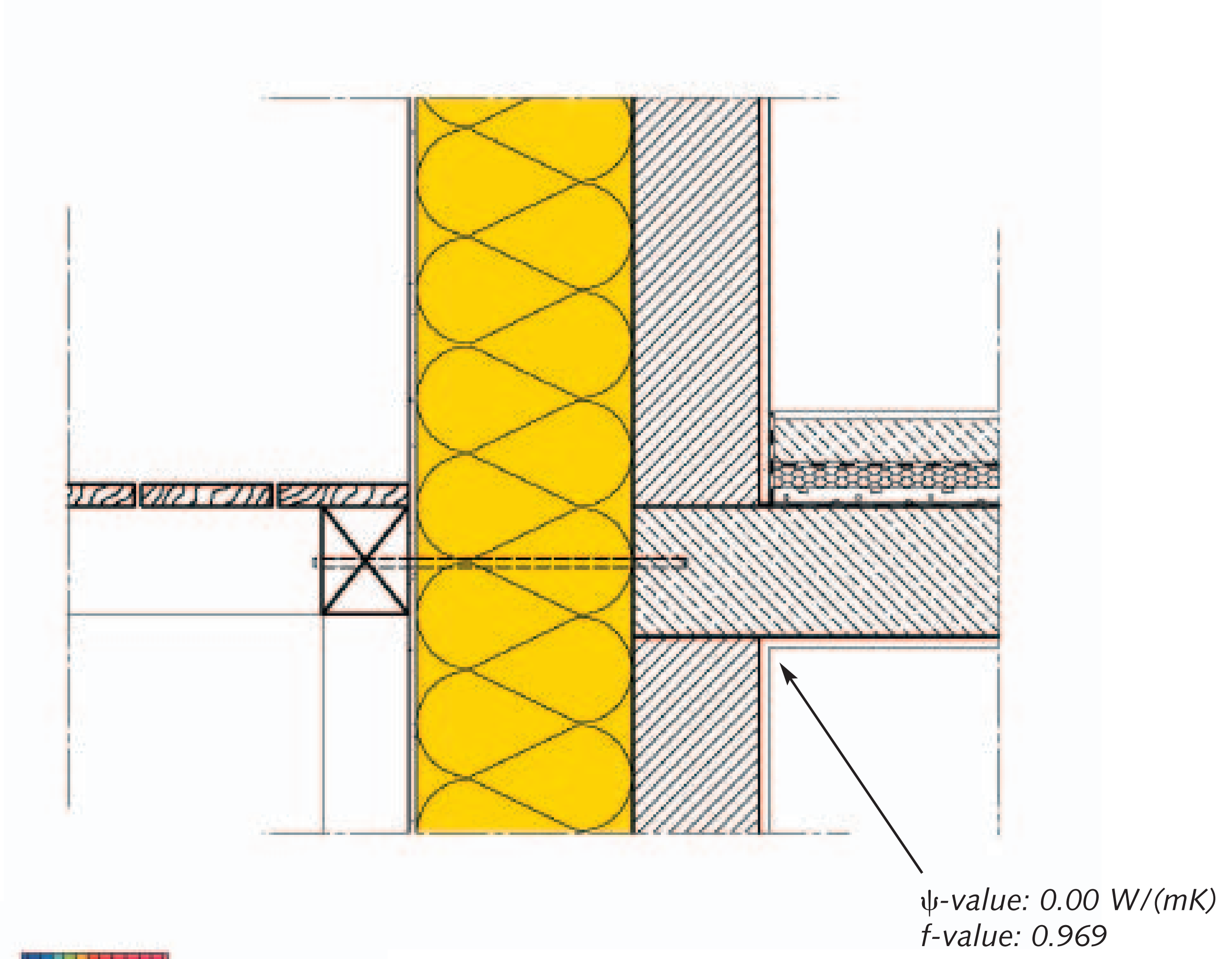
ψ-value[1] = 0.00 W/(mK); f-value[2] = 0.969; minimal surface temperature ϑsi = 19.2 °C; at 20°C indoors and -5°C outdoors.

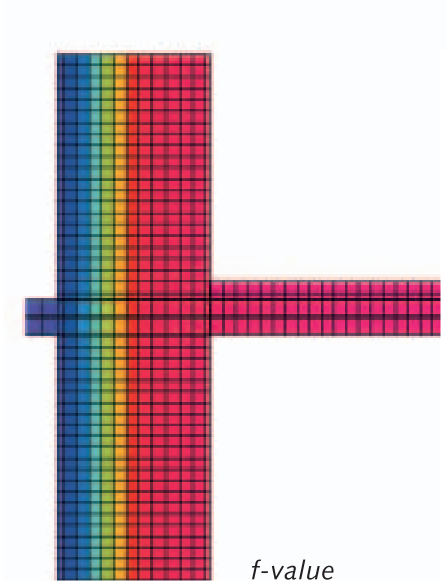
[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

[2] The f-value is a dimensionless temperature factor. It is a measure for the minimal surface temperature of a construction when the outdoor and indoor temperatures have been predefined. It describes the risk of condensation and mould formation.

