WALLS

Guidelines for renovation of historic buildings

Interreg
Alpine Space
ATLAS
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INTRODUCTION

These guidelines are intended to explain to interested owners as well as professional planners the fundamental steps towards the concept definition for a sustainable renovation of a historic building providing a basis for further planning and implementation.

There are many reasons to renovate a building: The Property does not get warm properly, there is a draught through old windows, heating bills are high; and often there is decay or damage to the masonry or roof that triggers renovation. In addition, there is the awareness that climate change is happening and that we can all do something for our environment by saving energy and using existing material resources.
However, if the building that is to be renovated is historic or traditionally built, many questions immediately arise.

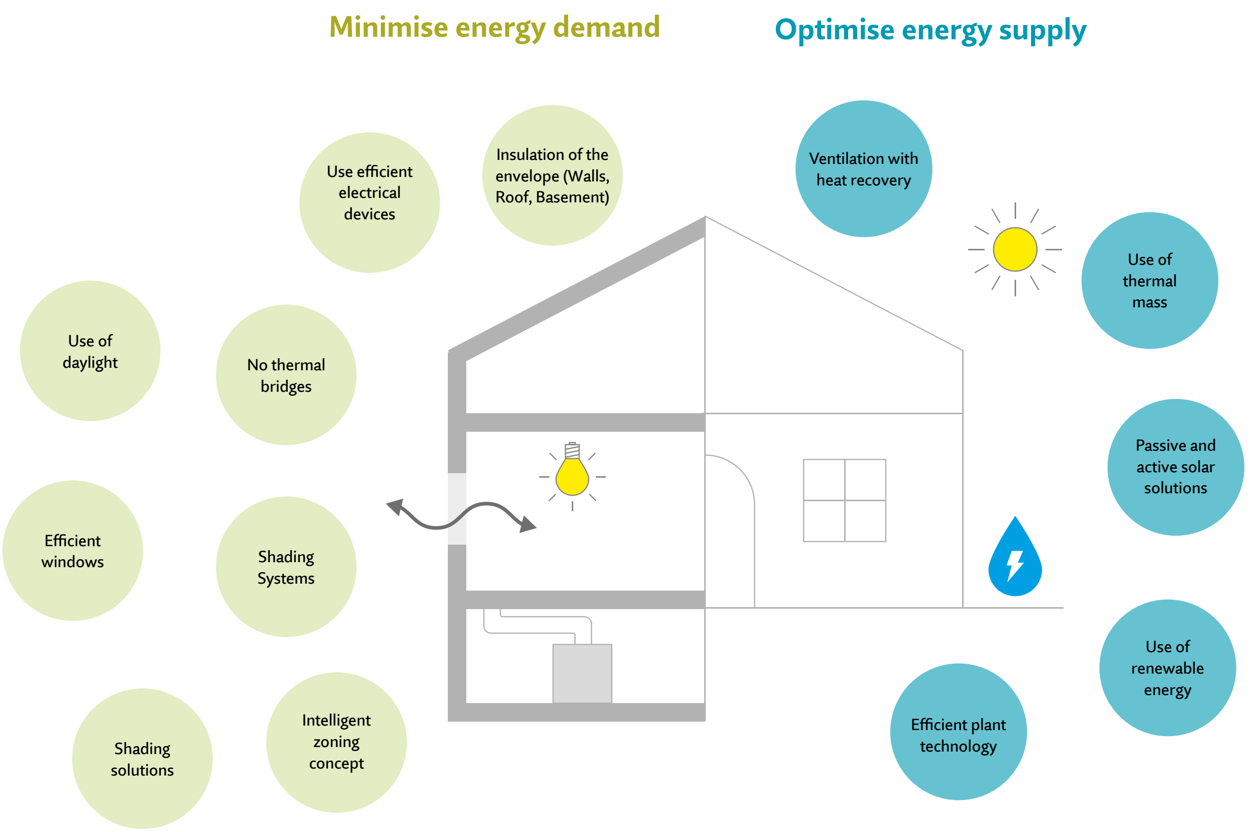
- *Does my building have a special cultural value and how can I preserve it?*
- *Do I have to observe the requirements of monument protection?*
- *Is modern living comfort possible within the old walls?*
- *Are new renovation solutions suitable for the old building fabric?*
- *Whom do I best ask for advice?*

However, historic buildings do not only include the large universally recognised monuments, such as churches, castles and monasteries. It is the many traditional residential and agricultural buildings that characterise the Alpine landscapes and towns. They are intrinsically linked to their environment, built using local building materials and local craftsmanship. And yet each one of them is quite individually designed. Many of them are not protected, and yet it is just as important to preserve them.

WHAT DOES ENERGY-EFFICIENT ACTUALLY MEAN?

Energy-efficient renovation can reduce the energy consumption and operating costs of a building. At the same time, however, it can also improve living comfort and thus increase the market value of a property. Energy efficiency measures therefore contribute to the preservation of the building structure by ensuring its usability in the future. Through energy-efficient refurbishment, you therefore make a major contribution to the preservation of building culture as well as to environmental protection. However, it is important to consider the special legal, physical and design conditions in old buildings - this is the only way to plan sustainable renovations.

EXAMPLE: The renovation of a historic wall can be beneficial for several reasons. In addition to the preservation of the historic wall and thus also of the building, with the renovation also the energetic property can be improved, what increases the living comfort at the same time because of a higher surface temperature. With this discomfort inside the rooms is prevented, because annoying draughts are avoided and the perceived room temperature increases.



