MOOC Zero-Energy Design

Course Reader Module 3

TU Delft

This reader provides additional information for the Massive Open Online Course (MOOC) Zero Energy Design.

Andy van den Dobbelsteen
Eric van den Ham
Tess Blom
Kees Leemeijer

Special thanks to BOOM (environmental research and design) for the use of the book Energie Vademecum and to BuildDesk / ROCKWOOL international A/S for translation of Energie vademecum.

Please note: The numbers and figures in this reader are based on buildings in the Netherlands.

1

Spatial design

1. Spatial design

After establishing an energy-efficient design brief the next step is to create an integrated spatial design. As with a conventional design, the relationship between the urban plan and the building design is very important. The urban plan should contain important preconditions that must be incorporated to build highly energy-efficient homes.

The choice of an east-west orientation (the streets go from east to west) enables optimal use of passive solar energy. However, the building design has to make use of this with as many windows in the south façade as possible, placing rooms with a relatively high heat demand in winter on that side. The potential heat of the summer months should also be considered, including whether shading and passive cooling is required from underground to minimise high internal temperatures and prevent residents from purchasing air conditioners with a relatively high energy consumption as a result.

Strive for a pleasant microclimate: for example by limiting wind nuisance and encourage the application of green areas (such as trees and vegetation roofs) to limit the 'heat island effect'. But prevent shading of windows, solar collectors and PV panels.

1.1 Shape and orientation of buildings

1.1.1. Compactness of building

The more 'compact' a dwelling is, the lower the transmission losses will be. 'Compact' stands for the ratio between the outer surface and the volume (fig. 1.1) of the building. The complexity of its shape plays a role as less extensions and additional volume not only result in a more compact design, but also less structural connections in the building envelope. The fewer connections, the less chance there will be of thermal bridges and air leaks, resulting in fewer transmission and infiltration losses.

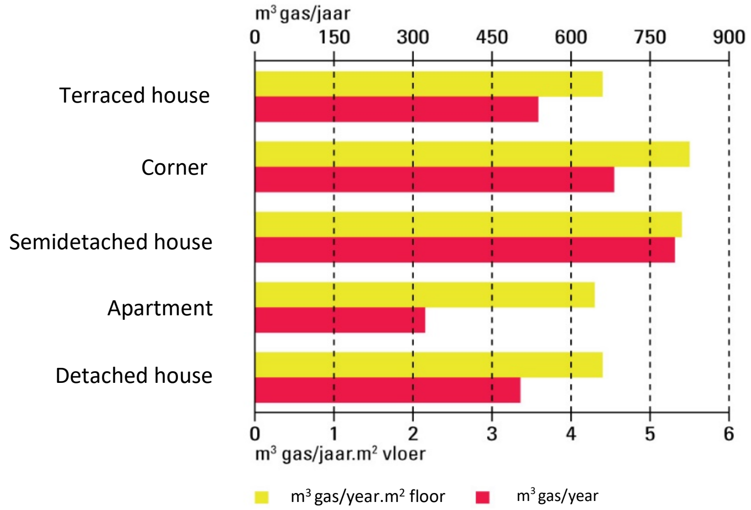


Fig 1.1: The differences in energy consumption for five homes with an energy performance of 0.8 EPC (level in the Netherlands 2010) in m^3 natural gas per year. Gas consumption for heating depends on size and compactness of the housing type. To see the effect of compactness alone, the gas consumption per square meter floor space is given. When insulation of the skin is improved, the effect of compactness decreases.

Other qualities

Of course, compact buildings should not come at the expense of effective utilities and daylight. For example, reducing the width of a terraced house while retaining the amount of floor space makes the house more compact, but, it reduces the design options within the floor plan. As a result, less daylight and sun is entering the building.

1.1.2 Building orientation

Roof orientation

Roofs provide an ideal space for solar collectors and photovoltaic (PV) panels. In terms of design, the spatial requirements, optimum positioning and angle of inclination of both systems need to be taken into account.
• The optimum orientation for both systems is south.
• The optimum angle for hot water collectors is around 40° when they are specifically used for space heating. It is around 50° (for mid-Europe) for collectors used for both and so the ideal angle is between the two.
• The optimum angle for PV is around 40° (for mid-Europe).
• Deviation is possible, but results in a smaller output per m^2 collector or PV-panel.

Avoid shading that is created by, for example, surrounding buildings, roofs, dormers, flues and vegetation as PV systems are very sensitive to this.

Façade orientation

The positioning of walls is important in terms of generating passive solar energy, as windows are placed in façades to let sunlight enter the house. However, it is not necessary for orientation to be south (in the Netherlands) to ensure that this sunlight makes an effective contribution to energy production. It is possible to vary positioning by about 20°.

Passive solar orientation does not need to generate a monotonous street plan. During the planning of the EVA Lanxmeer project in Culemborg, existing structures were taken into account, including waterways and a mix of living and working solar energy (fig 1.3).

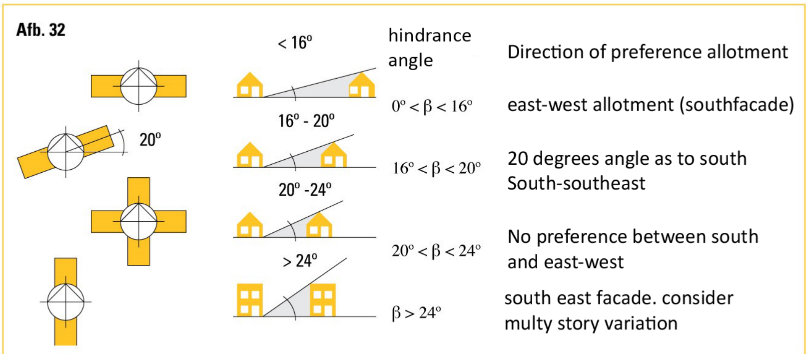


Fig.1.2: Direction of allotment for single-family houses by obstruction angle

Fig.1.3: The urban plan 'EVA-Lanxmeer'

Sun and wind shelter in urban areas

Outdoor spaces, such as gardens, playgrounds and routes for slow traffic will benefit from sunlight, and shelter from wind, in all seasons. Neither has a direct effect on the energy consumption of households, but may conflict with the optimum use of sunlight for the dwellings.

The positioning of the sun in outdoor spaces is different to that of optimal sunlight for dwellings. For instance, In the Netherlands an obstruction angle of between 16 - 20° would require a south facing structure to be turned slightly to the east. This provides better solar positioning for both low-rise and stacked houses in an outdoor space. For obstruction angles larger than 24°, an east and west façade position should be considered. In these cases, passive solar energy is already minimal but it means that outdoor spaces will receive some sunlight at midday (fig 1.4).

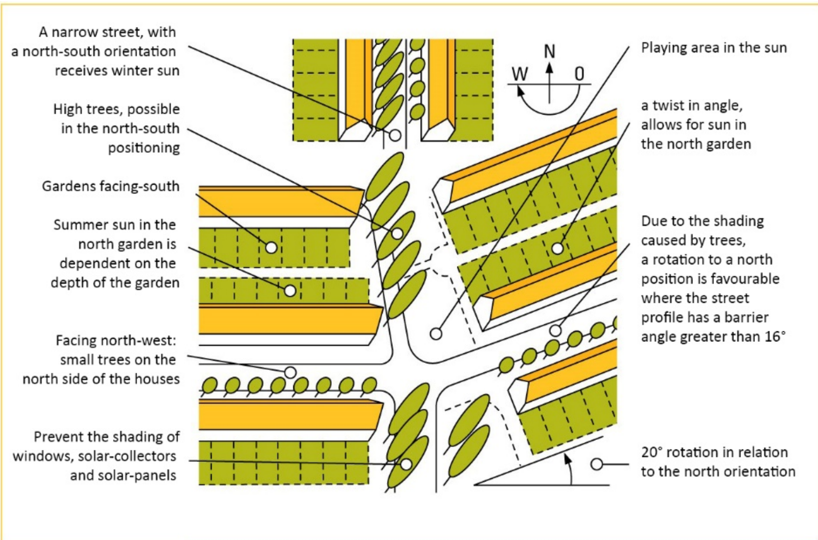


Figure 1.4: Diverse design decisions for the allotment related to sun orientation. (in the Netherlands)

1.2 Passive use of solar energy

The use of passive solar energy means to use solar radiation to contribute heating the home during colder seasons (or the heating season). For residences, located in the Netherlands, with an EPC of 0,4 (current Dutch requirement for new built residences, English: Energy Performance of Building Directive, EPBD) solar energy, internal heat sources (people, lighting and devices in the house) and heating installations each contribute to about a third of the house's heat supply.

In the design, the contribution from the sun is mainly determined by the house's position, shading, window size and floor plan. For the best results, solar gain properties are added to glazing. Sometimes conservatories or atriums are built for an even higher concentration of passive solar energy. Façade collectors and Trombe walls can offer benefits in an appropriate climate.

A survey regarding the use of passive solar energy showed that residents with these systems are very appreciative of the warmth and daylight that they provide. This further increased where there was also a south-facing back garden.

Do take care that adequate measures, such as shading, passive summer-night ventilation or a heat bypass recovery unit should be used to prevent houses from reaching unbearable temperatures inside.

1.2.1. Facade orientation

Solar radiation through windows

Calculations indicate that a south facing house has the highest sun contribution. Deviations of around 20° to the east or west are shown to reduce the effectiveness of solar windows by an equivalent of $10m^3$ of natural gas per year, per dwelling.

When the deviation is even greater, the energy consumption increases relatively quickly. This depends on, among other things, the glass surface in the façade, the orientation and the extent to which the buildings are insulated. A sample semi-detached dwelling is used below:

• The glass division in the sample house is evenly divided between the north and south façade (50% south/50% north). If 25% of the glass is moved from north to south (75% south/north 25%), a saving of about $50m^3$ of natural gas per year is made.
• If the property is now rotated by 180°, the distribution is 25% south and 75% north and the energy consumption will increase by approximately $95m^3$ of natural gas per year.
• If the house (50% south and 50% north) is rotated by a quarter so that the distribution is 50% east and 50% west, it changes the annual energy consumption as follows:
  - for the front façade directed to the north: an increase in consumption of about $50m^3$ of natural gas
  - for the front façade directed to the south: an increase of almost $10m^3$ of natural gas, caused by the window in the front façade.

Avoid overheating

Sun protection is essential to avoid indoor temperatures that are too high during the summer months. Sun blinds are a valuable source of shade and they can minimize the need for air conditioning. Paragraph 2.3.2 provides more information about different types of shading systems.

There are many other options in terms of sun protection, such as overhangs, movable shutters (shutter door, vertical cloth, screens, awnings or blinds) or vegetation. Adjustable solar shading is most effective as it has no negative effects during the heating season and provides maximum protection if properly operated.

Do take into account sun protection during the design and detailing of the façade and consider:

• the orientation: An overhang will only work well with a south-façade. East and west façades require movable sun blinds which should also ideally be placed on the south wall in addition to an overhang
• sufficient space for the sun protectors, particularly important for shutters (fig 1.5) because they need to fold or slide to one side
• attachment points for awnings: A wooden façade element may need to be further reinforced for an expanding awning
• integration ventilation grills in the blinds: Several manufacturers supply ready-made products (fig 1.6). Pay attention to the size (of the frame itself and the location of the frame in the wall) in relation to the placement within the frame and provide ventilation between the screen and glass (see point below). Select screens that minimise solar heat transmission, such as lighter colours
• adequate ventilation of the space between the blinds and the glazing, especially where screens may have insufficient ventilation. Choose screens with an aperture on the side and/or top and a stainless steel cable as a conduction solution along the side
• maintenance access.

Fig. 1.5: Louver shutters or sliding screens: one of the many options for sun protection. The lamellae can be both fixed or rotated, depending on the type and make. The photo shows the project 'Delfts Blauw' with shutters made of an aluminium frame and lamellae. Producers are Limelight, developer and architectural firm Eurowoningen and Architecten Cie.

Fig. 1.6: Example of a screen with an integrated grill where where the air cavity between screen and glass is ventilated. Image: Duco.

Solar glazing should be considered if, for example, the site is too vulnerable for sun blinds or if the wind load is too high.

Glass in the south façade

A passive house usually has an asymmetric glass division: a relatively large glass surface in the south façade and small in the north one. When too much glass is used on the south, there is a decline in energy efficiency and an increased risk of high temperatures in the summer.

Glass in the north façade

The north façade should not contain too much glass as additional glass increases energy consumption. An exception would be if effectively insulated glass is used. This will diffuse radiation through the north window and compensate for the loss of heat transmission during the heating season. The tipping point lies around a total U-value of 1.0 for a framed construction (glass and frame together).

Calculations for the semi-detached sample house show the following results for replacing a 1m^2 solid north façade with a 1m^2 window:

• HR++ glass in a wooden frame with a U-value total of 1.7: additional energy consumption of about 5m^3 of natural gas per m^2 window per year
• triple glazing in a wooden frame with thermal insulation providing a U-value total of 0.8: energy savings of about 1m^3 of natural gas per m^2 window per year.

Please note:
1. These results apply to a limited number of square metres of window and energy performance values of around 0.8.
2. With highly energy-efficient dwellings with values of around 0.4 the tipping point shifts to a total U-value of 0.8 for the window construction.

Glass in the east and west facades
For houses with an east and west façade a fairly equal distribution of glass should be evident. The glass surface should not be too large to avoid high indoor temperatures. In summer months, the sun endurance is higher on the east and west façades than on the south and the sun will shine in at a relatively low angle making it more difficult to block.

Glass in sloping or flat roofs
Windows in sloping roofs catch more sunlight in the heating season than windows in façades. Skylights in flat roofs catch only slightly less sunlight than glass in south-facing façades, but more than glass in alternative positions. Both windows have the advantage of a relatively large amount of incoming daylight. A disadvantage is that sloping and horizontal windows have a large sun load (fig 1.7) and they have extra heat radiation on clear winter nights.

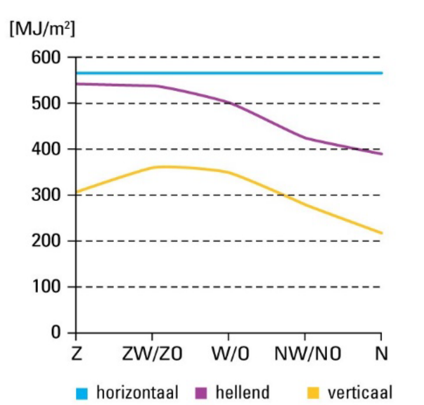


Fig 1.7: The graph shows the solar radiation by m^2 of glass in the month June.

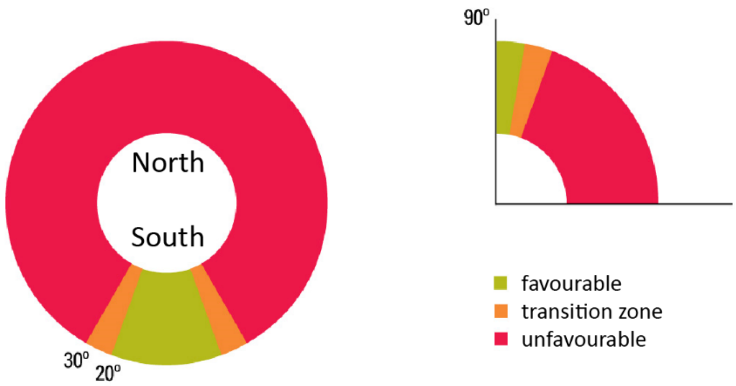


Fig 1.8: Optimum orientation and slope windows. An angle of 90° is preferable to prevent high summer temperatures. Nightly radiation is lowest for vertical windows. If wooden frames are used, windows applied at an angle are difficult to maintain.

1.2.2. Floor plan dwelling
Partitioning and zoning of dwellings reduces transmission and ventilation losses and solar heat usage is improved.

Partitioning
By separating spaces in different compartments, unnecessary heating and/or ventilation of certain rooms can be avoided. For example
• A closed kitchen, compared to an open kitchen, can bring heat savings by reduction of transmission and ventilation losses
• A vapour screen between the kitchen and living room improves air quality in the living room
• Draught portals at the front and back door

• Insulation of the upper and loft floors (for an unheated loft)
• Insulating dividing walls and floors between dwellings makes energy consumption less dependent on the behaviour of neighbours. This especially makes a difference in very well insulated houses.

Zoning

Zoning means organising rooms close to each other that have roughly the same desired temperature. The general recommendation is to situate 'warmer' rooms like the living room and children's rooms on the sunny side of the house where possible and the 'cool' rooms such as the entrance, separate kitchen and storage room on the more shady side.

For a relatively high density of low-rise buildings with heavily obstructed angles, consider situating the living room on the upper floor. This will improve the amount of daylight in the room considerably. To get the most benefit from partitioning and zoning, a good adjustable heating installation per room or zone is required.

Avoid relatively narrow widths for terraced dwellings that are situated on the north side of a street. There is too little space for the entrance and living room to be situated on the south side, unless the living room is located on the upper floor. Design the dwellings on the north side in such a way that the north gardens get the best possible sunshine. For instance, choose an asymmetrical cross section.