Thermally separated balcony with optimized static safety.

Thermal bridge loss caused by detached balconies can be completely avoided in a Multi-Comfort House when the static safety has been optimized.





Thermally separated, bracket-mounted balcony. Massive construction with ventilated facade.

A. Outer wall (structure from the inside out)

Component layer	d in m	λ in W/(mK)	R in m²K/W
1. Interior plaster	0.015	0.700	0.021
2. Sand-lime wall 1600	0.175	0.790	0.221
3. Mineral wool insulation	0.280	0.035	8.000
4. Cladding, ventilated	–	–	–
Total sum of thermal resistances			8.242
Thermal surface resistances			0.170
U-value of the construction			U = 0.12 W/(m²K)

ψ-value[1] = 0.00 W/(mK); f-value[2] = 0.969; minimal surface temperature ϑsi = 19.2 °C; at 20°C indoors and -5°C outdoors.

[1] The ψ-value describes the additional heat loss of a construction caused by thermal bridges. The values indicated above are based on the building's external dimensions. The psi values have been calculated in keeping with EN ISO 10211, based on the boundary conditions laid down in Supplement 2 of DIN 4108.

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Thermally separated balcony with optimized static safety.

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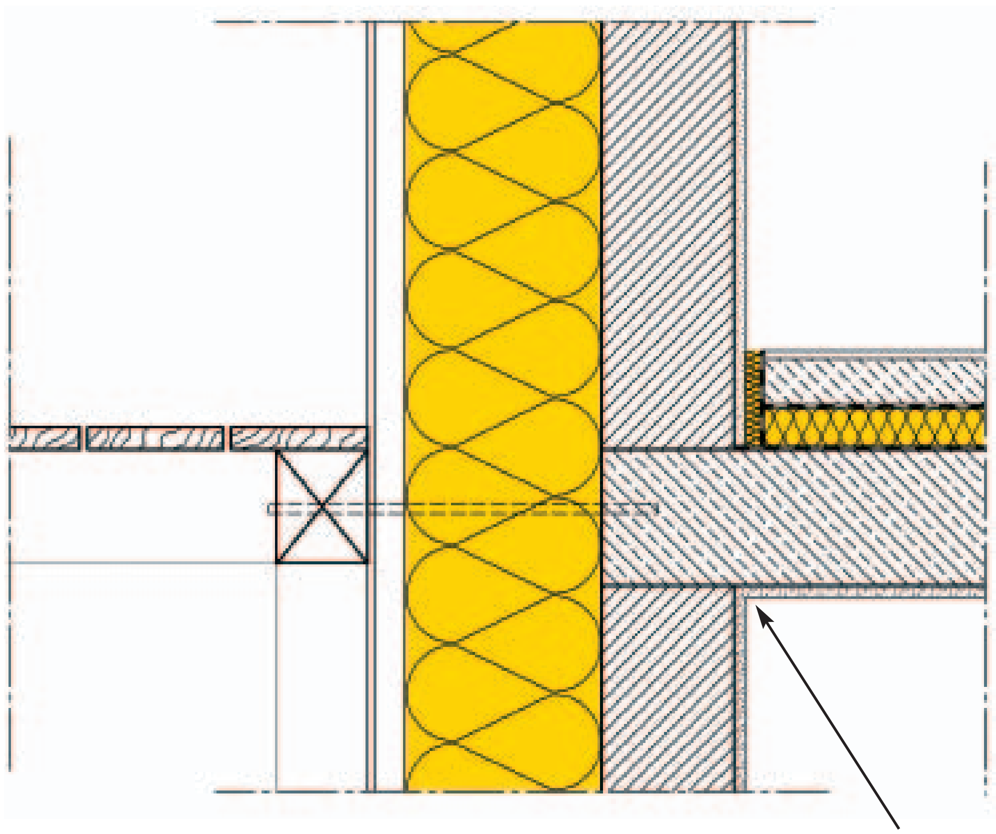
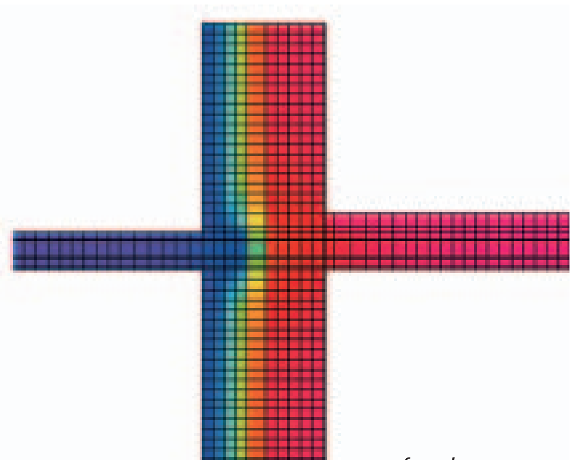


ψ-value: 0.00 W/(mK)
f-value: 0.969



f-value