Integrated Design

Energy renovations must always be planned holistically. This means that the entire building is considered from the very beginning. Individual measures, such as the replacement of windows, are always examined in interaction with all other components. The associated additional planning effort and the higher investment costs at the beginning of a project are often a barrier for many people. A thorough planning phase usually saves more money than it costs during the later implementation. Details and structural component joints are clarified in advance. Expensive construction delays, unattractive "tinkering solutions" and structural damage are avoided. Renovation steps that are staggered over several years can be coordinated through detailed planning in such a way that the investment costs become more reasonable, but the measures do not interfere with each other. Even with limited financial resources, it is worthwhile to invest in planning in order to obtain cost certainty and to take the most effective steps first.

EXAMPLE: The retrofit of historic windows must be part of an overall concept. If the window is regarded as a singular building element without considering the connection to the wall and the threat of thermal bridging there, condensation and mould formation can easily occur in the reveal. In addition, the expected humidity in the room, which can be ensured by manual or mechanical ventilation, is a crucial factor. Some solutions for insulating the reveal that would work in dry rooms will cause damage in more humid rooms.

For holistic design, the principle should always be followed of first saving as much energy as is reasonable and possible and covering the remaining demand with renewable sources.

Is energy-efficient renovation worthwhile?

It is difficult to determine the right moment for an energy retrofit. However, if maintenance measures are to be carried out anyway (e.g. new roofing) or a change of use is planned (e.g. conversion of the utility part into living space), then the opportunity for a sustainable refurbishment should be taken. All measures should also be examined with regard to their follow-up costs. The sooner I have to replace a solution, the more costs arise. In most cases, repair proves to be more cost-effective than complete replacement. When implementing renovation measures, importance should therefore be given to their reparability and maintainability in order to save high follow-up costs for a complete renewal, but also to preserve material resources.

The path from idea to concept

A renovation should be well prepared in any case. Before planning starts, the conditions of the building, one's own ideas and the general framework must be clarified. The time and effort invested in the preparation phase and conceptualisation will avoid later changes to the plan and unforeseeable costs.

1. Project idea: inspiration through examples

At the beginning of every renovation project are the initiatives and ideas of the building owner, usually prompted by the desire for change.
Inspiration from examples that have already been implemented can provide a wide range of ideas. The HiBERatlas, in which many examples from the Alpine area are documented, can help here.

2. Partner: energy renovation is teamwork!

The preparation, planning and implementation of an energy-efficient refurbishment involves a wide range of aspects, from special technical challenges and complicated permission procedures to the application for subsidies.

The building owner can reduce the workload considerably by commissioning an architect. Only in cooperation with an experienced designer can a holistic design concept be implemented. In the course of planning, other experts are involved, depending on the objectives and the existing building. If the building is a protected building, contact should be made with the relevant heritage protection authorities at an early stage.

> The municipalities often offer advisory services for building owners who are planning to renovate.

3. Framework Conditions: Possibilities and limits

From the beginning of the planning process, the client and the architect should agree on the existing framework conditions:

- *Which regulations must be observed for the planned renovation? (The balance of Building regulations, energy saving regulations/ monument protection/ landscape protection).*
- *What is the available budget?*
- *What subsidies may be available?*
- *Which renewable energy sources are suitable and available?*

4. Analysis: getting to know the building

The basis of any planning on historic or traditional buildings is the survey and documentation of the existing situation. The following information should be collected:

- *General building information*
- *Documentation of the building's structure and components (survey, construction details)*
- *Building history and cultural-historical significance*
- *Condition of the building, damage, and environmental impacts*
- *Conservation possibilities and limitations*
- *Assessment of building use, functionality*
- *Assessment of energy performance and existing indoor climate*

f the building is a protected building, the heritage authorities can help with the historic specification and heritage value assessment. If it is not a protected building, a comparison with other buildings of the same typology can be informative.
Experienced experts should be consulted to assess the condition of the building, especially when it comes to the analysis of damages. Incorrect assessments lead to incorrect repair and implemented measures being short-lived.

EXAMPLE: If a wall is to be insulated despite the presence of moisture, this will always lead to destruction and mould. However, in order to dry out the masonry, one must know exactly where the moisture is coming from, so a horizontal barrier will prevent rising damp from the ground, but not the condensation of air moisture in the interior. Incorrect masonry drying measures can cause high costs without having a positive effect.

5. Concept: Define your own targets

Based on the knowledge of the initial situation and one's own wishes, the objectives for the renovation can be defined, as well as suitable measures that can be considered for achieving these objectives. This concept forms the basis for an architectural renovation design. The concept should answer the following questions:

- *What should be preserved of the structure and substance? Appropriate repair and conservation measures*
- *What energy level and comfort level do I want to achieve? Suitable solutions for energy upgrading and systems technology*
- *Which building-ecological aspects are important to me? Suitable local and natural building materials*
- *Which functional requirements should be met? Suitable architectural design measures*
- *How important is it for me to support the local economy? Suitable craftsmen and products*
- *What time frame do I plan for my renovation? Decision for a complete renovation or a step-by-step approach as part of an overall concept*

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WALLS

This guideline summarises the most important points to be considered when renovating a historic external wall and should provide interested owners with the basic procedure. Architects, planners and energy consultants can use this guideline to understand the fundamental technical requirements and the handling of historic buildings.