1.2.3. Unheated conservatory

An energy-saving conservatory/greenhouse is an unheated, enclosed outdoor space that is adjacent to the dwelling. It should be mainly constructed with glass to benefit from solar energy.

Warning: Instruct residents to prevent incorrect use. If they start to heat a conservatory or combine it with the living room, the savings can fade out and it might even increase energy costs. This section contains some suggestions to reduce the chance of misuse. Therefor a conservatory should only be considered if the living room is large enough. This reduces the likelihood that residents will remove the separation wall between the conservatory and the living room or start to heat the conservatory with extra energy consumption as a result.

Use and indoor climate

1. The conservatory is primarily an additional space to the house. It offers a sheltered area to stay in spring and autumn, a great playground on rainy summer days and a good place to dry laundry.
2. Ideally install one that offers sufficient space for different functions. This should be at least 3.5 x 2.5 metres.
3. A conservatory can also be used as a buffer for noise (traffic, industry) (fig 1.9) and can save energy under certain conditions.

Fig 1.9: Renovation and construction project 'De Leeuw van Vlaandren' with 72 rented apartments with a new double-façade as a noise barrier. To buffer noise and pollution from traffic on the A10 (Amsterdam) the second skin is placed in front of the existing east façade. The space behind this curtain wall serves to access dwellings and is ventilated with clean air from the west façade. Because of fire safety the glazed area is supplied with thrust ventilation to spread and disperse the smoke in case of fire.

Client: Far West, architect: Heren 5 architecten, contractor: Coen Hagedoorn, built in 2005.

Conservatories have a highly variable climate that is warm in the summer, cold in during the winter and can be susceptible to frost. Measurements show that the average temperature of a conservatory is about 4 to 6°C higher than the temperature outside during the heating season.

A conservatory can improve the comfort of a house, especially if a part of the required ventilation (heated by the sun) is supplied through it. The disadvantage is that the amount of daylight coming into any adjacent rooms is reduced, especially if the roof of the conservatory is not transparent.

Energy saving

A south-facing conservatory results in the greatest energy savings. However, this depends on shape, size and the materials it is made of, plus its use for preheating ventilation air.

The combination of pre-heated ventilation air through a conservatory and balanced ventilation with heat recovery makes little sense from an energy point of view, as they are competing systems. The combination should only be considered if the house is extremely energy efficient.

Calculations show that the effectiveness of an unheated conservatory decreases with increased insulation of the house. This is logical because there is less heat demand. However, even in highly energy efficient dwellings the conservatory remains energetically attractive if it is used to preheat ventilation air. Using HR++ instead of single glazing can increase its benefits.

Fig 1.10: Conservatories for apartments in Banne-Oost in Amsterdam. The roof of the conservatory is partly glazed (transparent) for daylight access. On the roof solar panels are installed.

Design: Tjerk Reijenga, formerly BEAR Architects, Gouda. Built in 1995

Investment and payback

The investment of a conservatory is so high that the reduction of the energy consumption for the dwelling is unlikely to payback. The added value is mainly the extra space and functionality combined with energy reduction.

Development and implementation

For the windows in the dividing wall between the conservatory and the adjacent room(s) good insulating glass should always be chosen. Any mass, eg. a stone floor, will have a positive effect on energy savings. Some of the heat will be stored for 1 to 2 hours in the flooring and can be used when the sunlight disappears. It is more energy efficient to apply only vertical glass in a conservatory rather than sloping roof panes.

Advantages:

- There is less radiation in winter and less chance of high temperatures in summer.
- There is also no pollution of the sloping/horizontal glass and less condensation.
- You can expand the daylight entrance with extra skylights at the back of the conservatory (fig 1.10) or with windows in the wall above it. If safety glass is used at an angle, ensure that measures are in place to capture any condensation.

Night insulation in the form of, for example, an insulating curtain is highly recommended for single glazing. This decreases the energy consumption of the house by some dozens m^3 of natural gas per year.
To prepare the conservatory as an outdoor space you should, for example, floor with quarry tiles and use facing brickwork on piers and parapets. Where the ground underneath is very wet, a floor with a vapour barrier is recommended. Facilities should be provided to clean the conservatory glazing. High summer temperatures can be avoided through sufficient ventilation and shading. A survey of residents showed that, in practice, such provisions are often not applied sufficiently. Take care to provide easy operational systems for blinds and vents, especially with high conservatories.

Improvements for renovation

The renovation of high-rise conservatories with a second skin can provide additional benefits. Besides saving energy and improving the quality of living, engineering enhancements can also be achieved, such as such as eliminating thermal bridging by wrapping insulation around it.

1.2.4. Atrium

An atrium is a large glass-roofed space outside the insulated building envelope. In terms of housing development, they usually contain an entrance to the building. An atrium may be used to make the exterior more attractive or a sheltered outdoor space, for example in housing for the elderly (fig 1.11). Various evaluations indicate that residents highly appreciate an atrium as a covered outdoor area. If sufficient measures are taken, the climate in atria is manageable.

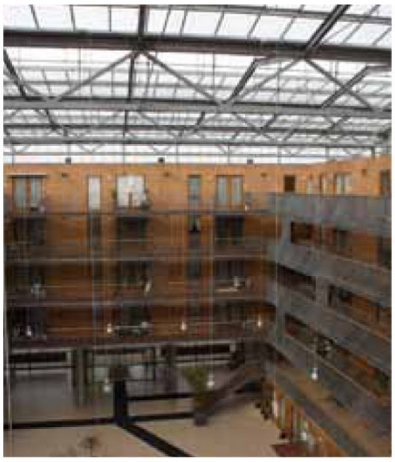


Fig. 1.11: The Residential Emerald in Delfgauw with 111 dwellings has a central atrium and is designed for seniors. The widening of the corridors at the dwelling entrance stimulates social contact. The glass roof originates from the greenhouse industry. Initiative: Housing corporation Vestia Delft; architect: Kees Christiaanse Architects & Planners; execution: Bouwcombinatie Delfgauw, built in 2001.

Energy saving

An atrium can save energy, similar to a conservatory. Again, it can only be energy-saving if it is not actively heated. The heat loss transmission through the façade and thermal bridges are reduced and ventilation air is preheated.

The energy savings of an atrium are highly dependent on the technical design of the project, ie insulation of the residence and atrium, ventilation and solar radiation. Overall, a saving of 10 to 15% on heating energy consumption can be expected. Use as much natural ventilation as possible to save energy. Additional mechanical ventilation may be desirable.

Given the costs of an atrium, qualities other than energy savings will be a determining factor in terms of development.

Noise

An atrium may function as a noise barrier against traffic, for example. However, noise that arises in the space itself may require attention. Sufficient attenuation and scattering of sound should be developed by applying various components such as interior walls and corridors with acoustic damping. Acoustics can also be improved with vegetation, or, for example, by arranging walls so they are not quite parallel to each other.

Adequate sound insulation should be installed between residences and the atrium to prevent noise from travelling from the entrance to people's living spaces. It is recommended that the corridors are also acoustically separated from the houses.

Daylight in dwellings adjacent to atrium

Adequate daylight should be provided to the dwellings that border the atrium. Factors to consider are sun protection and shading, (roof construction, corridors, stairs, etc) as well as colours and reflective materials.

In reality, the amount of daylight that penetrates through an atrium can be disappointing, especially on the lower floors.

Ventilation and shading

It is strongly recommended that ventilation systems and awnings with an automatic control are provided (fig. 1.12). Manual operation should always be possible.

For a pleasant interior apply in- and outlet grills sufficiently far away from seating areas or walking routes. Preferably place cool air ventilation outlets high above these areas, although they should be lower in atria than conservatories.

In atria with balanced ventilation systems, the airtightness between it and the housing is likely to require a great deal of attention.

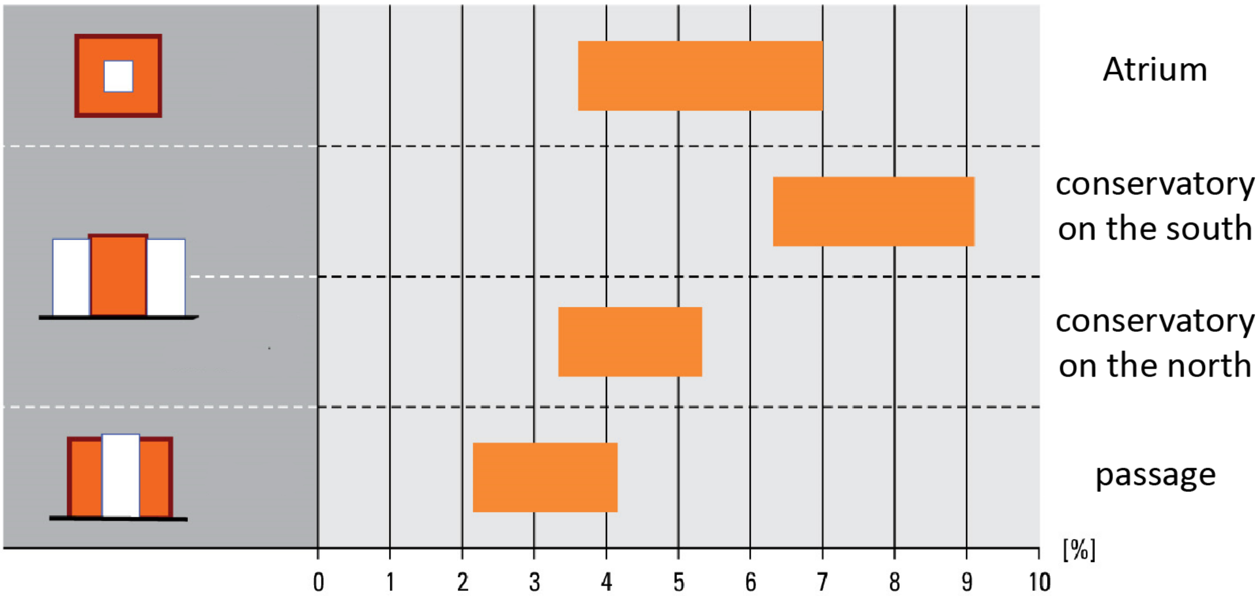


Fig. 1.12: Summer ventilation: General indication of the proportion of ventilation openings (as a function of the floor space) that is required for the air temperature in the atrium to vary less than 3 °C from the outside temperature. The surface of openings should ideally be placed at both the top and bottom of the atrium.

Regulations

To meet the Dutch building regulation ventilation requirements, at least 50% of the air required to ventilate a dwelling should officially come from outside of the building. This is because the air in the atrium is not of the same quality as air from outside.

Fire Safety

If a fire breaks out, it is essential that escape routes via the atrium remain viable long enough for people to get out of the building and that fire and smoke is prevented from spreading too quickly.

Possible measures include using:

- a smoke and heat exhaust system
- smoke detectors for general alarm and smoke screens
- materials for the corridors, stairs, finishing and interior that can withstand as great a heat load as possible
- effective fire resistance in the wall between the atrium and dwellings.

Cleaning

The entire atrium must be easily accessible for cleaning and maintenance, both inside and out. This is not only with regards to the accessibility of the glass envelope, but also installations such as fans, smoke detectors and lighting.

1.2.5. Facade collectors and Trombe walls

Other known passive systems are the façade air-collectors for preheating ventilation air and Trombe walls (see below).

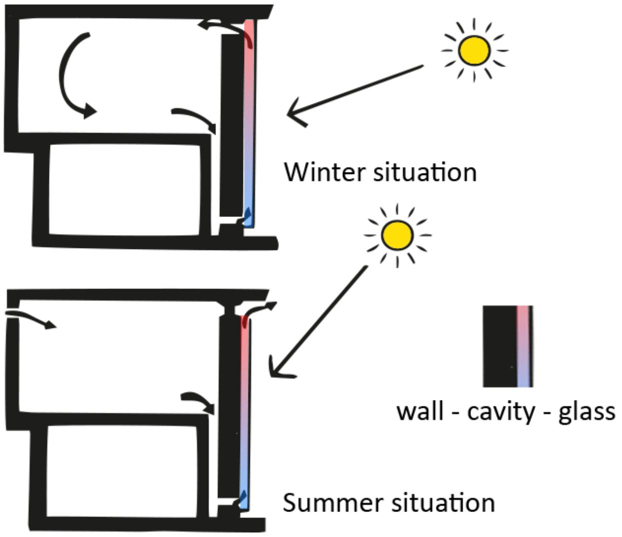


Fig. 1.13: Showing the use for ventilation and heating of air in the summer and winter condition of a Trombe wall.

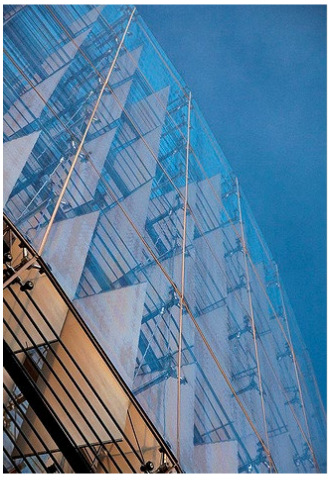
A Trombe wall is a heat-absorbing, sun-facing wall, separated from the outdoor an air cavity and glass. The wall is mostly south-facing and made of a dark, heat absorbing material. After absorbing the solar energy, this heat is released during the evening and night. During the winter the indoor air is circulated through the cavity, thereby the air is heated. In this way the building is passively heated. In the summer the pressure differences stimulates natural ventilation, see figure 1.13.

Facade collectors are mostly glazed constructions where a glass pane is placed in front of an absorber with a cavity between this glass plane and the absorber. The glass insulates the absorber and at the same time it allows solar radiation to heat this absorber. An air flow is forced in the cavity by a fan or by the buoyancy (stack effect) of the heated air. There are multiple modes in which the facade collector can be used.

1) Fresh outdoor air into cavity, heated, forced into building. Thereby this incoming ventilation air is preheated, increasing both the indoor comfort as decreasing the energy demands.
2) Circulating the indoor air through the cavity, thereby the air is heated, resulting in passive heating.
3) Indoor air forced to the outside via the cavity. Resulting in passive cooling of the building.

By these different modes the facade collector suitable for different climates.

1.2.6. Double skin facades



A trombe wall is an example of a double skin façade. More often you see the application of double-skin, aimed to improve thermal performance of usually glazed envelopes. An extra glazed layer is added to the façade; the air cavity functions as a buffer and that thereby improves the performance of the building in terms of energy and comfort. Often solar shading systems are integrated into the cavity. (fig. 1.14). The double skin can also be used to passively pre-heat the ventilation intake air before entering the building. The double skin facade is mostly suitable for moderate and cold climates.

Similar to the Trombe wall the double skin façade is preferably placed at the sun-exposed side of the building. The façade reduces heat losses, improves thermal comfort and results in a noise reduction.

Fig. 1.14: double skin façade with shading applied in the cavity. Vivian and Seymour Milstein Family Heart Center, Photo credit: Paul Warchol

1.3 Daylight

Resident surveys show that those living in houses where more glass has been used, really appreciate the greater amount of daylight that is allowed in. This refers not only to the higher luminosity, heat gain and energy reduction but also an improved sense of security.

Roughly 1/6 of total electricity consumption in a household is devoted to artificial light. As energy saving bulbs are still not universally used, daylight is still the main source of substantial reduction in energy consumption. Optimal use of daylight in building design is therefore highly recommended.

Think of relatively large glass façades on the south wall, windows that run up to the ceiling, skylights in the roof and a spatial design that makes full use of daylight.

The amount and type of light (direct or diffuse) that enters a home depends mainly on the orientation, position and size of windows, as well as the type of glass. Different type of glass have different transmittance of light. Also colours and materials that are used outdoors can affect the amount of daylight that comes in. For example, use light colours for façades and paving in densely built locations or courtyards, as the light is better reflected.

Besides windows and skylights, it is also possible to use 'tubes' or 'skylight spots' (fig. 1.15). This allows indirect daylight to enter the house through the roof (via a flexible or rigid tube). You can also utilise daylight reflection and dispersion of light indoors through:

- light coloured finishing
- daylight reflectors that allows light to enter deeper into a room or space.

Reflectors are also used in non-residential construction and offer options in spaces such as atria and stairwells in dwellings and residential buildings.

Fig. 1.15: A 'light tube' or 'roof light spot' can be useful to provide built-in or long rooms with (more) daylight when a skylight or sky dome is not possible. The tube is internally equipped with a highly reflective material. There are several manufacturers who provide these daylight tubes.

Photo: Solatube International Inc.

1.4 Technical installation space

The spatial (sketch) design should include the following important points:
An optimum installation location, for example, where:

- the shortest piping and cabling is, especially those for hot water, air ducts and collective space heating systems noise from installations and associated piping and ductwork can be prevented (see below)
- there is a sufficient mass of constructive building elements (floors, interior walls) to place or attach installations, especially to prevent noise; consider applying soundproof fixings
- there is sufficient space for placing the equipment and for maintenance and replacement (see manufacturers' instructions)
- there are (vertical) ducts of a sufficient size, such as air ducts with large diameters to reduce resistance. Insulate pipes against heat and sound and, for multi-level buildings, also fire flashover and sound absorption ducts are accessible for maintaining and replacing parts.