In addition to the windows and the roof, walls are a main component of the outer shell of a building. Consequently, the designs and also the requirements of an exterior wall are numerous. Depending on its use, a wall has to meet a wide variety of physical requirements. In addition to these technical necessities, the wall is also an expression of design and architecture. High quality materials, workmanship and designs can be created in a wide variety of solutions. With the increasing standards for buildings, however, many existing walls no longer adequately fulfil their physical tasks and need to be renovated. In addition to technical improvements, it is important that the design and architecture of historical walls be fundamentally preserved. The following pages explain how refurbishment can be carried out, taking these aspects into account.

1 Appraisal of the existing stock

In order to determine the existing conditions for the refurbishment of a wall, two basic points must be distinguished:

- *the technical aspects about the physical condition of a wall*
- *the aspect of heritage preservation and cultural value*

1.1 First check of the wall to be upgraded (technical observation)

To verify the performance of a wall, it is necessary to be clear about the functions of a wall. An exterior wall usually serves as a static load-bearing component for walls, ceilings and the roof. Furthermore, a wall must provide protection against wind, weather and acoustic noise.

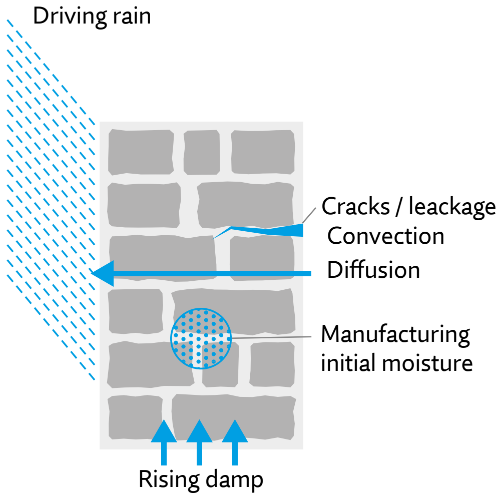
1.1.1 Structural verification

Cracks and bulges as well as areas of spalling at the wall indicate a problem with the structural condition of a building. If such signs are detected at the wall, it is advisable to consider a structural assessment of the building in order to be able to estimate the exact condition and the effort required to repair the building fabric.

1.1.2 Moisture Protection

The main problem of any building is moisture. Whether it is rain, rising damp or sources of moisture inside the building, any kind of moisture load poses a major problem for the building over time. On walls, a damp problem can usually be recognised by falling and loose plaster, discolouration or even mould. In the case of wooden walls, the damp can also cause the wood to rot, which in turn can lead to a structural problem. Basically, three types of moisture load must be evaluated in this context:

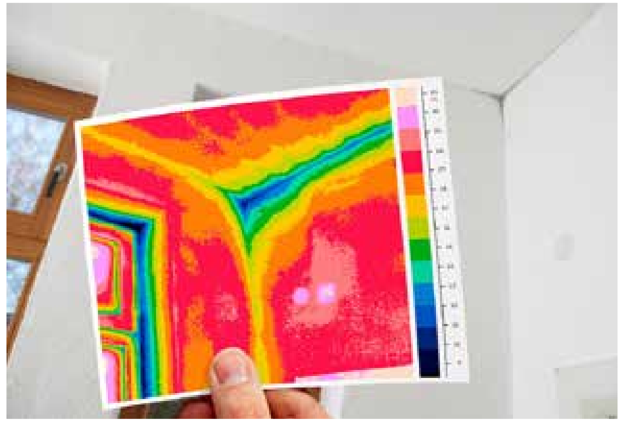
- *Moisture load from the environment which can penetrate the wall via rain if there is insufficient protection against driving rain. In this context, the condition of the façade must be checked. Are the façade cladding and/or plaster intact? Are there constructive driving rain protection through balconies and/or canopies? Rising damp from the ground (groundwater / slope water etc.) which is drawn into the wall by capillary suction can also lead to damp spots in the lower area of a wall.*
- *Moisture load due to moisture transport from the inside to the outside: In addition to the obvious moisture loads from the environment, moisture transport mechanisms (water vapour convection, water vapour diffusion) occur due to different temperatures and relative humidities between the interior and exterior.*
- *Manufacturing and initial moisture (e.g. due to additional plaster etc.)*



Moisture load:
- from the outside (rain, rising damp)
- from inside (moisture transport - diffusion, convection)
- Manufacturing and initial moisture

1.1.3 Thermal Protection

In most historic buildings, there is insufficient thermal protection, namely the absence of modern insulation materials. Due to the high heat losses through the exterior walls, the interior wall surface (of the exterior wall) is significantly colder than the wall surface of the walls that exist only on the interior (such as partitions). Due to this temperature difference of the surfaces, the living room climate can be perceived as uncomfortable. If, in addition, there are high humidity loads in the interior (high relative humidity), the moisture condenses on the wall or reaches a very high relative humidity and can lead to mould growth. The U-value of a wall can be determined by surveying wall constructions. Possible thermal bridges can be determined with the help of a thermal imaging camera.



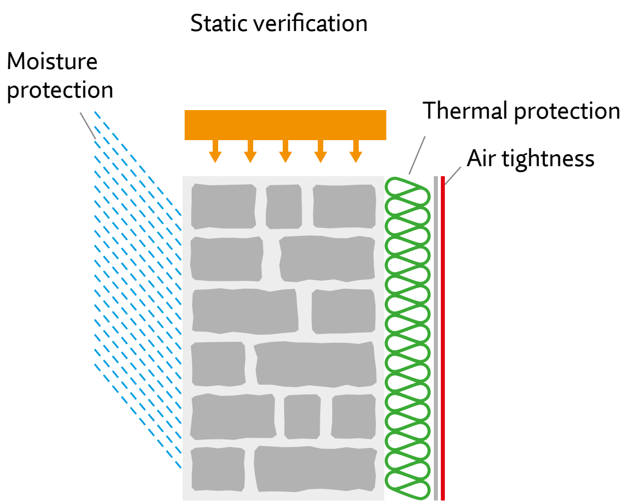
The argument that there has been no mould growth in recent decades must be regarded critical, since the existing situation can change depending on the use (number of people, air tightness, etc.).