Tank location This should be as close to the taps as possible to reduce the loss of heat through the piping system. This point is especially important with taps where hot water often is demanded in small amounts throughout the day, such as in the kitchen. Also consider the maximum length of the ducts for the supply and discharge of combustion air and flue gases.

Air ducts These should be the shortest possible ducts from the ventilation system. A system with a compact network of air ducts will operate more energy efficiently and quietly and require less maintenance. Fewer bends will also benefit.

Solar boilers Hot water pipes, especially to the kitchen, should be as short as possible. This is to reduce heat loss and shorten the waiting time for hot water.

Piping circuits The piping circuit in a solar boiler system with a discharge tank, particularly between the collectors and the tank itself, may sometimes make a gurgling sound. It is therefore important to ensure that the piping circuit does not, for example, run through a bedroom. If this cannot be avoided then soundproof casing should be applied.

Electric heat pumps Heat pumps may also produce unwanted noise. They should therefore be fitted in a soundproof room rather than near noise sensitive areas, such as bedrooms. The ground floor is generally a more ideal place to situate a heat pump.

Heat pump boilers The risk of noise is less of an issue when positioning heat pump boilers close to the ventilation system. This is because the ideal place for it is the collection point and/or (roof) outlet where the system extracts discharged ventilation air.

Vertical shower-heat recovery units A location as close to the shower as possible should be used to ensure heat losses from the intermediate tubing are kept to a minimum.

Converter(s) near the solar panels in PV systems Small systems require little space so converter(s) can, for example, be placed in the loft or first floor corridor.
In the spatial design, converter(s) only require attention when a separate cupboard or space is needed, such as if:

- the converter(s) need to be accessible to third parties
- there is one or more central converters, usually relevant with larger (collective) systems.

2

Building envelope

2. Building envelope

2.1 Thermal insulation, thermal bridges and airtightness

Important aspects for consideration in terms of the amount of heat loss in the building envelope are the:

- thermal insulation of the construction
- number of thermal bridges
- degree of airtightness in joints and cracks in the structure.

Thermal insulation

For the building envelope (excluding windows and doors), the thermal resistance (R-value m^2K/W) indicates the insulation value of the construction. The higher the thermal resistance, the greater the R-value becomes, resulting in less transmission losses.

R = d/λ **[m^2K/W]**
R = thermal resistance [m^2K/W]
d = thickness of the layer [m]
λ = thermal conductivity [W/(m·K)] , material property

In 2010, the average R-value of various building envelope components in the conventional housing industry was roughly between 3.5 and 4.5 m^2K/W. For a passive house the value should be between 8.0 and 10 m^2K/W for closed façades and roof elements, and around 6.0 m^2K/W for ground floors. To achieve these values, traditional structures have to become very thick. This especially has significant consequences with façades in terms of use of space. By integrating insulation in, for example, light, wooden facade elements; a great deal more space is gained. When I-shaped framing is applied in addition, the thermal bridge through the wood is constrained.

For structures with good thermal insulation, energy loss due to 'thermal bridges' in the construction reduces to 20 to 30% of the total amount of transmission losses. It is important to avoid thermal bridges through careful detailing and implementation, as well as thorough education in the design office and on-site. Specific guidance is provided in this section to ensure insulation quality is improved.

Density and λ-value of building materials

In λ-values (lambda values) a distinction is made between the λ_D and the $\lambda_{calculate}$ values. The λ_D value relates to the thermal conductivity of the material (determined in the laboratory, the D stands for declared) and the $\lambda_{calculate}$ value, in calculations. The $\lambda_{calculate}$ tends to be the same as the λ_D when it comes to insulation materials. However, in some cases, it needs to be corrected for moisture absorption, ageing and temperature. The following values should only be used as an indication. Always use official data with a manufacturer's certificate for final calculations. When two different values are provided for the λ-value and density, the λ-value can be linearly interpolated for an intermediate value of the density.

Several insulation material suppliers have very useful information on the calculation of U-values by means of λ values on their websites. There are also some digital models that can be downloaded. The following table provides an overview of the density and λ-value (calculated value) of common building materials. All values are indicative.

Material	Density [kg/m^3]	$\lambda_{calculate}$ value [W/mK]	
		Dry indoor environment	Other
Gravel concrete			
Normal reinforced concrete	2300	1,83	2.06
Lightweight concrete	1900	1.28	1.44
	1600	1.03	1.16
Aerated concrete	800	0.23	0.25
	600	0.17	0.19
Bricks			
Façade bricks, grey	1900	0.90	1.21
Red	1500	0.64	0.87
Limestone	1750	1.14	1.52
Poriso stone	1350	0.57	0.76
Plaster			
Cement plaster	1900	1.0	
Lime plaster	1600	0.70	
Gypsum	1300	0.5	
Insulating plaster (e.g. PS-balls or expanded clay beads)		0.08-0.11	

Material	Density [kg/m^3]	$\lambda_{calculate}$ value [W/mK]
Wood and sheet products	800	0.21*
Hardwood	550	0.13*
Coniferous	700	0.17
Plywood	1000	0.30
Hardboard	250-300	0.10
Soft board	350-700	0.10-0.23
Wood wool	400-700	0.14-0.23
Cane fibre board	250-350	0.08-0.09

Material	Density [kg/m^3]	$\lambda_{calculate}$ value [W/mK]
Insulation materials**		
Plastic foams		
Expanded polystyrene (EPS)	15	0.04
Expanded polystyrene (EPS)	20-25	0.030-0.035
Extruded polystyrene (XPS)	30-40	0.027
Extruded polystyrene (XPS) (CO^2 blown)	25-45	0.025-0.036
Polyurethane (PUR) with HCFC	30-35	0.026
Polyurethane (PUR) (H) CFC-free	30-35	0.028
Polyurethane (PUR) locally injected	30-35	0.035
Polyisocyanate (PIR)	30-35	0.026
Resol with HCK	35	0.023
Inorganic materials		
Mineral wool (glass and mineral wool)	>35	0.030-0.040

Cellular glass	115-150	0.036-0.06
Foam concrete	350	0.15-0.2
	1000	0.30-0.35
Expanded clay granules		
Cement	600-1200	0.10-0.20
Perlite	100-120	0.045-0.055
Vermiculite	70-100	0.05-0.06
Organic materials		
Expanded cork	100-200	0.041-0.046
Straw loam	300-1600	0.1-0.7
Cellulose	30-60	0.04
Flax	25-50	0.035-0.04
Wood wool blanket	55	0.038
Insulation board	140-180	0.040-0.045

Reflecting foil, adjacent to a non- or weakly ventilated air cavity ≥ 20 mm on one side of the insulation material, gives an extra R-value of 0.45 m^2K/W

** perpendicular to grain*
*** Officially only materials with an λ-value of ≤ 0.06 W / mK are called 'insulation material'*

Special insulation materials

Besides the usual insulating materials, some lesser known materials are available:

• Aerogel: An aerogel-plate is welded gas tight (in metal, plastic foil or sometimes glass) to create a vacuum. The interior is provided with a heat-reflective finish. This results in heat being conducted through the aerogel and along the edges of the panel. With correct and careful positioning of these edges, the total insulation (including the effects from the edges) improves by a factor of 5 compared to conventional insulation materials. The panels must be precisely tailored during the prefabrication process, as once they have been welded it is impossible to make any alterations. Attention should be paid to lifespan and the risk of damage. These panels are worth considering as filling for panels and second skin façades.
Major disadvantage: The material is very expensive.

• Blankets with heat reflective layers: These eliminate the radiation from heat transfer as well as improving the convection (cavities up to 13 mm) and conduction through enclosed air during distribution. This leads to an equivalent thermal conductivity (λ value) of 0.028 W/mK for the whole structure, excluding the edges and fixings.
Disadvantage: In many applications the attachment can create a great deal of work.

• Nanoporous materials: The insulating effect of these materials is based on reducing gas-conduction by substantially reducing the pores. The size of the pores is smaller than the length of the present gas molecules by a factor of 10 to 100. The risk of collisions between molecules reduces significantly, which decreases gas-conduction. The thermal conductivity (λ value) (for room temperature and atmospheric pressure) is 0.014 W/mK. These materials are available in the form of blankets. Note that thermal bridges have a more exaggerated effect at fixings and edges.
Major disadvantage: These materials are very expensive.

(Linear) Thermal bridges

A thermal bridge is a relatively small part of a structure in which an area is poorly insulated compared to the adjacent faces. (fig 2.1) thermal bridges are common in transitions between different components (façade-floor, façade-roof, window frame-façade etc) and are therefore called linear thermal bridge. It is also possible for thermal bridges to occur inside constructions. Examples include steel structural components in façades, wooden framing in façade elements and rafter roof framing.

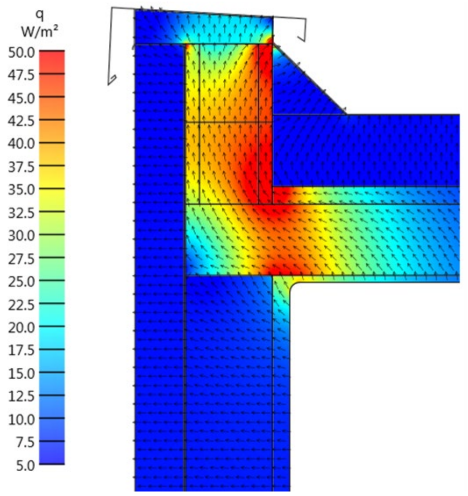


Fig 2.1: example heat flow through thermal bridge

Performance check

It is recommended that thermographic photos, taken with an infrared camera, are used to measure the thermal quality of the building envelope. The integration of this qualitative control as part of the specifications will have a preventive effect. In a larger project, the check can be done randomly after the first house has been sufficiently completed. Any deficiencies can still be relatively easily improved, especially in any further houses.

Airtightness: Cracks and seams

The air density (also called air permeability) of a dwelling is determined by the cracks and crevices in the house's shell. If these are not properly sealed, additional ventilation will create undesired energy loss. Cracks will form in the connection between moving and fixed parts as well as seams where fixed parts connect (see fig 2.2.).

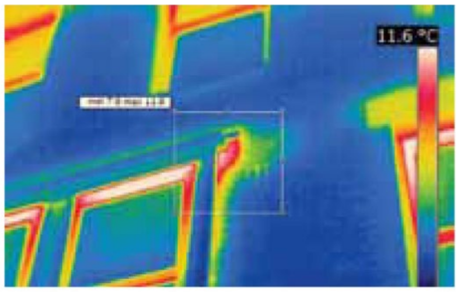


Fig. 2.2: Example of a study by thermographic photo. The heat leaks (seen as red spots) are clearly visible around the window frames. Photo: Adviesburo Nieman BV

Fig 2.4 shows some of the most common air leaks in practice.
A good seam sealing can be achieved by effective design and careful construction:

- Limit the length of the connections through a simple design (not too many extensions, dormers, angles, offsets etc).
- Consider the necessary tolerances and deformation that will occur over time.
- Place the sealing material (film, tape, compress strips etc) as carefully as possible on the 'warm side' of the structure.
- Avoid openings in films by, for example:
  - avoiding the integration of piping in light façade or roof elements. Do not make sockets or light switches in these elements;
  - incorporating a small cavity on the inside (still within the vapour barrier) for piping;
  - placing sockets and pipes on the wall (so that they are visible). This should only take place if there is no risk of the vapour film being damaged.

If a roof duct is unavoidable, then it should be sealed carefully.

Fig 1.3: Airtightness measurement using a temporary 'blower door'. With a smoke detector, air leaks can be made visible. Photo: Adviesburo Nieman BV

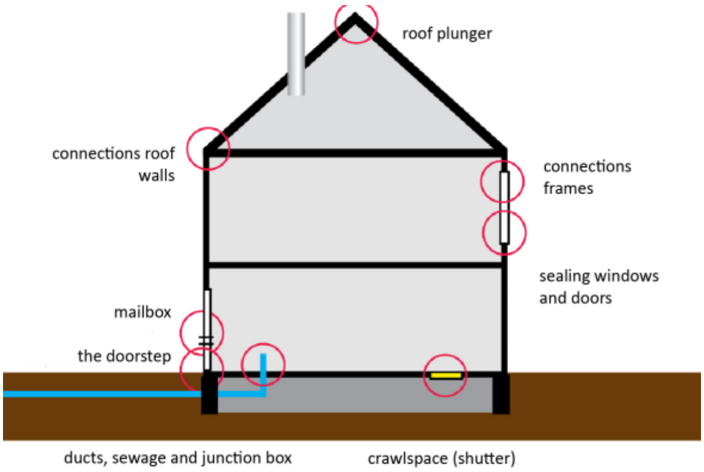


Fig 1.4: Note the airtightness in the detailing and construction of the building envelope. Indicated points how common air leaks.

For mechanical ventilation, the house should be as airtight as possible. Passive houses are usually equipped with balanced ventilation, a highly energy efficient concept that requires an excellent degree of airtightness to be effective. To achieve this, class 3 air density is added.

Performance check

Check the airtightness of each house, at least visually, before the (interior) finish is applied. It is also recommended that the air tightness of the building envelope is measured through a 'blower door test' (fig 1.3), preferably at a stage in which air leaks are relatively easy to eliminate. The inclusion of this qualitative control as part of the technical design (and the contract) will have a preventive effect.

In a larger project, the check can be done randomly. This should be done after the first house has been sufficiently completed. Any deficiencies can still be improved relatively easily, especially in any further houses.

2.2. Elements

This paragraph discusses the building envelope. It focuses on thermal insulation, airtightness and (sun) light. There are several related areas like passive solar energy, shading, ventilation, passive cooling, thermal mass and natural daylight.

The following elements are described:

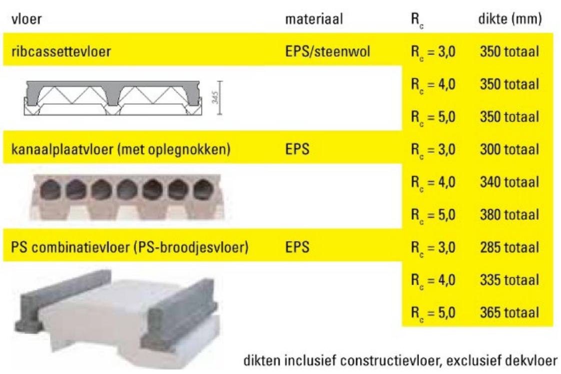
- Foundation and ground floor
- Roof
- Closed façade elements
- Separating walls and floors between dwellings
- Window frames, windows and doors
- Glazing

2.2.1 Foundations and ground floor

Thermal insulation

It is relatively simple to accomplish a high insulation value for the ground floor. As highly insulated prefabricated elements (to achieve passive house status) are not always available; a good solution is to apply a floating floor decking.

Heat loss through floors is relatively limited compared to loss through walls and ceilings because it is directed towards solid ground. In the heating season, the average temperature of the ground is significantly higher than outdoors and so there is less of a difference in temperature between the inside and 'outside'. This means that the floor usually requires less insulation than the walls or roof. In modern housing an R-value of around 3.5 m^2K/W is widely used. For passive houses the R-value is around 6.0 m^2K/W.



vloer	materiaal	R_c	dikte (mm)
ribcassettevloer	EPS/steenwol	R_c = 3,0	350 totaal
		R_c = 4,0	350 totaal
		R_c = 5,0	350 totaal
kanaalplaatvloer (met oplegnokken)	EPS	R_c = 3,0	300 totaal
		R_c = 4,0	340 totaal
		R_c = 5,0	380 totaal
PS combinatievloer (PS-broodjesvloer)	EPS	R_c = 3,0	285 totaal
		R_c = 4,0	335 totaal
		R_c = 5,0	365 totaal

dikten inclusief constructievloer, exclusief dekvloer

Fig. 2.1.: The thickness of the insulation is indicative.

Thermal bridges

To reduce the risk of thermal bridges and ensure that there is no structural surface condensation, a construction detail should have a factor ≥ 0.65. However, the positioning of the ground floor may still cause relatively high heat loss.

Thermal bridges generally occur where the foundation and partition walls on the ground floor connect between houses and façades. Heat loss can be reduced through:

- complete insulation (on site) around the foundation beams with:
  - U-shaped boxes of expanded PS-foam: These also serve as permanent cast (fig. 2.2). Note that this is only applicable for pile foundations. The boxes can be formed in one piece as well as of loose bottom and side elements. First, the bottom element is placed where the reinforcement is attached. Then the side elements are attached
  - rigid foam boards: These are placed after the construction of the foundations and are also only applicable for pile foundations.
- use of pressure resistant insulation strips in the floor and/or wall. For example, cellular glass or concrete can be used. Note the (long-term) strength of both.

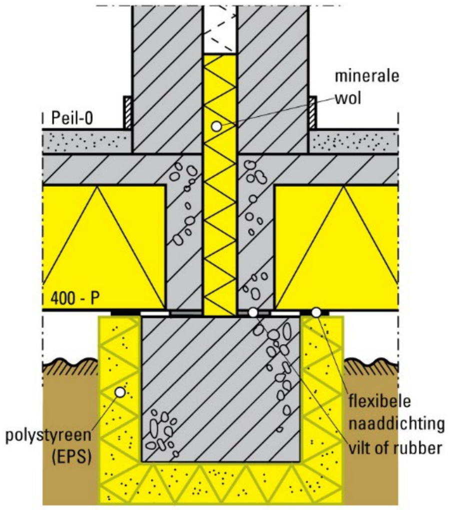


Fig. 2.2: Principle-detail: Insulated foundation beam with an anchor-free cavity wall and separating wall

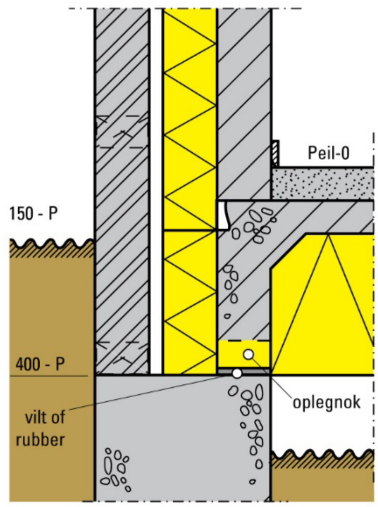


Fig. 2.3: The use of support cams in the ground floor reduces energy loss. Ensure a good air seal between the crawl space and cavity to prevent humid air and the risk of condensation. This applies not only to an end wall, as shown on the drawing, but also to a cavity without wall ties in a separating wall

Fig. 2.4: Make sure the insulation underneath a hatch is well joined with the insulation in the floor. A good solution for this is to place a separate prefabricated insulating cover in a special mounting bracket. The hatch and insulation cover are not linked together. The floor element shown here includes a hatch drilled by the manufacturer. Use a good airtight hatch with a smooth double draft seal. Apply a sunken handle into the top of it instead of a thumbhole. Illustration: VBI

2.2.2 Roof

Thermal insulation and sealing seams

It is relatively easy to install effective insulation in a roof. Most modern dwellings, have a roof with an R-value around 6.0 m^{2}K/W. Roofs in very low-energy projects such as passive houses, have an R-value of around 8 to 10 m^{2}K/W. This means an insulation thickness of about 0.3 to 0.4 m is required, depending on the insulation material and construction.

- Pitched roofs: A wooden roof box with rafters may be used where the rafters are applied as an I-beam to limit thermal bridging through the wooden beam.
- Sloping roofs: The airtightness between the cam- and roof connection (elements) and the (loft) floor requires a great deal of attention.

		thickness isolation (mm)			
	isolatie material	$R_c = 3{,}5$	$R_c = 4{,}0$	$R_c = 5{,}0$	$R_c = 8{,}5$
sloped roof with tiles					
Singleshielded prefab element [1]	mineral wool	145	165	210	365
	cellulose platen	140	160	200	340
	PIR	110	125	155	270
	EPS	140	160	200	340
sandwich panel without wood	PIR	90	105	130	220
	EPS "HR"	115	130	165	285
flat or near flat roof with ballast wood					
	resol	75	85	110	185
	EPS	130	145	185	320
	cellulair glas	135	150	190	330
gravel concrete 200 mm	resol	80	90	115	195
	EPS	130	145	185	320
	cellulair glas	135	150	190	330
	XPS omgekeerd dak	120	140	175	300
cellular concrete beton 200 mm	hard foam insulation	50	60	80	160
	EPS	85	100	140	270
	cellulair glas	85	105	145	280

[1] the required thickness depends on the constrution
every manufacturer uses their own constructionmethod, use their values.

Fig. 2.5: Some examples of roof constructions. The insulation thickness converted of a construction is indicative and rounded up to 5mm.
R = m^2K/W

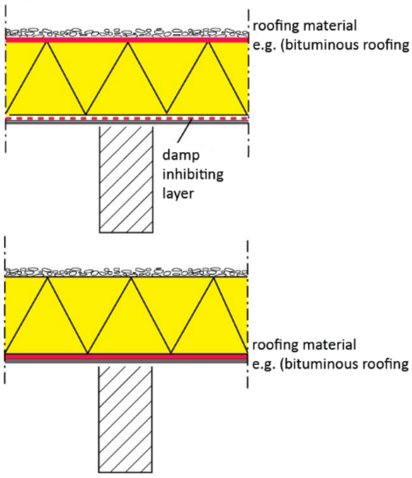


Fig. 2.6: Principle structure of a warm roof and a inverted (warm) roof

Tips:

- By applying eaves (0.75m, measured horizontally to the two underlying floors) walls can be protected from rainwater, which can decrease maintenance requirements.
- Consider the possible placement of a solar boiler and PV panels: angle, orientation and space requirements.

Warm and cold roof

Flat roofs are usually insulated on top of the construction to create a 'warm roof'. With a 'cold' roof, the insulation lies under the construction. (fig 2.6) However, these are rarely used due to the risk of internal condensation.

There are two ways to construct a 'warm' roof. Insulation should be installed:

1. below the waterproof layer on top of the waterproof layer (this structure is often referred to as an 'inverted' roof and the insulation protects the roofing material against extreme temperature fluctuations).

For an inverted roof, insulation material should be moisture repellent. Extruded polystyrene (XPS) is most suitable for this application.

When calculating the insulation for an inverted roof construction, take into account additional heat loss brought about by rainwater seeping under the insulation boards.

Airtightness

The airtightness of pitched roofs requires particular attention:

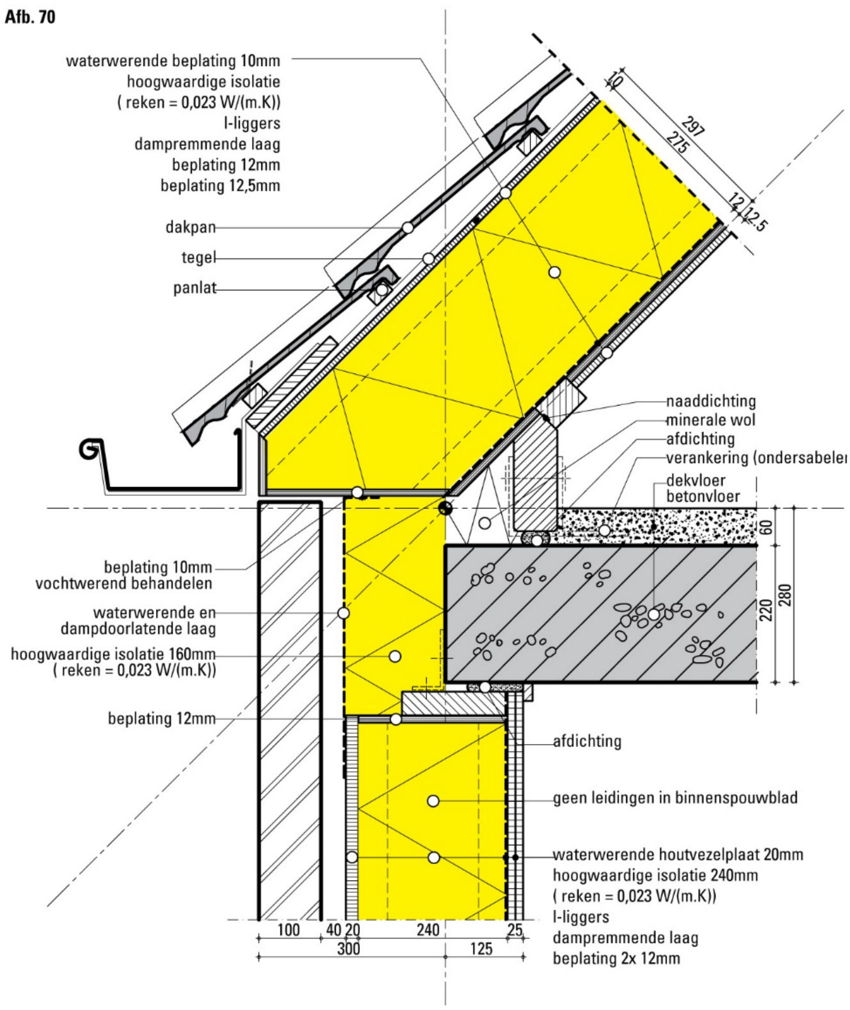
- Ensure there is a good air seal at the ridge. Choose hinged roofs, for example, with compression tape applied to the ridge. In addition, an overlap of (vapour barrier) films can be beneficial.

- When connecting roof elements to the wall plate, use compression tape as a seal. Provide a detailing to ensure that the tape cannot slide away during assembly.
- Ensure that the seam between the front side of the wall plate and construction wall is closed.
- Check the seal around drain pipes. For example, use a cover with wind strips between the plate and the roof and between the plate and the drain pipes. The edge should be designed to ensure that the tape is clamped down.

Vapour barrier

Check during implementation that vapour barrier films are applied correctly:

- Find the relevant location in the construction: The vapour barrier should always be placed on the warm side.
- Use the right film: Avoid confusion with breathable (often also water-resistant) film, which is intended for the cold side (outside) of a construction. These films can be identified by the colour of the markings: red for the warm side (vapour barrier), blue for the cold side (breathable) of a structure.
- Ensure there is a sufficient overlap (at least 100mm) of vapour barrier film and/or an airtight attachment to the edges. Also, the seams can be finished with special tape (make sure the tape is applied properly).
- Always check the manufacturer's processing guidelines.



Vocabulary:
Betonvloer: concrete floor
Dakpan: roof tile
Dampdoorlatende laag: breathable film
Dampremmende laag: vapour barrier
Dekvloer: finishing floor
Hoogwaardig: high-grade
Hout: wood
Leidingen: piping and ducts
Naad dichting: sealing
Panlat: batten
Tengel: counter batten
Vochtwerend: moist-resistant
Waterwerende beplating: water-resistant plates

Fig. 2.8: Connection detail of a pitched roof with a loft floor in a very well insulated house. Source: SBR

Ballast


Fig. 2.9: Example of an extensive green roof

The use of ballast on a flat roof has two advantages:

1. Protection of the underlying roofing material from ultraviolet light and major temperature fluctuations
2. Protection of the underlying rooms from rapid heating in summer

The disadvantage of ballast is the increased total weight of the roof.

Options for ballast are, for example:

- gravel
- tiles
- extensive vegetation.

Extensive vegetation

An extensive green roof (Fig 2.9) is one with a variety of greens in the vegetation.

Key features:

- The vegetation (and roof construction) requires little maintenance.
- The vegetation remains low and consists mainly of sedum, moss, grass and herbs or combinations.
- The drainage and substrate layer (in which the vegetation grows) is relatively thin and has approximately 60mm of moss and sedum and 100mm of grass and herbs.
- The roof angle can vary from 0° to about 30° in comparison to a roof with gravel as ballast.

- Important benefits of a (extensive) green roof, in addition to the aforementioned general benefits of ballast, are:
- Buffered rainwater: This decreases the peak load on the sewage. The effect depends on the thickness and structure of the vegetation. Ongoing research should reveal the precise impact of the buffering
- Extra cooling in summer
- Improved urban environment
- Decorated roofs: This is particularly important when local residents overlook them

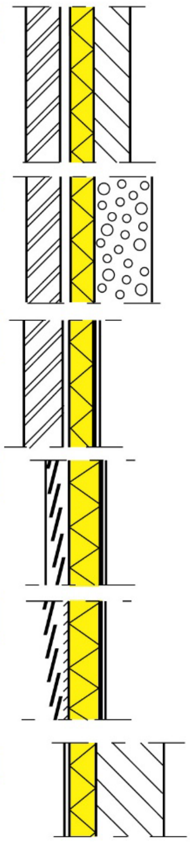
Concerns:

- An extensive green roof offers little or no insulation. This means that the roof should be insulated
- Take into account the thickness of the vegetation and any required slope when designing the façade and roof.
- Several local authorities and water boards grant the use of extensive green roofs for existing buildings, as well as for new construction.

2.2.3 Façades

Thermal insulation

Façades are harder to insulate than roofs and floors. The constructions are more complex in structure because of windows and door openings. Many modern dwellings (2010) have façades with an R-value of around 4.5 m^2K/W. Very energy efficient homes, such as passive houses, have R-values of 8.0 to 10.0 m^2K/W. For these houses more focus is required on limiting thermal bridges. An early example of a well-insulated apartment project is the 'Urban Villa' (fig 2.11), built in 1995. Here R-values of 5.0 to 6.0 were already applied.



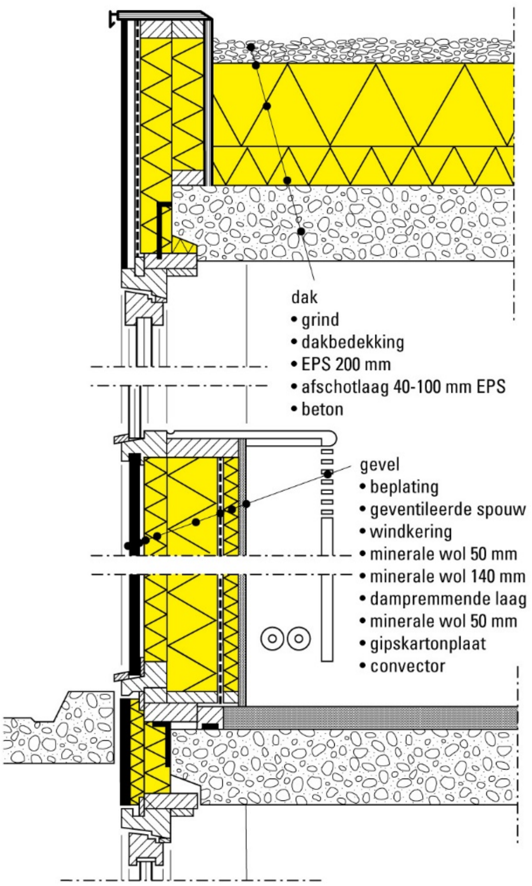
	isolatie materiaal	$\lambda_{declared}$	dikte isolatiemateriaal (mm) $R_c = 3{,}5$	$R_c = 4{,}0$	$R_c = 5{,}0$	$R_c = 8{,}5$
bakst. - kalkzandst. of beton (rvs spouwankers)[1,2]	steenwol	0,035	100	135	175	305
	glaswol	0,035	100	135	175	305
	EPS 15	0,036	105	140	180	315
	EPS "extra"	0,030	85	120	150	265
	resol	0,023	65	90	115	205
bakst. - 150mm cellenbeton (rvs spouwankers)[1,2]	steenwol	0,035	70	105	145	275
	glaswol	0,035	70	105	145	275
	EPS 15	0,036	70	110	145	280
	resol	0,023	45	70	95	185
bakst. - houten element (12 % hout)[3]	steenwol	0,037	135	180	230	405
	glaswol	0,035	130	175	220	390
	houtvezeldeken	0,038	135	185	235	410
	cellulose	0,037	135	180	230	405
hout - houten element (12 % hout, geventileerde spouw)[3]	steenwol	0,037	150	195	245	415
	glaswol	0,035	145	190	235	400
	cellulose	0,037	150	195	245	415
	houtvezeldeken	0,038	150	200	250	425
hout - isoplaat- houten element (12 % hout, geventileerde spouw)[3] (30 mm isoplaat met een $\lambda < 0{,}04$ over alle stijlen en regels)	steenwol	0,037	110	155	205	375
	glaswol	0,035	105	150	200	365
	cellulose	0,037	110	155	205	375
	houtvezeldeken	0,038	110	160	210	385
stuc - isolatie - kalkzandsteen	EPS 20	0,035	105	145	180	310
	XPS	0,028	85	115	145	250
	houtvezel plaat	0,043	130	175	220	380

[1] Bij toepassing van gegalvaniseerde spouwankers is 5 % extra isolatiemateriaal nodig
[2] Met een blijvend warmte reflecterende laag aan de ongeventileerde spouwzijde, is 20 mm minder isolatiemateriaal nodig.
[3] Bij houten elementen is er vanuit gegaan dat de stijlen en regels in één vlak liggen.

Vocabulary:
Baksteen: brick
Cellenbeton: cellular concrete
Dikte: thickness
Glaswol: fibreglass
Hout: wood
Resol: hard foam insulation material
Steenwol: stone wool
Stuc: plaster
Vezel: fibre

Fig. 2.10: Some examples of façade and end façade structures. The thicknesses of the structures are indicative and rounded up to 5mm. R-values are in m^2K/W

Afb. 73



Vocabulary:
Afschotlaag: gradient layer
Beton: concrete
Dakbedekking: roofing material (e.g. bituminous roofing)
Dampremmende laag: vapour barrier
Geventileerde spouw: ventilated cavity
Gipskartonplaat: plasterboard
Grind: gravel
Windkering: wind protection

Fig 2.11 Cross section of one of the façades in the project 'Urban Villa' in Amstelveen, a precursor of the passive house and a successor of the 'minimum energy house' from 1983

The insulation package consists of a total of 240mm of mineral wool and the vapour barrier is well protected. The framing lies in more than one plane so that the only place where the structure has any uninsulated wood is where it intersects. This results in reduced heat loss.