1.1.4 Airtightness of the building

Particularly in historical buildings, hardly any importance was attached to an airtight outer shell during construction. Depending on the type of wall, the airtightness varies greatly. Log walls are relatively air-permeable due to the numerous cracks and connections with the interior walls. Plastered masonry (natural stone, brick, etc.) is quite airtight due to the continuous plaster finish, but most penetrations such as windows or timber frame ceilings have major leakages. Increased airtightness is necessary for the preservation of a wall construction because it prevents warm moist air from penetrating into the interior of the construction assembly, condensing there and leading to moisture damage. Some are concerned that an airtight layer does not allow the wall to breathe, but this statement is a myth as no wall should be designed to breathe in an uncontrolled manner. An exchange of air between the interior and exterior air is necessary to ensure the removal of moisture loads and harmful substances, but this should take place in a controlled manner through mechanical ventilation or at least through sufficient ventilation behaviour on the part of the users. Uncontrolled ventilation due to air leakage can lead to damage in the construction and is associated with enormous energy loss. The airtightness of a building can be tested by means of a so-called "airtightness test".

The following table summarises the different factors for the technical assessment of a wall:

		Examination by
Structural verification	Cracks, bulges, spalling, rotten components in wooden walls	structural engineer
Moisture Protection	Damaged façade, e.g. cracks in the plaster / falling plaster or broken façade cladding, mould and/or discolouration on the wall, fungal growth or rotting on wooden walls.	Building physicist, architect > Moisture measurement
Thermal Protection	High energy demand, cold wall surfaces, mould	Building physicist, architect > Infrared thermography
Air tightness	Draughts, cracks	Air tightness testing by air tightness test / infrared thermography



The existing condition of a wall contributes significantly to the financial outcome of a renovation. The restoration of a ruin, where practically all the points mentioned need to be improved, is accordingly associated with a far greater financial outlay.

1.2 Determine the historical values of the walls

In addition to the technical appraisal, the historical and cultural values of the building must be identified and assessed. In the case of a listed building, this has already been recorded by the heritage office and evaluated with their expertise. If the building is not listed, the stakeholders involved have to determine the history of the building and study old plans, photos and descriptions of the building. Based on this knowledge, the historically relevant elements

The craftsmanship and workmanship are an essential part of the historic value of the building.

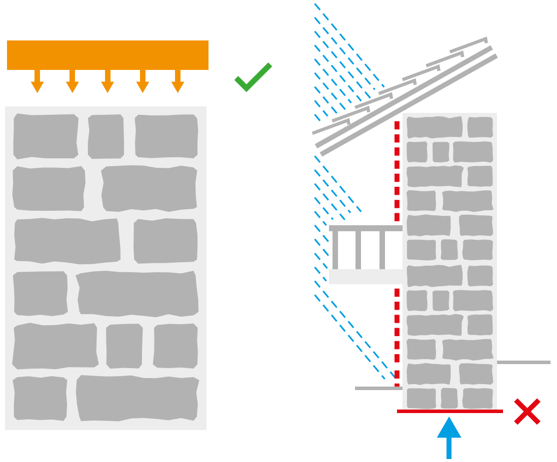
can be determined. In the case of exterior walls, this can range from historic plaster, stucco and paintings to the type and craftsmanship of the masonry.

The main focus of any renovation should be on the preservation of the building itself. Thermal improvements and the associated increase in living comfort as well as new design elements of a building's architecture must always take second place. If the basic structures are damaged by choosing the wrong insulation system or a design is chosen that irrevocably destroys the historic building fabric, the historic value is destroyed forever.

2 The redevelopment process

2.1 Minimal measures for every refurbishment of the wall

After assessing the existing condition of the building, at least two points must be fulfilled in the development of the renovation strategy, which also represents the basis for all further measures. The wall must be structurally functional and moisture issues must be solved.
The driving rain protection may have already been solved by sufficiently large canopies and / or balconies. If no constructive protection is available, the external surface of the wall, i.e. the plaster or cladding, must be sufficiently water-repellent. This is a fundamental problem, especially when preserving historic facades, as the facade should not be altered. Appropriate plaster, paint, waterproofing the masonry or ventilated cladding can provide a remedy and are a necessary basis for additional energy improvements. It is important that the façade is water-repellent but at the same time open to diffusion. This can be compared very well with a rain jacket. It should keep out the rain but allow the moisture that accumulates during sport to pass through sufficiently.



Minimum intervention and basis for additional measures:

- Wall must be structurally functional
- Eliminate possible moisture issues

Rising damp can be controlled by inserting horizontal barrier layers. Lateral air sealing must be avoided, as this will even further promote capillary moisture transport, as lateral drying is prevented. Attention should be paid to the application of diffusion-open plasters in order to guarantee lateral drying.

Paintings, frescos, old plasters or other facades worth preserving are characteristic of the era and region. An energy efficient renovation makes sense, but a system must be chosen that protects the historic elements that are worthy of preservation.