Architect Atelier Z - Zavrel Architecten, Ontwikkeling BAM Vastgoedbeheer, and Rabo Vastgoed, research and advice Damen Consultants, Delft University of Technology and DWA. Built in 1995.

Detailing and construction

- For wooden façade elements, mineral wool panels limit thermal leakage that is created by the framing. These plates are mounted onto the cavity side of the façade element and also serve as a vapour permeable and waterproof layer.
- Always use a double seamed seal around windows and where the façade elements meet, preferably with compression tape and/or film (fig. 2.13). Consider subsidence in the floor structure, which can be up to 5mm in the centre of the span. The seal between wall and floor must be able to absorb this difference.
- Good detailing will ensure that the use of polyurethane foam on-site is reduced, which is environmentally beneficial.
- It is recommended that random thermostatic photography is used to control the implementation process and ensure that great care is taken.

Cavity structures

- Take care that the bottom of a cavity is properly drained through open joints. For cavity insulation below ground level, use material that is not sensitive to moisture, such as hard foam insulation boards.
- For cavities with a brick outer wall, leave at least 40mm between the insulation and the outer wall (fig. 2.14). The benefits of this are:
  - unhindered drainage of rainwater that has penetrated the outer wall
  - higher quality masonry due to the bricklayer having the room to lay bricks quickly and easily.
- With regards to wide cavities, the insulation consists of two layers (instead of one thick layer) with staggered seams. For example 2 x 70mm layers can be used instead of 1 x 140mm layer.• Consider the negative impact of wall ties on the R-values of insulated cavity walls. When using stainless steel

anchors (Ø 4 mm), 5% less insulation is required compared to when using galvanised wall ties (Ø 6 mm). The omission of stainless steel anchors (if possible) would save another 5% of insulation.

- For mineral fibre boards with sand-lime bricks for the inner wall, there are special cavity wall ties available that should be mounted between layers during their application. The anchors are then in the right place and minimise the risk of damage to the insulation, unlike when standard puncture anchors are used.
- Protect soft insulation material from rain and wind during the construction. Cover cavity plates during breaks when it rains.
- Check the implementation of the insulation regularly and rigorously during construction. For example, ensure that there is a good overlap and join of insulation layers for outer corners. When using soft insulation, plastic strips (or corner anchors) are available to align them (see fig. 2.16).
- Check that insulation is properly aligned to the inner cavity wall and avoid a 'false' cavity (see fig 2.15).

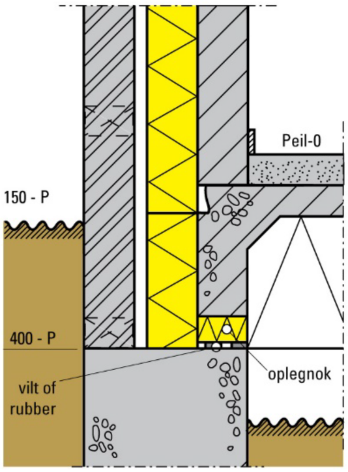


Fig. 2.12: Use non-capillary hard foam panels (e.g. EPS or XPS), which are resistant to water, at the bottom of the cavity

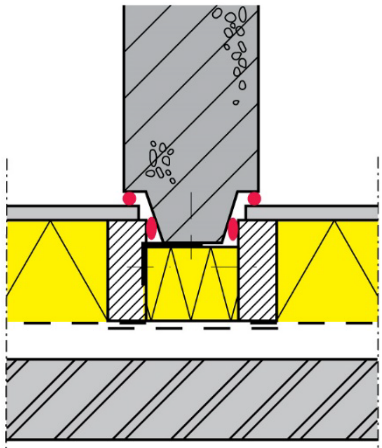


Fig. 2.13: Always use a double seam seal around window frames and façade elements

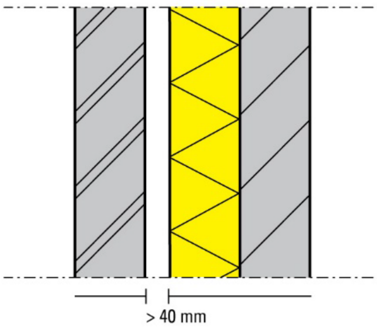


Fig 2.14: Outside walls made of brick require a cavity width of at least 40mm.

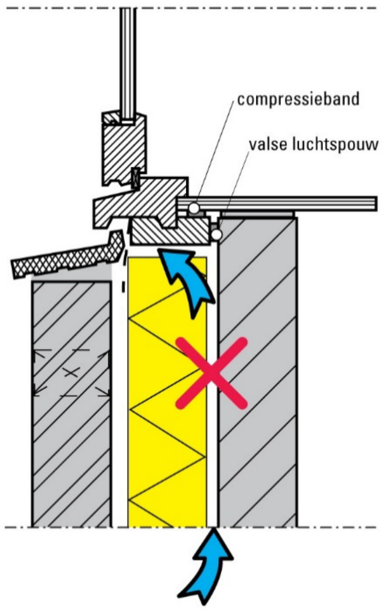


Fig 2.15: If there is any space between the insulation and inner wall, and there are cracks of 5 to 10mm below and on top of the insulation, the heat loss can more than double

Fig. 2.16: Plastic strip (or corner anchor) to align soft insulation layers carefully with each other on external corners.
Photo: Gebroeders Bodegraven BV

Fig. 2.17: Careful implementation reduces energy loss. The picture clearly shows that the insulation does not fit together, causing serious thermal leakage

Hard or soft plates in (masonry) cavities

The insulating ability of a cavity structure could halve if the insulation is not aligned well against the inner wall (known as a 'false' cavity). Furthermore, if there are cracks in, or on, the edges of the insulation boards, their efficiency decreases even further. This means that a great of attention should be paid when choosing insulation, as well as detailing and constructing the insulated cavity.

Other insulation plates:

- Hard plates, such as EPS (expanded polystyrene) and cellular glass, usually have grooves all around. Polyurethane boards are available with one relatively soft side due to the coating of mineral wool.
- Soft plates such as stone-, glass- or flax wool, or wood fibre, are sometimes coated on one or both sides for reinforcement. This allows easier handling and cutting of the plates. There are also stone wool slabs available which have a relatively hard and soft side. The soft side can be sealed against the inner cavity wall and the hard surface of the plate adds wind resistance.

Benefits of soft plates compared to hard plates in a masonry cavity wall construction are that they:

- are flexible and can therefore align well with the edges of excess material. With hard plates, seams often remain at the edges and need to be sealed with polyurethane foam. For narrow seams (<6 mm) this is more difficult
- are more suited to uneven finishes in the cavity wall as hard plates require it to be entirely smooth for a good fit
- have less recesses and use anchor frames. This results in a higher quality of insulation and less work
- work better with cavity ties than hard plates do.

The advantage of hard plates is that:

- they can withstand wind and rain better than soft plates during construction and therefore need less protection against it.

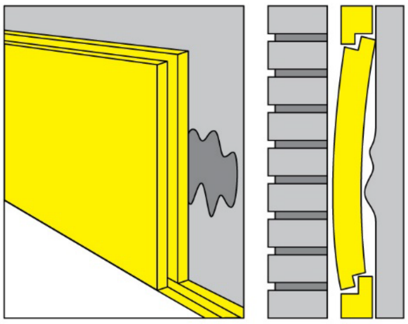


Fig. 2.18: For hard plates, a flat inner cavity wall is required. Whilst soft plates are effective on a more uneven surface, coarse mortar beards, adhesives and other imperfections need to be removed to align the plates flush against the inner cavity wall

Vapour barrier

Structures such as walls and roofs need to be constructed in a way that no internal structural condensation can occur. Therefore, the 'vapour resistance' of a structure should decrease from the inside (the warm side) to the outside. To achieve this, a vapour barrier film may be required with a waterproof and damp permeable finish on the outside.

Sometimes vapour barrier film is applied insufficiently, not at all or on the wrong side of the structure during construction. To combat this, close monitoring is advised:

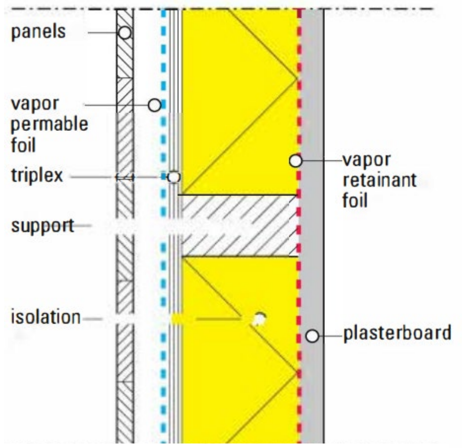


Fig 2.19 A vapour barrier should especially be applied on the warm side.

- Check the vapour barrier before the (inner) finish is applied.
- Ensure that the barrier and breathable films are not reversed.
- It should be possible for the films to be identified by the colour of the markings:
- red for the warm side (vapour barrier), blue for the cold side (breathable) of a structure.
- Always read the manufacturer's instructions.
- A good supply of information to the construction workers is strongly recommended.

Note detailing and construction:

- Use a polyethylene film (PE) as a vapour barrier with a thickness of about 0.20mm, or a film with similar properties. The vapour resistance and strength are important, with the latter being particularly vital to reduce the risk of damage to the film on the façade and roof elements during production and construction.
- Apply an overlap of film on the framing of at least 100mm.
- Seal the film edges well where there is no overlap. This could, for example, occur where the façade connects to a window frame.

2.2.4 Separating walls and floors between apartments

Thermal insulation

When the average temperature in neighbouring homes is not equal, heat transmission occurs through the separating wall or floor from the 'warm ' to the 'cold' home. As fig. 2.20 shows, these 'losses' are significant. These figures are estimated, however, field studies show that a significant heat exchange between dwellings can occur. With multiple levels, heat is not only transported through the building walls, but also through the floor and ceiling.

By thermally insulating a construction, the separating elements limit the transportation of heat. To what extent the insulation saves energy per terraced house or residential building, depends on how the added heat in the relatively 'cool' homes is utilised. The more effectively a house is insulated, the more superfluous any heat transferred from a neighbour's house becomes. This results in wasted energy. Insulation in the separating walls and floor balances out energy consumption and ensures that the temperature in one dwelling is less dependent on that in the adjacent house.

Insulation also prevents long heating times when the neighbouring houses have a relatively low indoor temperature. The heating capacity can be reduced because of the insulation, which lowers costs. Filling a cavity with soft insulation between apartments also improves soundproofing.

Applying thermal insulation in a tie-free cavity wall is simple. For example, mineral wool can be blown in afterwards. In a cavity wall that features stacked elements such as lime-stone, mineral wool plates are also used during the placement of these elements.

Separating floors between apartments can be insulated as follows:

- For stone floors, a floating floor is most relevant. This is a fairly expensive measure, but will not pose any technical problems. A floating floor is ideal for this kind of flooring due to the need for effective sound insulation between houses.
- For timber frames, insulation in the floor construction is standard to meet sound insulation and fire safety standard requirements.

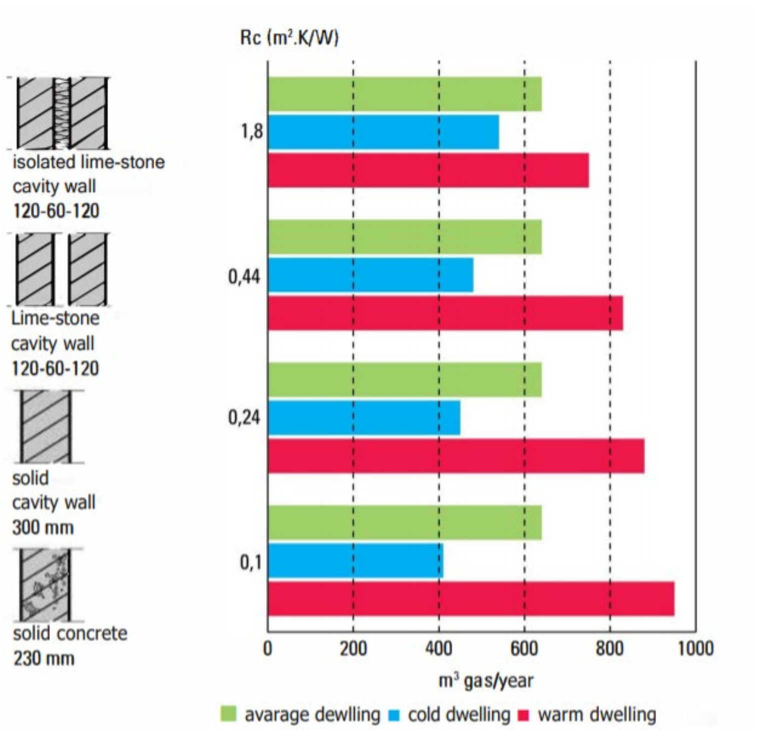


Fig 2.20: Energy consumption in m^3 of natural gas per year when the sample house is heated, on average, 2 °C more than the neighbouring houses during the heating season. The consumption depends on the insulation value of separating walls. Cavity wall insulation should be a soft material for soundproofing, such as non-packed mineral wool.

Sound insulation

A tie-free cavity improves sound insulation between dwellings compared to a solid wall of similar thickness. These cavity walls are a viable construction method, particularly in low-rises.

Partial filling of the cavity with mineral wool increases sound insulation considerably, especially with relatively 'light' construction materials such as aerated concrete. For heavier constructions, it is recommended that the tie-free cavity is at least the height of the floors, and the roof is filled with mineral wool (see fig. 2.21). This improves sound insulation as noise penetration via the 'flanking' faces, such as the foundation and roof elements, is limited.

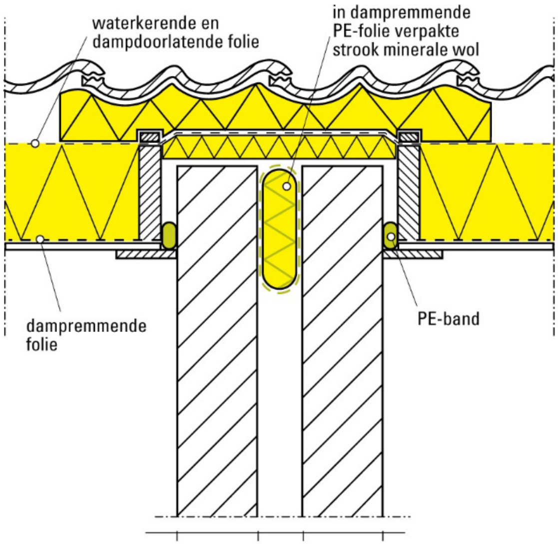


Fig 2.21 Detail of the connection of a tie-free cavity wall as separating wall on a roof system. Ensure sufficient insulation is applied on top of the building wall. Cover the top of the cavity with a vapour barrier film to avoid any condensation from the bottom of the roof tiles

	Uglas	kozijntype A (hout of kunststof; Ukozijn ≤ 2,4 [W/m².K])	kozijntype B (thermisch onderbroken metaal; Ukozijn ≤ 3,8 [W/m².K])
HR Glas	2,0	2,3	2,8
HR ++	1,2	1,8	2,2
HR ++	1,0	1,6	2,1
HR ++	0,9	1,5	2,0
drievoudig HR ++	0,7	1,4	1,9
drievoudig HR ++	0,5	1,3	1,7

Fig 2.22 The influence of the frame on the U_w (is the average U-value) of a total window (frame + glass). Design values of heat transfer coefficients for windows, U_w in $W/(m^2K)$

2.2.5 Window frames, windows and doors

Frames, windows and doors are still a clear weakness in the building envelope. This situation is greatly improved by using wooden frames with a thermal bridge interruption and insulated doors. This should be combined with triple glazing where 'better' insulating spacers are used.

This section covers what you should look for in products for these areas to ensure that a house is well insulated.

Windows and frames

When calculating the U-value of a window (U_w), in addition to the glass and frame spacers, the frame, and relationship between the glass (U_g) and frame surfaces (U_f), should also be included. The average U-value of all doors and windows in a house should, in the Netherlands, not exceed 1.65 W/(m²·K).

The table below shows a simplified overview of the heat transfer of windows with different glass and frame types, The U value of the window (U_w) is made bold. You see that some combination do not meet the Dutch standards of 1.65.

	Uglass (U_g)	Frame type A (wood/plastic) $U_f \leq 2.4$	Frame type B (thermal bridge interrupted metal) $U_f \leq 3.8$	Wooden frame, light wood-type $U_f = 1.3$	Aluminium frame (thermal bridge interruption) $U_f = 1.3$
HR^{++}	1.2	**1.8**	**2.2**	**1.4**	**1.55**
	1.1	**1.7**	**2.15**	**1.35**	**1.45**
	1.0	**1.6**	**2.1**	**1.25**	**1.4**
Triple glazing	0.9	**1.5**	**2.0**	**1.2**	**1.3**
	0.7	**1.4**	**1.9**	**1.1**	**1.2**

If you add intermediate values to the table above, what is clearly visible is the strong influence of the thermal quality of the frame to the U-value of the total window when effective insulation glass is used.