2.2 Increase of energy efficiency

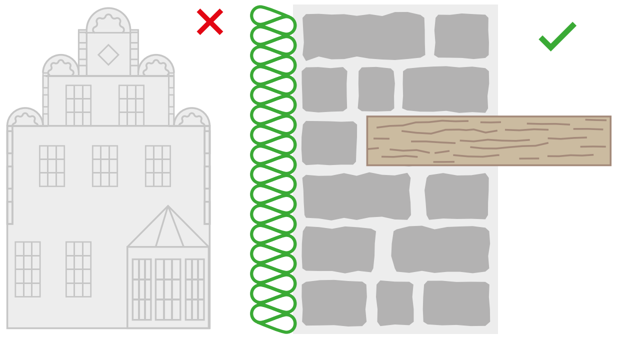
To improve the energy efficiency of a wall, additional insulation must be added. This can be attached either on the external or internal side of the wall or in any cavities that may exist. Each type of insulation has its pros and cons. From an energy and technical point of view, external insulation is always preferable to internal insulation. Unfortunately, external insulation also entails a visual change to the façade. However, there are also many applications for historical buildings where external insulation can be combined with the values of the building.

2.2.1 External Insulation

External insulation by means of aerogel plaster
In the Mariahilferstraße in Vienna, the façade was refurbished by using 5 cm of Aerogel - high performance insulation plaster. The plaster has the same effect as 15 cm of conventional insulation material.

Pros:
External insulation has the great advantage that it is not problematic from a building physics point of view and that integrating walls and ceilings can simply be insulated over, thus reducing thermal bridges. Another important advantage is the maintenance of the façade. Weak points with regard to driving rain can thus be solved.

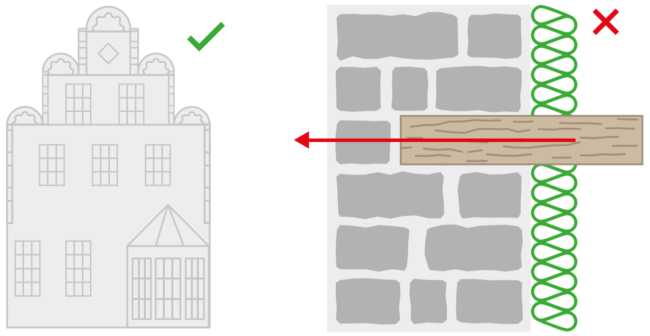
Cons:
The big disadvantage is the intervention on the appearance of the building. The additionally applied insulation layer covers the original façade. The proportions of the building are also altered and thus change the visual appearance of the building.



Thermal bridges are insulated but the appearance is changed.

2.2.2 Internal insulation

Pros:
The major advantage of internal insulation, and thus the explanation why this solution is used in so many historic buildings, is that the external appearance of the building remains more or less unchanged. Interior insulation reduces the effective heat capacity of the interior. This refers to the heat capacity of the interior surfaces that are in exchange with the air in the room. The higher this capacity, the more inertly the indoor air reacts to temperature changes. With interior insulation, a room can be heated up very quickly because the inert outer walls do not have to be heated up as well. However, the lower capacity also makes it more difficult to compensate during peaks of hot or cold temperatures.



Appearance is unchanged but the problem of thermal bridges remains.

Cons:
The disadvantages of internal insulation are the increased risk of damage and the space required.
As a result of the internal insulation, the existing wall is cooled down. Depending on the insulation thickness, the wall is thus "heated" from the inside to a much smaller extent and moisture due to driving rain and rising damp

can dry out at a slower rate. For this reason, these moisture entries must be prevented and solved without fail, especially in the case of thermal refurbishment! Another disadvantage is the transport of moisture from the inside to the outside. If the warm moist air meets the cold existing wall, condensation or very high relative humidity can occur, which can lead to the growth of mould. Therefore, precise planning and an analysis of the existing wall are necessary for the implementation of internal insulation, which must be checked for suitability in consultation with the architect and building physicist.

Building physics of internal insulation

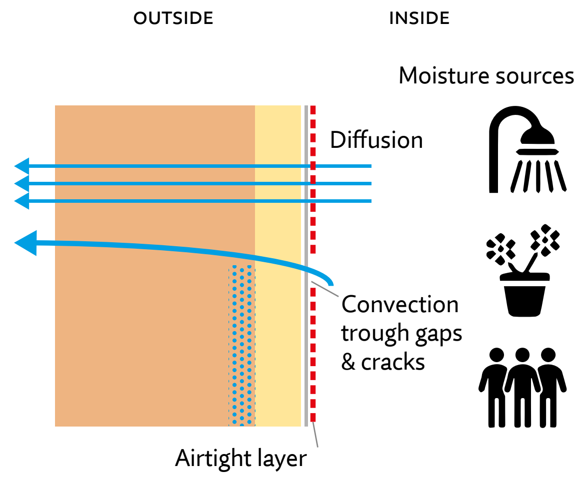
In order to understand the difficulties of internal insulation as well as the advantages and disadvantages of the different internal insulation systems, some basic principles of building physics must be explained in this context.

As already mentioned in the chapter "Moisture protection", moisture can enter the wall not only from the outside (driving rain and rising damp), but also from the inside. In winter, it is significantly warmer and moister inside the building than outside. The occupants of a building as well as plants and animals constantly release moisture into the indoor air. Activities such as cooking, showering and washing are also sources of moisture. Since this difference in humidity between inside and outside seeks to balance itself out, moisture transport takes place through the wall. This moisture transport can take place through diffusion and convection. With water vapour diffusion, the water vapour diffuses through the material. Depending on the diffusion resistance number (μ) of a material, this transport can vary in magnitude. Multiplying this resistance number by the thickness of the material gives the Sd - value (equivalent air layer thickness Sd = μ · thickness [m]). The larger the Sd - value, the greater the diffusion resistance and the slower the transport through the material will be.