Tip: It is beneficial for a low U_w-value to have the largest possible glass- and smallest possible frame surface.

Doors

When calculating the U-value of a door, the frame should also be included. For example a door with > 65% glass surface is considered to be a window, according to Dutch building law. For other doors with transparent parts, the door is considered as two parts: the fixed parts of the door and the glass surface(s).

The U-value for a non-insulated door, without glass, including wooden frame is 3.4 W/m^{2}K. In 2010 the U-value of 'standard' insulated doors is, according to manufacturers, around 1.2 W/m^{2}K (= 1.8 W/m^{2}K including a standard wooden or plastic frame). There is a door available with a U-value of around 0.8 W/m^{2}K (= 1.45 W/m^{2}K including standard wooden or plastic frame), which has been specifically developed for passive houses. In insulated (front) doors, manufacturers usually use polyurethane foam as insulation, or sometimes expanded cork.

Afb. 86

Fig. 2.23: This BUVA-ISOSTONE ® plastic bottom sill is reinforced with fibreglass and two air chambers and has a relatively good (low) U-value of 1.4 W/m^2K. Photo: BUVA BV

Seams and cracks in window frames

Avoid seams and cracks. This is important for:
• reducing 'unintentional' ventilation losses.
• improving sound insulation, which plays a role in terms of façades with high sound loads.

Seams

Seams are connections between solid parts. Good details should be provided regarding the connection between frames and walls, floors and roofs. With precast concrete and timber inner cavity walls, factory assembled frames, or frames including glass, are preferable.
Prefabricated seams are generally more carefully executed than on site work.

Please note:
• A decreasing vapour resistance from the inside to the outside is important in terms of the lifespan of structures.
• There should be enough joint width for sealing tape to be sufficiently compressed. The joint should not be too wide and be reasonably uniform in shape. Check this, especially where the cavity slat connects to a brick, or glued inner, cavity wall. The use of woodwork that provides a double seam seal is also recommended.
• Use a wide strip of adhesive film for sealing the seam under wooden sills of exterior doors.

Cracks

Where moving parts are connected (doors and windows) you will always find cracks.

It is recommended that you use: welded profiles (frame profile) for the corners: The crack sealing profiles at the hinges and locks in the corners should not be interrupted

- sufficient hinges and locks to prevent the warping of windows and doors. Take, for example one hinge or a closure per metre
- three-point locks for doors so that the door is fixed in one operation toggle closures adjustable hinges and closing plates double-crack sealing. However, its effect on the reduction of ventilation losses is under discussion because a relatively large force is required to close the frame. The first four measures are more important than the fifth. For sound insulation, double-crack sealing may be necessary.

There are several draught-sealing profiles for rotating parts:
• Lip profile: This provides effective sealing and the pressing force can be limited to provide good results.
• Tube profile: This can provide a good seal, but only at a fixed slit width (low dimensional tolerance) and a fairly to large pressure force is needed. A good result will only be achieved with enough locks.
• Intermediate forms: These are combinations of tube and lip profiles or multiple lip profiles and have intermediate qualities in terms of performance

Windowsill

Prevent warm air flows behind closed roller blinds directly from heating elements. Note, for example:
• the correct size of windowsill
• the opportunities for curtain rails to be fixed in the right place.

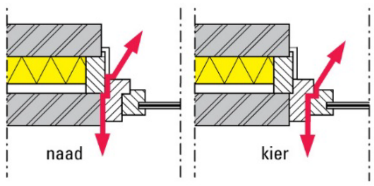


Fig. 2.24: Seams and cracks require a lot of attention. Ensure that there is a continuous sealing at the corners

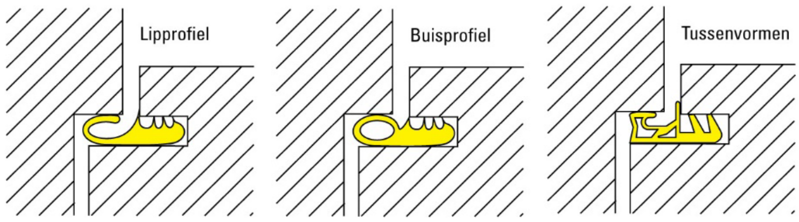


Fig. 2.25: Lip and tube profiles and combination forms

2.3. Glazing

The use of glazing in building affects:

- heat loss (U-value)
- solar gain (absolute solar access factor (ASA))
- daylight access (absolute light access factor (ALA)).

ramen	U-waarde (in W/m²K)	LTA-waarde	ZTA-waarde
blank enkel glas	5,8	0,90	0,80
blank dubbel glas	2,8	0,80	0,70
HR++-glas (niet zonwerend)	1,0 - 1,2	0,70 - 0,80	0,60 - 0,70
drievoudige beglazing (niet zonwerend)	0,5 - 1,0	0,60 - 0,75	0,50 - 0,70
daklichtkoepels (inclusief geïsoleerde dakopstand, transparant)			
dubbelwandig kunststof	2,8	0,85	0,80
driewandig kunststof	1,9	0,80	0,75
HR++-glas met kunststof enkelwandige koepel	1,4	0,70 - 0,75	0,50 - 0,55

Vocabulary:
Dubbelwandig: double sided
Drievoudig: triple
Koepel: dome
Kunststof: plastic
LTA: absolute solar access factor (ASA)
Ramen: windows
Zonwerend: sunblind
ZTA: absolute light access factor (ALA)

Fig. 2.26: Overview of a few types of glass (without effects spacers and frame) with overall indication of the U, ASA and ALA values
Note: These properties are only for vertical windows. The U-value of a window when placed at an angle increases (=decrease of insulation) up to about 50%. With regards to skylight domes, always contact the manufacturer or supplier for exact data.
Vocabulary:

2.3.1 Heat loss

Differences in the thermal insulation of double and triple glazing can be achieved by using:

- different types of coating
- air or an inert gas cavity filling.
- the width of the cavity. Most effective values with an width of 15-22 mm.
- Spacers are usually made of aluminium or stainless steel. These form a significant thermal leakage between the inner and outer glass panes. This is reduced if plastic spacers are applied (fig. 2.27).

In HR++ and triple glazing, an inert gas usually argon, or, for higher insulation values, sometimes krypton, is used. Neither gas is harmful to health or the environment, however, it is expected that the amount of inert gas in the cavity will decline by several percent per year. Extra sound insulation can be achieved by lining the inner pane (residential side) of laminated glass with PVB (A) film.

The heat loss of the entire window also depends, aside from the type of glass and spacers, on the frame (see section 5.1.5). This can be improved by the application of structural elements such as thermal insulating shutters and blinds (see below).

U-waarde in W/m²K	houten kozijn	PVC kozijn	aluminium kozijn
U-glas	1,2	1,2	1,2
U-kozijn	1,5	1,8	2,7
U-raam totaal			
aluminium afstandhouder	1,5	1,6	1,9
kunststof afstandhouder	1,4	1,5	1,6

Fig. 2.27: Example of the influence of spacers on the U-value of a total window with frame dimensions 1.2 x 1.5 metres. The plastic spacer in this example has a λ-value of 0.19 W/mK and a psi-value (Ψ-value) of 0.06 W/mK. Other polymers with different values are also possible. U-values are in W/m^{2}K

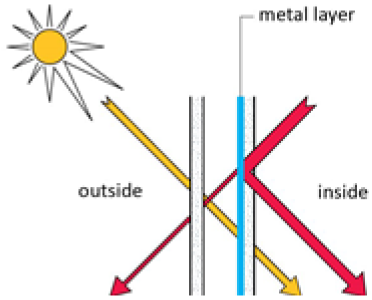


Fig. 2.28: Principle structure: HR++ glass. Heat radiation is reflected back in the room by the metal layer and solar radiation radiation is transmitted

NOTE: U-values used in this example only apply to the better for insulated types. Source: Saint-Gobain Glass.

Thermal insulating panels

There may be a reduction on the heat transfer coefficient of windows if shutters can be operated from inside the living space. This is based on an operating scheme in which 80% of the hours in the heating season, between sunset and 7 o'clock in the morning, takes place when the shutters are closed.

By applying a non-permanent solution, such as insulating panels, the insulation of the window can be temporarily increased. However, the use and improved insulation is entirely dependent on the resident. With this increased insulation, shutters can be left 'open' for sunlight and views for longer periods of time. Insulation shutters may be relevant for special applications, such as seasonal variable facades. In the heating season a large glass surface in the north facade can be partially closed with shutters.

It is possible to have shutters both on the inside and the outside of the window. With a wide cavity sliding shutters can also be applied between the glass panes.

Please note:
• When applying insulating shutters there still has to be room to ventilate the space behind. This does not apply if there is mechanical ventilation.
• Shutters should fit well onto the frame. This requires a sophisticated design, especially when it comes to outdoor shutters which need to be operated from inside the house. With interior shutters, the crack seal has to be effective to reduce the risk of condensation on the windows.
• Shutters can block escape routes.

Thermal insulating blinds

Blinds increase the insulation of a window, especially if they have a heat reflective layer. They are even more relevant in conservatories, especially if it has single glass as the blinds can serve as insulation and shading at night, For example, the U-value of the total window construction with single glazing in a wooden frame supplied with a roller blind, is 3.1 W/m^{2}K, instead of about 5.1 W/m^{2}K without blinds.

Translucent insulation

Translucent insulation materials (TIMs) are opaque but they allow light to penetrate them. There are various types and they insulate reasonably well. For more effective results, a barrier is required both on the interior and exterior, such as a glass or plastic plate. The plate consists of two adjacent glass panes filled with plastic tubes that have a diameter of several millimetres. The tubes are perpendicular to the two glass panes and the thickness of the plate is 50mm with a U-value of 0.7 W/m^{2}K. TIMs can also be processed into transparent stucco plaster which consists of translucent resin with glass beads.

Silicon based aerogels can be used as a TIM. They may, for example, be included in the form of granules placed between glass panes. The space between the two plates can be vacuumed which makes the insulation value very high, approximately 8 to 10 times more efficient than conventional building industry insulation materials. The λ-value is approximately 0.004 W/m^2K without the negative effect of the edges. Edges are still a problem in terms of thermal bridges and the lifespan of the panels.

Translucent material lets light through, but it is not clear glass, so you cannot see through it. In some cases transparency (for seeing) is not necessary, because diffused light for solar gains is enough. However, given the relatively high costs of TIMs and the development of new types of glass, it is doubtful as to whether TIMs will ever be widely applied.

2.3.2 Sun blinds

Incoming sun provides 'free' heat in the winter. However, in the summer, solar heat is often undesirable because of the risk of generating internal temperatures that are too high. The energy performance calculation needs to therefore take into consideration increased average temperatures of up to 24 °C, in degrees °C, for the month of July.
This information is provided for each heated zone within the dwelling. There are three risk classifications to distinguish high temperatures: low-moderate, moderate-high and high.

The energy performance also calculates the energy required to mechanically cool this excess heat using air conditioners. By using sun blinds as an alternative, the zone will be cooled without any additional energy consumption. Sun blinds are acceptable in terms of energy performance, but they are only relevant when shading is featured before the delivery of the project.

The solar contribution depends on:

- the solar-transmitting properties, ASA value (see fig 2.26)
- the presence and properties of sunscreens.

The size, orientation and any obstacles are obviously important in terms of the windows, skylights, etc.

There are different forms of sun blinds:

- Outdoor sun protection
- Fixed, architectural elements (e.g., eaves)
- Interior sun protection
- Sun protection in a glass cavity
- Sun protection glass, transparent-PV
- Vegetation

Fig. 2.29: Example of a project in which the movable blinds were included in the price. Part of the façade has transparent PV panels, also a form of sun protection. The dwellings are located in the energy district in Roomburg in Leiden

Plan development: Gemeente Leiden, architect: Han van Zwieten Architecten bna, developer/contractor: ACL, Aannemingscombinatie Leiderdorp; built in 2004.

Solar heat-transmitting properties, sun protection glass

The absolute solar access factor (ASA) indicates the relationship between the incoming and total amount of solar radiation, both direct and diffuse radiation are included. The absolute light access factor (ALA) indicates the relationship between incoming and visible solar radiation at a perpendicular angle.

The sun protection properties of glazing can be increased by applying sun reflecting- (using coatings) or sun absorbing glass. A better degree of shading can be achieved with sun reflective coating than sun absorbing glass, so modern glass types are usually reflective. Reflective glazing for housing has ASA-values of 0.40 to 0.50 and solar HR++ glass is available with an ASA of 0.41 and a ALA of 0.70. The latest bright, non-reflective, HR++ glass types have ASA values of about 0.60 to 0.65 and ALA values of around 0.80.

Please note: A high ASA value generally means a slight reduction in daylight factor (ALA) compared to clear glass. It may also discolour the daylight to some extent.

A further disadvantage of sun protection glass is that solar heat is unable to penetrate in the winter when passive solar energy is most needed.

Outdoor sun blinds

The best sun protection is obtained when solar radiation is collected on the outside of the glass. Outdoor sun blinds therefore provide the greatest amount of sun protection. In winter, when the heat of the sun is welcome, the blinds can be lifted.

Types of outdoor sun blinds are:

- drop screens
- blinds
- awnings
- outdoor venetian or Persian blinds.

The degree of sun protection for almost all models is good to very good. The most favourable is a dense tissue and a light colour. The ASA-value of outdoor sun blinds in combination with HR++ glass is 0.10 to 0.15.

Fixed, architectural elements

These include elements such as cantilevers and fixed awnings, which are included in the architectural design. Through these elements, the glass surface is partially shaded. The shading will depend on the sun’s position in relation to the wall, which means that the ASA-value is variable. Another feature of this method of shading is that, as with solar protection glass, it is always present, including in winter when the heat is actually welcome.

In practical terms, the use of awnings is primarily relevant for façades that sit between the south east and south west. The high sun in summer is blocked, while the low sun in the winter can pass through. For other façade orientations, the solar position, even in summer, is too low to achieve a reasonable degree of shading with fixed elements.

Interior sun blinds

Indoor shades are also an option. However these blinds are much less effective than outdoor shading. On average, outdoor sun protection blocks twice as much as any used indoors. The degree of shading depends on the type and colour of the blinds.

It is only possible to achieve a reasonable degree of interior sun protection with a highly reflective curtain, consisting of a tightly woven fabric or a non-transparent film. Both must be supplied with an aluminium vapour coating. The ASA-value of this kind of interior blind with HR++ glass is roughly 0.30.

Sun protection in a glass cavity

It is also possible to place blinds between two glass layers. The advantage of this over outdoor shading is that there is no need to take the influence of wind into account. This is a complex solution which is generally used in non-residential construction rather than for housing.

2.3.3 Daylighting

The entry of daylight in a room is one of the factors that helps to determine the room's usefulness. Relatively little light and views can lead to a negative perception of space, and extra electricity for lighting. Daylighting is dependent on the illuminating properties of a window or skylight.

Daylight-transmitting properties

The daylight factor (ALA-value) (fig 2.26) represents the ratio between the incoming and visible radiation (daylight) at a perpendicular angle. Solar and thermal barrier coatings reduce the ALA-value. The third layer of glass in triple glazing also reduces the ALA-value, compared to double glazing (HR++ glass).

For example, to calculate the minimum glass surface required, the daylight factor (ALA) of the glass should not be less than 0.6 unless a reduction factor is calculated.

Light Level differences

It is recommended that strong contrasts in daylight are reduced as much as possible for visual comfort. An advantage of this is that people will use less artificial light. Apply frames, for example, that are a light colour and divide the daylight openings (windows and doors with glazing) over the façade(s). If possible, use skylights or 'tubes'/'roof light spots'.

2.4 Building mass: heavy or light constructions?

The mass of a house plays an important role in decreasing temperature variations. A 'light' house heats relatively quickly and can also cool quickly, while a 'heavy' house needs a relatively long time to heat but retains the heat longer. The rapid heating of a light house is an advantage in winter but a disadvantage in the summer. For a heavy house the opposite is true.

The mass has little or no effect on the annual energy consumption for space heating as passive solar energy and internal heat sources are less effective in a small house than a heavy one. However, the impact of lowering the night temperature will have an effect on reducing energy consumption in a light house. It is believed that both effects offset one another.

The mass does influence the energy performance calculation. Lighter houses, such as those made with timber, have a lower energy performance. This is due to the extra energy needed for mechanical cooling (air conditioners). However, if adequate measures are taken against high internal temperatures, such as as blinds and summer night cooling, the light house scores are almost equal.

A lightweight thermally active building

A light building can become thermally 'active' by using a 'phase transformation material' or 'phase change material' (PCM). It is possible to integrate PCMs in building materials, substantially increasing their thermal capacity while hardly increasing the mass (weight).

The operation of PCMs is as follows:
When the ambient temperature is above roughly 25°C; the PCMs change from fixed to liquid form. The required heat generated by this process is then extracted from the environment.
When the room temperature decreases, it solidifies and emits the heat back into the room. The cooling or heating effect in a house can reach a few degrees Celsius.