The second decisive moisture transport mechanism is water vapour convection. This moisture transport takes place due to an air flow. If there is no sufficient airtight layer (plaster, foils, etc.) on the inside of the exterior wall, the moist warm air can penetrate the construction due to pressure differences (wind, buoyancy forces, etc.). **Convection has a much higher transport potential than pure diffusion, about 100 times greater.** For this reason, it is particularly important to ensure sufficient air tightness to prevent convection.

Measures for a functional internal insulation

- Airtight level is required (avoidance of water vapour convection!)
- Minimise sources of moisture, such as rising damp and driving rain.
- Remove sources of moisture through regular ventilation or, ideally, through controlled mechanical ventilation with heat recovery.



The main issue with internal insulation is the reduction of the temperature of the existing wall. Since the insulation (R2) has a very high thermal resistance compared to the existing wall (R1), the temperature (Tx) at the surface between the new internal insulation and the existing wall is much lower than with the originally uninsulated wall.

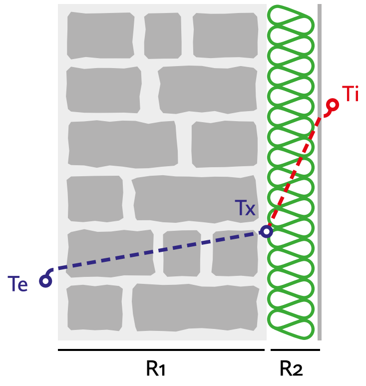
The higher the thermal resistance of the existing wall (R1) (e.g. wood has a better insulating effect and therefore a higher thermal resistance than stone masonry), the higher

Diffusion resistance:

- The greater the diffusion resistance on the inside, the less moisture is transported into the construction.
- The diffusion resistance depends on a material value, the diffusion resistance number (μ) and on the thickness of the layer.
- The higher the diffusion resistance number and the thicker the layer, the greater the resistance.
- If the diffusion resistance of the existing exterior wall is too high compared to the moisture entering from the inside, condensation will form on the cold surface of the existing wall. The same effect can be observed in winter when entering a heated room from outside and eyeglasses fog up.
- Therefore, the following is valid:
  A CONSTRUCTION MUST ALWAYS GET MORE OPEN TO DIFFUSION TOWARDS THE OUTSIDE!

and therefore less problematic the temperature between the existing wall and the insulation. The thicker the internal insulation, the higher the thermal resistance of the internal insulation (R2) and the lower the temperature on the internal surface of the existing external wall. The temperature thus adjusts itself exactly according to the ratio of the resistances in the building component.

However, the temperature alone is not yet a problem. It becomes critical as soon as moisture comes into the game. With diffusion-open external insulation, the diffused moisture can be immediately transported away to the outdoor air. With internal insulation, however, the moisture can accumulate due to the diffusion resistance of the existing wall and lead to condensation and the associated formation of mould on the cold surface between the insulation and the existing wall. Here, too, transport occurs according to the resistance of the respective materials. Therefore, a construction should always be more open to diffusion towards the outside, i.e. the diffusion resistance should become smaller towards the inside. How high the damage potential is depends significantly on the climate. In warmer climates, the existing wall does not cool down as much and internal insulation is less problematic than in a very cold climate.



Temperature distribution with internal insulation:

- the temperature between the insulation and the existing wall depends on the respective thermal resistances of the different layers.
- the bigger R2, the lower the temperature (Tx).
- the bigger R1, the higher the temperature (Tx)

Thermal resistance:

- the thermal resistance depends on a material value, the thermal conductivity > and on the thickness of the layer.
- The higher the thermal conductivity, the lower the thermal resistance
- The thicker the material layer, the higher the thermal resistance.

E.g. a 20 cm thick reinforced concrete wall has a much lower thermal resistance than 20 cm thick insulation.

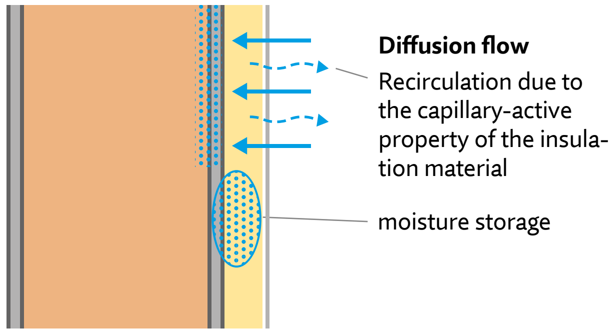
Internal insulation systems

There are basically two ways to ensure a functioning moisture management wall design:

- *tolerating diffusion through suitable insulation materials*
- *retarding the vapour diffusion flow*

Capillary-active and diffusion-open internal insulation systems

Under the condition of a solved driving rain situation and the prevention of rising damp, there are insulation materials that have the property of absorbing a certain amount of moisture, storing it temporarily and releasing the moisture back into the interior against the diffusion flow. These materials are also known as capillary-active insulation materials. It is important that these materials are applied as a complete system (e.g. capillary-active insulation board with suitable adhesive). Another important aspect of this system is that unhindered drying to the interior can take place. For this reason, the room-side finish must be designed to be as open to diffusion as possible.



The best-known capillary-active insulation material is calcium silicate and mineral foam. Meanwhile, there are also PUR foam boards with small calcium silicate tunnels that ensure the return of moisture to the interior. When laying the board, care must be taken to ensure that it is installed without cavities. Cellulose and numerous insulating plasters such as lime plasters also have capillary-active properties, although the insulating effect of the plasters is much lower. Softwood fibreboards are also often advertised as capillary-active insulating materials, but the effect is not nearly as high as with the previously mentioned insulating materials. In diffusion-open systems, materials with very good moisture storage properties must be distinguished from materials with capillary-active properties. However, there are also materials that combine both properties.

Capillary active insulation materials

With these materials, the moisture is transported in the direction against the diffusion flow. Care must be taken to ensure correct installation. Panel material must be applied to the wall without voids and with an adhesive that is adapted to the overall system. Also wet applied cellulose has capillary-active properties. However, the moisture introduced by the application must be taken into account. It is important to ensure that the interior wall surface is open to diffusion!

Diffusion-retardant internal insulation systems

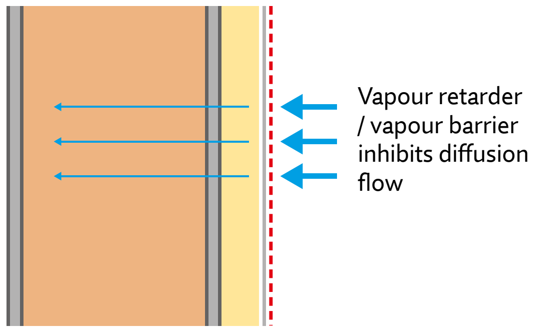
Diffusion-retardant internal insulation systems slow down the diffusion flow from the inside by means of so-called vapour retarders or vapour barriers. These diffusion-retardant layers have a very high diffusion resistance despite their low thickness. Due to the lower diffusion flow, less moisture gets into the construction and structural damage can be avoided.

Vapour retarders are available in various designs (polyethylene foils, PVC foils, aluminium foils or wooden boards). To estimate the effect of a vapour barrier, the Sd - value must be considered. The higher this value, the greater the diffusion resistance created. Moderate vapour retarders can be made of OSB boards, for example, a 15 mm thick OSB board achieves an Sd - value of 3.0-4.5 m. If higher diffusion resistances are required, there are countless manufacturers of vapour retarders. Usually, foils are used as vapour retarders which also achieve much higher Sd - values, up to aluminium foils which are considered vapour-tight and achieve a Sd - value of more than 1500 m.

Unfortunately, the diffusion resistance does not only work from the inside to the outside but also in the opposite direction. In the summer, the diffusion flow is reversed and drying out towards the interior is possible in principle. However, if a vapour retarder or even a vapour barrier is installed, this drying is impeded or prevented. This can be remedied by moisture-adaptive vapour retarders which adapt their properties depending on the environment.

Moisture balance

The choice of the right vapour retarder is decisive for the function of the construction and must guarantee a balanced moisture management. The retarding effect in winter must be adapted to the drying potential in summer. Location-specific conditions (rising damp, driving rain load, damp masonry and climate) must also be considered in the moisture balance.



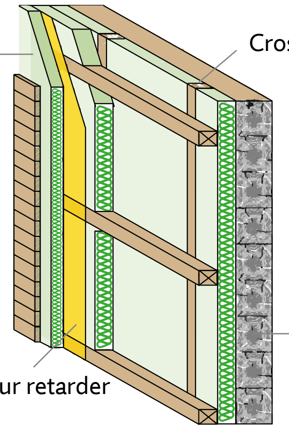
Vapour retarder on the inside of the insulation also serves as an airtight layer. However, the function is different.

Thus, the Sd - value is higher in winter and slows down the penetration of moisture. In summer, the Sd - value decreases and allows the construction to dry out.

The installation of vapour retarders and barriers requires profound expertise. A consistent installation and accurate connections to penetrations are a prerequisite for the successful functioning of the internal insulation system. The vapour retarder usually also fulfils the role of an airtight layer, but the function of a vapour retarder and airtight layer must be strictly separated. For example, a butt-glued OSB board can be considered airtight, but the diffusion resistance is limited and in some cases not sufficient. Leakage, in turn, can cause convective moisture entry, which quickly pushes the system to its limits. Therefore, gapless airtight installation is essential.

Vapour retarder made of foil

Continuous bonding of the joints is the basis for a functioning vapour retarder. In this case, a vapour retarder was applied as a foil to a wall using sheep's wool insulation. The foil has a double effect, vapour retarder and airtight layer. However, the functions must be evaluated separately although, in many cases, they can be realised in one layer.



Especially with old walls or log walls, it is advantageous to install flexible insulation to compensate for the unevenness of the wall. The insulation can be clamped between studs fixed to the wall (e.g. mineral wool, wood wool, etc.) or blown in (e.g. cellulose). However, a vapour barrier made of foil cannot resist the pressure of a blow-in insulation, which is why OSB boards are very suitable as a top layer. If the diffusion resistance of the OSB board is too low, another board material can be used as a support layer and an additional foil can be applied.
On the vapour retarder layer, it is recommended to install a so-called installation layer of approx. 4-5 cm, which can be covered on the room side with the preferred design. Building services or electrical connections can thus be installed in this installation layer and save penetration of the vapour retarder and airtight layer.
In order not to weaken the insulation layer unnecessarily, a two-layer crosswise substructure is used for thicker insulation or alternatively T-beams which have lower thermal bridging capacity.

Moderate vapour retarder made of OSB boards
Errors that impact OSB vapour retarder performance can occur in the installation details. The connections in particular must be installed precisely. The connection to ceilings and floors must be carefully considered and professionally installed. The joints of the OSB board must be glued as well to ensure an airtight level. The airtightness of the assembly is checked by means of an "air tightness test".