Please note:
PCM's have been around for a fairly long time, are very expensive and are rarely used in the building industry.

2.5 Renovation projects

6.5.1. Ground floor

When the existing building has a reachable crawl space with a sufficient height below the ground floor the insulation can easily be added from this space. When it is not possible to apply insulation or sprayed insulation underneath the floor another option is to place a relatively thin, high quality hard insulation plate on top of the existing floor.

6.5.2. Roof

Roof insulation can be placed from the interior or exterior. For a pitched roof adding insulation on the exterior means that the existing roof cladding needs to be removed. However in this way the interior structure remains visible. For flat roofs it is recommended to add the insulation on top of the existing roof. When this is not possible the insulation can be added on the inside between the roof beams.

6.5.3. Façade

There are three ways to add thermal insulation to an existing façade:

Exterior

Adding insulation to the exterior of the building chances the aesthetics. Therefor it is no option for monumental buildings. There are two main ways to place the insulation, depending on the current structure of the building. In the first method the existing cladding will be removed, replaced by insulation and a new cladding system. The insulation can also be added to the existing façade, covered by a new façade cladding. When heating the building the structure will be heated as well, since the building structure is not separated from the building by an insulation layer. In the case of a stone structure this results in a heavy mass building. This method has the preference for renovation projects since high insulation values can be reached while at the same time it is relatively easy to solve cold bridges.

Interior

It is not always possible to add insulation on the exterior of the building. For example when the old façade needs to be maintained by aesthetic reasons. In this case the cavity and insulation can be added on the interior of the building. The main disadvantages are the decreased floor area and the thermal bridges that will occur where the interior walls connect to the façade. Above that careful detailing is required to avoid internal condensation.

Cavity insulation

After the second world war it became common to construct building facades with a cavity. This uninsulated cavity give the opportunity to insulate the building in a relatively easy way. The insulation will be injected into the cavity through a small hole in the outer façade. The insulation material can for example be EPS insulation. With this type of insulation a lower insulation value is reached as with the interior or exterior insulation, however the nuisance for the residents are limited.

3.

Ventilation

3. Ventilation

In this chapter, various ventilation systems are described, as well as the recommended requirements for ventilation.

3.1 Indoor air quality

The quality of indoor air in houses is determined by:

- air polluting sources in the house
- the quality of the outdoor air
- the capacity, effectiveness and practicality of the ventilation devices.

Of course, the behaviour of the resident(s) affects indoor air quality. In the design this can only be positively influenced by providing adequate ventilation facilities that are clean and easy to use. A clear guideline for residents is also necessary.

3.1.1 Sources of air pollution

In a house, several air polluting sources are present that can affect indoor air quality and, consequently, the health of residents:

- Use of the space (CO_2 and bio-effluents of humans themselves, tobacco smoke, dust, allergens from animals and plants, moisture from showering, cooking etc)
- Materials (building construction, furniture, carpets, curtains) in the rooms (emissions, such as radon, formaldehyde, dust and fibres)
- The ground, through open spaces under the ground floor (radon, moisture)
- The fireplace (combustion gases and soot particles)

3.1.2 Quality incoming ventilation air

The quality of ventilation air from outside is determined by:

- the general air quality outside
- the placement of vents (windows, doors, ventilation grills, air inlets) in relation with:
  - traffic (gases, particles)
  - vegetation (pollen)
  - other installations (exhaust grills of ventilation systems, combustion appliances, etc)
  - flat roofs with dark roofing (heat in summer)
  - the sun (heat in summer)
  - barriers (airflow limitation).

Air filters

The quality of ventilation air can be improved by applying (fine) filters. They are used in balanced ventilation systems with heat recovery units, both for central and decentralised systems.

Heat recovery units are generally equipped with coarse filters (e.g. class G3) for normal filtering. The inlet filter can be replaced with a fine dust or pollen filter (e.g. class F6 or F7) that stops pollen from vegetation and fine particles from traffic and industry. These filters are important for patients with, for example, chronic lung diseases.

A possible disadvantage of these filters is that they usually have a larger resistance compared to standard filters. If this is the case, the capacity of the fan should be adjusted accordingly. Keep this in mind when choosing the type of installation and fitting it.

It is very important that filters are regularly cleaned or replaced. Residents should receive clear instructions on this matter (fig. 3.1).

Electrostatic filters may be used, such as a decentralised heat recovery unit (combined with a radiator). The filter acts similarly to a particle filter, but requires less maintenance, is easier to clean and lasts longer.

Fig 3.1. Three-position switch for a balanced ventilation system with a filter indicator light on the left. This red LED switches on when the filters need cleaning. It's a simple feature that ensures that residents are well informed and will clean or replace the filters on time. Photo: Brink Climate Systems

Dilution factor

It is important to make sure that the exhaust air from a vent does not pollute the incoming air. This can happen with adjacent houses as well as in the same house. There must be a minimum distance between the supply and discharge points. This can be calculated using the 'dilution factor'.

Tip
Locate the fresh air supply points so they complement the balanced ventilation system i.e. on the shady side of the house and not close to flat dark roofs to avoid additional heating of ventilation air in the summer.

3.2 Required ventilation

Quality

A ventilation system's final indoor air quality and degree of energy efficiency is determined by:

- capacity: basic ventilation, exhaust air and summer night ventilation
- effectiveness: demand controlled ventilation and the distribution of air supply in a room
- usability: comfort (no drafts or noise nuisance) and an ease of use (easy to understand, operate, maintain and clean).

Emergency situations

In an emergency like a fire, or escape of toxic substances, windows and doors must be closed and the supply of ventilation air stopped. Connect, for example, an individual power supply to the ventilation unit on a separate highlighted electricity group so that residents can turn off the air supply themselves. With collective systems, a system administrator has to be able to shut it down. The ventilation system should ideally have the capability of being turned off from elsewhere.

3.2.1 Capacity

There are demands on the capacity for:

basic ventilation The minimum amount of air that is required to create indoor air quality that sufficiently reduces any adverse quality on health

exhaust ventilation Periodic ventilation that facilitates the rapid exhaust of highly polluted indoor air and removal of damp or hot air during peak production. It also helps to expel the accumulation of moisture or heat.

Demands on capacity

Some rooms must be provided with a facility for ventilation. The general principle of ventilation is 25 m^3/h (=7 dm^3/s) per person.

It is recommended that the following additional quality aspects are applied, adhering to warranty and guarantee schemes for housing:

- space for a washer and/or dryer
  - area <2.5 m^2: 7 dm^3/s
  - area ≥ 2.5 m^2: 14 dm^3/s
- storage rooms of at least 7 dm^3/s.

The air exchange that is created through cracks and seams (infiltration) should not be regarded as ventilation air. Check whether a balanced ventilation air-tightness (Class 2) has been met to prevent large infiltration losses.

Capacity recommendations

With regards to the health of residents and reduction of energy consumption, it is advisable to pay particular attention to resource constraint and the effectiveness of a ventilation system.

Some considerations:

- Setup an air balance for the entire house: Make a calculation for all supply and exhaust airflows for each living space, toilet and bathroom. Also include the internal airflows between the different areas. To allow these airflows, the ‘overflow facilities’ should utilise voids under doors and/or grills in internal doors or interior walls. The house as a whole must also be in balance; an example of this is given in fig. 3.2.
- According to the ‘50% rule’, 50% of the incoming air to a living space may come from another living space and the other 50% should be fresh air.
- All air supply within a residential room may come from another room within the same sized living space.
- The exhaust air from a toilet and bathroom should be 'directly' (or via a ventilation system) discharged outside. In an (open) kitchen, at least 21 dm^3/s must be directly discharged outside. The remaining air may be used elsewhere indoors.
- An extractor hood in the kitchen is not included in the ventilation balance calculation. In practice, if you install a hood, there must be an additional (temporary) air supply. Inform the residents of this in the instruction manual.
- In a hood without an engine, a shut-off valve should not be present. This is to guarantee good, continuous ventilation.
- In addition to ventilation facilities, exhaust facilities should be installed (see below).
- For hot weather in summer conditions it is strongly recommended that summer night ventilation facilities are applied.

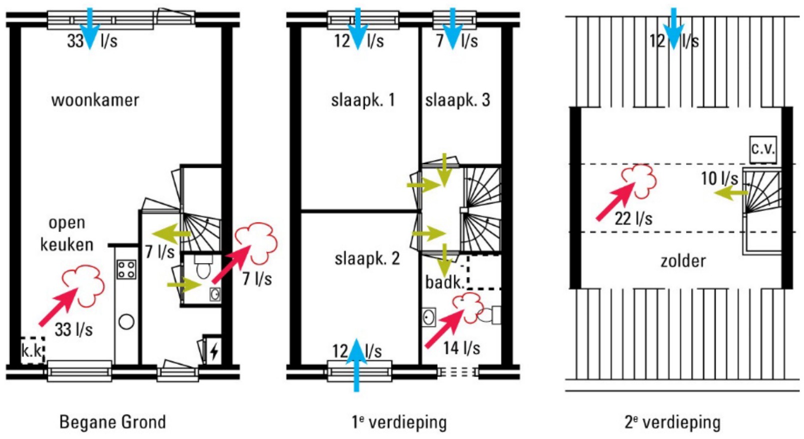


Fig. 3.2: Example of the ventilation flows in the sample terraced house, by Agentschap-NL

3.2.3 Serviceability

A ventilation system should be comfortable and easy for everyday use. Draughts and noise are priorities and maintenance, especially for residents, should not cause any issues.

Avoid complaints about drafts

Complaints regarding drafts can be prevented to a large extent by:

- ensuring that the air flow supply has the lowest possible velocity when entering the occupied zone (up to 0.2 m/s)
- placing air openings for 'cold' air supply (natural flow without preheating) as high as possible in the space (at least 1.8 m), i.e. as far away from the living area as possible, so that the air can mix with the existing warmer air first
- pre-heating the air supply through a conservatory or large glass cavity, or heat recovery from exhaust air or a heating system.

Reduce noise nuisance

In modern houses there is often not enough ventilation due to the fact that there are no restrictions on the sound that a system produces inside a dwelling. As ventilation systems make a lot of noise, residents resort to turning it to a low position or even pulling the plug out so it stays off.

To combat this, the following should be included in the technical design specifications:

- Ensure that the ventilation system produces as little noise as possible.
- Reduce the system's resistance and ensure it is positioned and mounted correctly. Use the following quality requirements for maximum noise levels measured in furnished rooms:
- 30dB (A) for living rooms
- 25dB (A) for bedrooms
- If there is an opportunity to provide (summer) night ventilation, apply the above mentioned requirements to the specification.
- Measure noise levels during installation.

diameter	surface area	natural (1,0 m/s)	mech. inlet (2,0 m/s)	mech. outlet (3,5 m/s)
ø mm	dm^2	dm^3/s	dm^3/s	dm^3/s
63	0.3	3	6	10
80	0.5	5	10	18
100	0.8	8	16	27
125	1.2	12	24	42
160	2.0	20	40	70
200	3.1	31	62	110

Fig. 3.3: Overview of ventilation ducts: Diameters with corresponding volume flows by particular ventilation system. Parentheses: the air speeds used in the calculations

Ease of use

Residents and facility managers need a ventilation system that is:

- understandable
- easy to operate
- easy to maintain and clean.

Recommendations:

- Provide clear written and verbal information to residents and facility managers. Some manufactures have developed a digital manual that installers, architects and clients can develop into a bespoke manual for a particular house.
- Place specific user instructions on the system facilities themselves.
- Give clear instructions for maintenance. Provide, for example, a three-position switch, with an LED signal that highlights when filters should be cleaned or replaced, to ensure balanced ventilation with heat recovery.
- Ensure that elements of a ventilation system are:
  - easily accessible for operation, maintenance and cleaning
  - easy to dismantle for maintenance and cleaning
  - can only be re-mounted in the proper manner.
- Give clear instructions on what needs to be done in case of emergencies (fire, severe air pollution) and make sure the system is prepared for these situations (e.g. easy to remove the power from the ventilation system/connection with a highlighted separate electrical group).

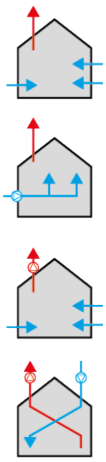
3.3 Ventilation systems

The required ventilation can be achieved in many ways and systems can be distinguished by the:

- supply of ventilation air
- exhaust of ventilation air.

There are four systems (fig. 3.4) with different combinations of natural and mechanical ventilation and many variations are possible within these.

The following sections discuss systems A, C and D with variants. System B is rarely applied. In §6.7 a relatively new development, the hybrid ventilation, is presented. This is a combination of systems that depends on weather conditions and the need for ventilation. These use the slogan ‘Naturally if possible, mechanically if necessary’.



ventilation system	supply	exhaust	system
natural	natural	natural	A*
combined natural/mechanical	mechanical	natural	B*/**
	natural	mechanical	C
balanced ventilation	mechanical	mechanical	D

* not allowed when the height of the top floor is more then13m above the ground
* * Not commonly applied by the high investmentcosts

Figure 3.4: Inventory of ventilation systems, based on the Dutch building norm 1087

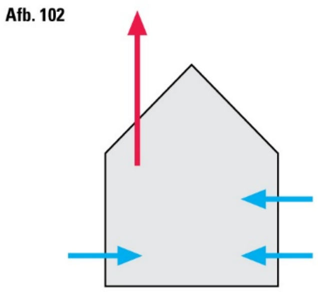
Tip

Set standards for the ventilation system to ensure scalability or adaptability of the house. This is relevant when a loft or garage could be used as living space. One possibility would be to connect that extra space to the existing ventilation system if it has sufficient capacity and a connection is practicable. Another option is to supply the extra space with its own ventilation system, e.g. in the form of a decentralised unit with balanced ventilation and heat recovery.

3.4 Natural supply and exhaust (system A)

Characteristics:

- Ventilation is achieved by pressure differences due to wind and/or temperature differences (stack effect).
- There is a natural supply of air, directly from outside, through vents, or easy to operate hinged windows. Grills are usually installed above the window frames and some are almost invisible from the outside.
- A natural exhaust is supplied via one or more air ducts.
- Air supply facilities (mostly grids) are placed in each room, so that the in-flow can be controlled by individual room.
- The air is transported from one room to another using overflow facilities, including interior slits or grills.
- In noisy locations (depending on the level of noise) soundproof vents (baffles) can be applied. Standard grills, integrated into window frames, do not block any sound when they are open, mainly because the outside faces noise from the street.



This ventilation system is rarely used in modern constructions, yet it offers attractive options as was demonstrated by the project Veldzicht in Valkenburg (ZH, The Netherlands). The apartments have a conservatory for the preheating the supply air as well as a limited mechanical ventilation system. Residents are generally very satisfied.

Figure 3.5: Principle of system A

Benefits

- Quiet, except with strong winds
- No auxiliary electrical energy
- Suitable system for residents. Operation is simple and the result of opening or closing a grill is immediately obvious
- Cool bedrooms: They can be ventilated at night with relatively cool air without the need to open a window
- Integral blinds: Several manufacturers supply air grills with integral screens and combined screens on the upper and lower windows are also available, providing a clear view

Disadvantages

- Highly dependent on wind speed: Sufficient ventilation is not always guaranteed due to temperature differences inside and outside
- Greater chance of drafty façades (see below)
- Wider discharge ducts: These are larger in diameter than in central mechanical ventilation.
- More attention is required to ensure a good fit into the spatial design
- No heat recovery (for heating ventilation air or water through a heat pump)

3.5 Natural supply and mechanical exhaust (system C)

Characteristics

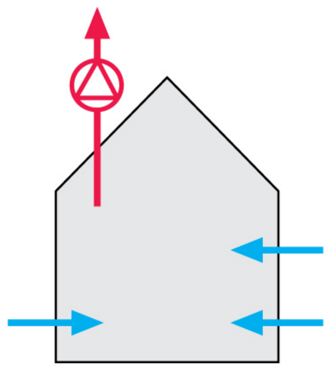


Figure 3.5: Principle of system A

- Ventilation is executed through an electric fan in the central unit.
- There is a natural supply of air, directly from outside, through vents, or easy to operate hinged windows. Grills are usually installed above the window frames and some are almost invisible from the outside.
- Supply facilities (mostly grills) are placed in each residential space so that the supply of air can be controlled in each individual room.
- Air is transported from one room to another by overflow facilities. (including slits under doors or grills)
- There is a mechanical exhaust linked to a ventilation unit through a system of ducts. Direct extraction from the kitchen, bathroom(s) and toilet(s) occur through extraction valves. The recommendation (housing institutions make this a requirement) is to do the same from a storeroom and washing machine and/or dryer outlet.
- There are three common ventilation levels and operation is controlled by a three-position switch (at least one in the kitchen).
- In noisy locations (depending on the level of noise) sound-proofing air vents (baffles) are applied. This ventilation system is often used in modern constructions, as well as balanced ventilation with heat recovery.