3 Retrofit measures for historic walls

3.1 Find the right solution

Retrofit strategies can entail different levels of intervention, based on the impact that the measure is allowed to have on the building, its occupants and the wider environment. After a thorough understanding of the context and the heritage significance, it is necessary to decide the allowed level of intervention for the specific wall in its context. A holistic assessment of the retrofit measures, which includes their impact on heritage, on the integrity (technical compatibility) of the building fabric, on the health and comfort of occupants, and on the environment helps in the decision making process. As already mentioned several times, most historic building are unique. The assessment therefore can be very complex. However, there are various systems and solutions that focus on different aspects of the assessment.

3.2 Measures prioritising environmental impact

These include systems and solutions with high energy efficiency. This is usually associated with large insulation thicknesses. The technical function must be checked by a building physicist, especially in the case of internal insulation for the respective location and use. Depending on the possibility in connection with the historical values of the building, solutions with large insulation thicknesses can be successfully achieved, as the example of Villa "Castelli" proves.

Villa Castelli – 20 cm internal insulation with perlite boards
The Villa Castelli is a listed building (as part of the lake "vincolo paesaggistico", as well as the building itself "vincolo architettonico") from the 19th century located at Lake Como. Modifying the external façade of the building was not possible, it was necessary to work together with energy-related and structural issues in order to find solutions that meet all requirements. The client required a high level of energy efficiency for the refurbishment and this could only be reached with internal insulation. In order to maximize the thickness of insulation and avoid hygrothermal risks, detailed dynamic simulations were carried out.

3.3 Measures prioritising Heritage

If the possibilities are limited due to the protection of historic elements, there are still solutions to increase the energy efficiency of the buildings. Thinner insulation layers and the use of cavities often minimally change the proportions and appearance.

Insulating plaster / thin internal insulation
The irregularities and appearance of the historic wall are minimally changed. However, various insulating plasters offer the possibility to improve the energy efficiency of the wall at least to some extent.

Blow-in insulation in cavities
If there are cavities in the wall, they can be used to fill them with insulation material. These cavities can occur in a wide variety of forms. If, for example, the insertion of insulation behind an old exterior wooden façade is relatively unproblematic, the insertion of insulation in interior cladding (e.g. in an old farmhouse parlour) may be much more tricky from a building physics point of view and should be checked.

Checklist – refurbishment of historical walls

Existing stock:

- Determine the condition of the existing wall
- static verification (cracks, bulges, spalling, rotten components in wooden walls)
- moisture protection (state of the plaster, balconies, rising damp etc.)
- thermal behaviour (material, insulation)
- air tightness (intact internal plaster)

Checkpoint 1 – stock analysis:
An accurate examination of the existing situation is the basis for any planning and a necessity for estimating the expected costs of the intervention!

Heritage aspects::

- What is the protection level of the building?
- Is there already some information about the building and/or typology available?
- What heritage values are associated with the walls?
- Is the material traditional (plaster, masonry etc.)?
- Special craftsmanship / workmanship (construction, surface)?
- Typical building of the time and/or territory?

Checkpoint 2 – heritage analysis:
Study the building and its history (photos, paintings, reports etc.) and identify the elements worth preserving.

Goal – define the targets you would like to achieve:

- Quality of indoor environmental comfort
- Future use of the building?
- Design requirements
- Financial aspects

Checkpoint 3 – the targets:
The targets for the final result must be clearly defined. This saves time, money and misunderstandings.

Planning – get your team:

- Legal aspects > What am I allowed to do? (Monument protection, building law clarifications)
- Heritage office / Historian
- Architectural concept
- Energy efficiency concept
- Building physicists / Envelope consultant
- Special Knowledge of craftsman

Checkpoint 4 – integral planning:
All stakeholders must work together. The overall concepts must be in considered from the beginning. Find out about examples that have already been realised, get information from practical experience. Find suitable companies and craftsmen who know how to deal with historic buildings.

The choice of right measures and their implementation:

- Repair the wall (structure)
- Solve possible moisture issues
  - Driving rain protection (on the surface, constructive protection)
  - Rising damp
  - Internal sources (ventilation)

Checkpoint 5 – minimal measures (static, moisture):
First and foremost, the building must be preserved. Therefore, the wall must be structurally functional and moisture protection must be ensured. If it is possible to refurbish the exterior plaster, it should be made as driving rain-proof as possible, but also open to diffusion (paint, etc.). Balconies and canopies provide additional structural protection.

Energy efficiency:

- FIRST: solve moisture issues
- SECOND: Choose the right measures considering the technical function and the preservation of the historic values of the wall (external insulation, internal insulation, impact on the heritage).
- Choose the right system for an internal insulation that fits for the project climate and type of wall

Checkpoint 6 - Internal insulation:

- Airtight layer is required (avoidance of water vapour convection!)
- Minimise sources of moisture, such as rising damp and driving rain.
- A wall cannot breathe. No matter what material is used, infiltration through the assembly must be removed! For that reason, remove sources of moisture through regular ventilation or, ideally, through controlled mechanical ventilation with heat recovery.
- Internal insulation requires expertise (building physicist).

The implementation::

- search for experienced companies and craftsmen
- obtain construction quotes for cost clarity
- check for a proper workmanship, especially for sensitive details

Checkpoint 7 - Execution control:
Careful control of the construction is necessary to achieve the planned goals and to ensure a sufficient quality of the execution. For this reason, it is even more important to work with companies that already have experience and good references. The cheapest offer in this context is usually not the best and can lead to hidden costs or undesirable outcomes during the construction.

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