Benefits

- Reasonably controllable ventilation, better than system A (a completely natural ventilation): Moisture and odour removal from the kitchen and bathrooms is almost guaranteed
- Noise free rooms: Where only ’natural’ air is supplied, except when there are strong winds
- Suitable system for residents: Operation is simple and the result of opening or closing a grill is immediately obvious
- Cool bedrooms: They can be ventilated at night with relatively cool air without the need to open a window
- Limited system of ducts: This is in comparison to a balanced system
- Integral blinds: Several manufacturers supply air grills with integral screens and combined screens on the upper and lower windows are also available, providing a clear view
- Heat recovered hot water: Created by ventilation air that has gone through a heat pump boiler

Disadvantages

- Limited ventilation: Adequate ventilation is only ensured when ventilation grills are open
- Less drafty facades: Drafts are reduced by the use of self-regulating grills
- Electric auxiliary energy is needed
- Unwanted noise: Noise may be produced in spaces with direct mechanical extraction, or near the ventilation unit

Variants

There are several ways of increasing the comfort and energy efficiency of ventilation systems, through the use of:

- self-regulating mechanical or electrical supply grills
- supply through a unit with a radiator, possibly with a self-regulating inlet valve

- a demand-driven system with a CO_2 or time control through the central ventilation system, possibly combined with self-regulating ventilation grills
- preheating the natural air supply through, for example, a conservator/greenhouse: An energy performance reduction of up to about 0.20 is possible.

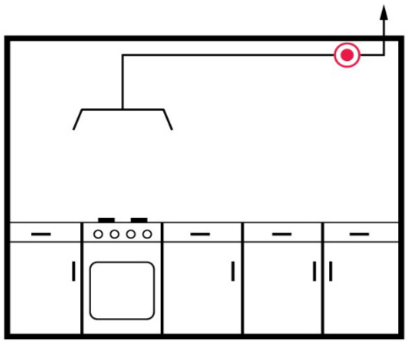


Fig. 3.6: Apply an extraction valve between the hood and the rest of the ventilation system

High-rise building

For buildings with multiple layers there is a choice between:

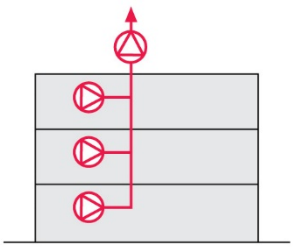
- an individual system per dwelling (only possible up to around 4 to 5 storeys) with more building layers and drains that demand a lot of space
- a collective system (see below).

Collective system

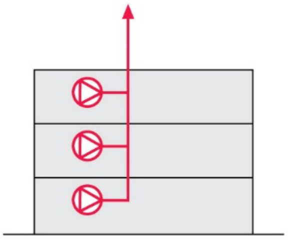
Here a choice can be made between:

- an individual ventilation unit per dwelling
- a central extraction through a roof-mounted fan
- a combination of both.

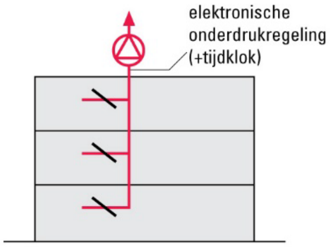
In all cases, the air is removed via a central discharge to the roof.



1. A collective roof-mounted fan, plus a fan unit per dwelling.
This system works, and can be controlled, very well. The roof fan provides a constant slightly negative pressure in the corporate duct system and this ensures that back flow does not occur. There is a chance of higher energy consumption than in the following two variants.



2. Each dwelling unit, has a fan unit and a special exhaust hood on the collective duct.
This is more simple than the previous system. However there is a risk of an undesired spread of vapour and odour when a resident switches off the fan. This means that each dwelling should have a check valve.



3. One collective roof-mounted fan plus electronic negative pressure control, and a regulation of valves per dwelling.

There should ideally be a timer control on the roof fan to save energy. However, this is only possible for special building functions such as a nursing home. This is a good system with relatively low energy consumption.

Concerns:

- There should be sufficient acoustic facilities to prevent noise from fans and other unwanted sounds.
- Fire barriers are required where corporate ducts connect.

3.6 Balanced ventilation with heat recovery (system D)

Characteristics

- This includes ventilation with two electric fans in the central ventilation unit: one is for the supply, and the other for the discharge, of ventilation air. There are two systems of air ducts through the house: one for supply, the other for discharge.
- The amount of supply and exhaust air is basically equal (in balance), aside from ‘mechanical ventilation system’ the term ‘balanced ventilation’ is also used.
- Heat is gained (heat recovery) from the exhaust air. This heat is transferred to the fresh air supply from outside and the heat recovery generally takes place in the ventilation unit. This is often known as a ‘heat recovery unit’.
- The living room and bedrooms are supplied mechanically as a minimum.
- With overflow facilities (slits under doors or grills) the air is transported from one room to another.
- Mechanical discharge takes place through the second duct system. The direct extraction through valves occurs at the very least from the kitchen, bathroom(s) and toilet(s). It is recommended that this is done from a storeroom, as well as from a washing machine or dryer outlet as insurance companies make this a requirement.
- Three fan speeds are common; the operation is controlled by a three-position switch in at least the kitchen.

Afb. 106

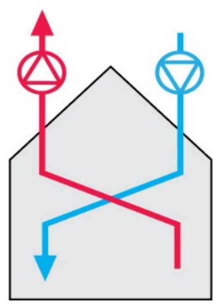


Fig. 3.7: Principle system D

Heat recovery takes place in a ‘heat exchanger’ and there are several types available. The most common is a ‘counter flow heat exchanger’, which has a high-yield of 90 to 95%. With this the supply and exhaust air run in opposite directions in small ducts and each duct is surrounded by canals opposite the airflow. Their high efficiency heats the air from outside enough so there is very little chance of draft. Reheating is not necessary.

In the heat recovery unit, a heating and cooling system can be added. Because of the low flow rates, the maximum heating and cooling capacity is limited. Cooling is strongly discouraged because of the relatively high energy consumption.

Heat recovery units are equipped with automatic frost protection. With severe frost, without protection, the exhaust air (with relatively high humidity) could freeze in the unit, which blocks the discharge of ventilation air completely. Frost protection temporarily reduces the supply of air so that the exhaust air cools less and does not freeze. In some systems, a heating element guarantees that the full supply is maintained.

Balanced ventilation with heat recovery is, as with system C, often used in modern constructions, especially for energy savings (favourable for energy performance) at relatively low costs. The system is also generally comfortable. A pre-condition is that the design and implementation receives a high degree of attention, but in current building practice this does not always take place.

Residents and facility managers must be well informed, both orally and in writing, about the use and maintenance (regular cleaning or replacing filters) of the system.

Benefits

- Well controlled ventilation if carefully designed, implemented and maintained
- Comfortable because of fresh air being preheated by heat recovery
- Energy saving because of heat recovery, assuming that the house has excellent air-tightness (class 2)
- Baffles are superfluous in façades with high noise nuisance levels, e.g. traffic noise,
- Limited contaminated air supply from outside due to the supply of air from the cleanest location and filters

Disadvantages

- There may be some noise from the supply or exhaust air heat recovery unit due to insufficient attention in design and implementation.
- Regular maintenance (by residents) of the filters is necessary.
- It is more likely with heat recovery for bedrooms to warm up (compared to other ventilation systems).
- The fans contribute to energy consumption.
- The construction of an effective system requires extra knowledge and attention from the engineer and architect.
- The building envelope needs to be as airtight as possible.
- There is less flexibility in changes in spatial layout due to the canal system.

Variants

There are some possible variations for balanced ventilation:

- Demand driven system: CO_2, air, humidity or time control through the central ventilation unit. Such schemes achieve optimum ventilation, adjusted to demand.
- Decentralised system for a (local) mechanical ventilation with heat recovery: One or more spaces is facilitated with a wall-ventilation unit with heat recovery; the other rooms are equipped with front grills for air supply. A separate mechanical exhaust system is required for the kitchen, bathroom(s) and toilet(s). The ventilation unit with heat recovery is available as a standalone unit, combined with a radiator

Advantages (compared to 'normal' balanced ventilation with heat recovery):

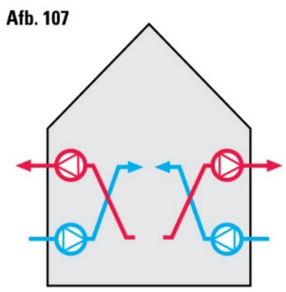
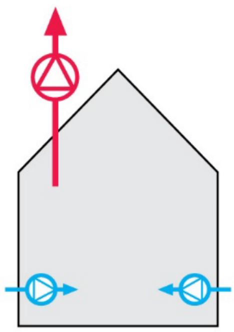


Fig. 3.8. Principle decentralised ventilation system with heat recovery

- No system of ducts is required for the supply and discharge of air (this is required for the mechanical extraction elsewhere)
- Clear system for residents
- No need for overflow facilities between the rooms with balanced ventilation and the rest of the house, so less chance of noise
- Disadvantages (compared to 'normal' balanced ventilation with heat recovery):
- Energy consumption of additional fans
- More chance of noise from the ventilation unit because it is placed in the room
- System with decentralised supply and central discharge: The fans are driven simultaneously creating balanced ventilation. The supply can take place in separate wall units, but can also be combined with a radiator or convector. There is no preheating of supply air by heat recovery.

Advantages (compared to 'normal' balanced ventilation with heat recovery):



- No duct system needed for air supply
- 'Cool' bedrooms (there is no heat recovery)
- Disadvantages (compared to 'normal' balanced ventilation with heat recovery):
- Energy consumption of additional fans
- No heat recovery, although the heat can be used for heat pump boiler
- More chance of noise from the ventilation unit, because it is placed in the room

Figure 3.9: Principle balanced ventilation system with decentralised supply and central discharge

Multi-level building

For multi-level buildings there are the following options:

• Individual system per dwelling (see above); This is only possible practically for multi-level buildings up to about 4 to 5 storeys, with additional building layers the supply and discharge ducts require a lot of space

• Collective system (several variants are possible): One possibility is an individual ventilation unit (with heat recovery) with a supply and exhaust fan. The supply takes place via the façade, and the discharge through a collective duct with an additional roof fan. Insulate the collective duct with damp proof material to prevent condensation on the outside. Also insulate the cover on the ventilation duct

3.7 Hybrid ventilation

A completely natural ventilation system (system A) can be significantly improved by combining it with system C. This combination is called a hybrid system. The operation is based on the principle 'natural if possible/mechanically if needed': Only when ‘natural forces’ (wind and temperature) in system A fail to achieve a certain ventilation capacity is mechanical support triggered. The low resistance of the air extraction system is important and because the mechanical support is only used some of the time, electricity consumption is limited. In the sample semi-detached house, with an energy performance of 0.8, the energy performance decreases with 0.20 with hybrid ventilation. All of these cases concern the combination of system A with system C, with an extraction fan included in the discharge duct.

There are several systems or products available. One was developed in the European research project ReshyVent, where the system was tested on a demonstration dwelling. The supply is regulated by electrical grills which are linked to a central control unit and each room is equipped with a CO_2 sensor. Once the CO_2 concentration exceeds a certain value the supply grid (below) opens. Simultaneously, the control unit will check whether the natural discharge is sufficient. Is this not the case, then first the natural discharge is increased by further opening the (motorised) valve in the exhaust unit. If this not enough, then the exhaust fan in the same unit will be switched on. It is so effective that when the fan is stopped, natural drainage is still possible (along the fan) with a similar amount to that of a normal natural system.

An important part of system is the low air resistance of the extraction valves, duct system and chimney with hood. The valves (fig. 3.10) and the hood are specially designed and the air ducts have a diameter of 180mm.

There are also simpler systems available.

Afb. 109

Fig. 3.10: Special tools have been developed for hybrid systems, such as a low-pressure extraction valve (left) and a duct with cover (right). Illustrations: Alusta (left) and Ubbink (right)

3.8 Summer night and ground pipe cooling

3.8.1. Summer night cooling

To prevent high internal temperatures in summer, night cooling is needed. The expectation is that the problem of high internal temperatures will increase in the near future. This is due to the increase in the insulation level of housing, as well as climate change.

The cooling is generated by the (natural) ventilation of relatively cool outside air. With an air change rate of at least 4 times per hour, this is much higher than the maximum ventilation requirements of once per hour. As a result, common ventilation facilities are far from sufficient. In principle, the discharge facilities (open doors and windows) are, but they are highly sensitive to intrusion, especially as cooling is particularly effective at night. This method of cooling can also be used in the morning when the outside air is still cooler than inside.

Summer night cooling facilities consist of parts in façades and sometimes roofs that can be opened. They must be intrusion- and weatherproof, equipped with thermal insulation (fig. 3.11) and enable cross ventilation and thermal drafts ('stack effect'). This means that the facilities should preferably be located on different floors and in opposite walls and/or in the roof. Sufficient overflow facilities are required within the dwelling, such as open doors inside or grills. The facilities must be located in such a place that residents are not affected by drafts during sleep.

Afb. 110

Fig. 3.11: Example of provision for a summer night cooling in a home in Zeist. The façade of the living room has two break free outlets (2 x 2 x 0.25 m = 1 m2) with an insulated hatch. A skylight provides good natural draft. Ii architect studio realisation Ettekoven Contractor & interior decorator, consulting BOOM-SI, built in: 2009

The required sizes of the facilities are considerable and this should be explicitly taken into account in the (façade) design. In a sample calculation of a 40 m^2 living room using thermal draft, provisions in the façade and roof are needed that are approximately 0.60 m^2 each (e.g. 0.3 x 2.0 metres). This takes into account a 50% passage of supply air resulting from a grill, for example.

3.8.2. Ground pipe cooling (and heating)

There are specific products for cooling (and heating) through an under-ground tube or air collector available and this system is applied in a number of dwellings.

The system is simple: Fresh air supply via a pipe that is buried at 1 to 1.5 meters is used in summer for cool ventilation air in the house. Calculations of a sample project in Nijeveen, show that the temperature from the ground pipe may be 10 °C cooler than the maximum outside air temperature on a hot day. In that project, the tube has a length of 20 metres and is linked to a balanced ventilation system.

In winter, the under-ground tube heats the fresh air supply. Ground pipe cooling (and heating) can be applied for all ventilation systems (A, B, C and D). System B and D, with central air supply, have the advantage of the already existing duct system that can distribute the cool air.

Considerations:

- Choose a good spot for the outdoor air inlet (cool place, clean air).
- Provide the under-ground tube with a drain pipe and a rough filter in the inlet opening.
- Make the system easy to clean and reduce the air resistance as much as possible.

Consider the use of a thermostatic control, so that the supply through the ground pipe can be stopped overnight when the cooling is not necessary; the ground pipe and its surrounding ground can then regenerate.

3.9 Operation and regulation

The following operating systems and regulations are applied:

Manual control inlet (grills)

The supply through natural ventilation (vents) is managed manually. Besides the closed (0%) and fully open positions (100%), the inlet openings must be adjustable in the range of 0% to 25% of the required capacity. Within that area, at least two positions must be able to be fixed. It is recommended that the air supply should be operated at a maximum of 1.5 m above the floor. The air supply in each living zone may have a speed of up to 0.2 m/s.

Multi-position switch

The modern multi-position switch has three ventilation modes: high, medium and low. This switch is common for central mechanical supply and/or discharge systems, and is installed by default in the kitchen. It is also advisable to place a switch (with timer) in bathrooms. As comfort is increased by improving the ventilation; the high position will often be used. A switch will prevent unnecessary use of the high position.

As mentioned previously, three-position switches, with an LED that indicates when the filter of a ventilation unit should be cleaned or replaced, are available and highly recommended.

Demand-driven schemes

In a demand-driven system, ventilation is dependent on the actual need for ventilation at a given time. This is usually monitored by CO_2 sensors. The quality of indoor air is related to the concentration of CO_2, which is taken as standard because, in comparison with other indoor air substances, it is easy to measure. Once the concentration starts to exceed the limit, the ventilation is increased. In the semi-detached sample house with an energy performance of 0.8, the energy efficiency decreases with around 0.10 of demand controlled ventilation.

There are many control systems available, such as for use with ventilation system C, with self-regulating electronic grills above windows that are linked to a central control unit. Each room is equipped with a CO_2 sensor. Once the CO_2 concentration in a certain area exceeds a certain value, the supply grill opens. The control unit will simultaneously check whether the central discharge is sufficient. Is this not the case, then first the natural discharge is increased. When the concentration decreases, the supply grill is closed again and the discharge fan is turned to a lower position.

For balanced ventilation (system D), a control is available where the living and sleeping area are each provided with a CO_2 sensor. This allows ventilation in the living room to drop to a minimum at night. While the ventilation in the sleeping area is increased, the total air volume remains the same.

A system with CO_2 measurements can be combined with RH-sensors in the bathroom and kitchen that measure the relative humidity (RH). This combined system results in the best air quality and highest energy savings when compared with other regulation schemes.

All systems can be manually adjusted if necessary and always maintain a minimum amount of ventilation, even if there is no demand from the sensors.

Time control

With time-controlled ventilation via a central control unit, each room has a present amount of air supply and/or discharge. The ventilation is based on the expected presence of one or more persons in that room during a certain period. Furthermore, there is always a minimum amount of ventilation. The ventilation system can also always be adjusted by hand.