Deliverable D.T2.4. [1]

Introduction

The tension between energy efficiency and cultural meanings (often referred to as heritage values in the heritage literature) assigned by residents of historic dwellings has been widely recognised both in academia and policy. However, what drives this tension and how this tension manifests itself over time is less well understood. To address this tension and enable the preservation of original features, national heritage organizations (such as Historic England) and European endeavours (such as the European Standard EN 16883:2015 Guidelines for Improving the Energy Performance of Historic Buildings) have provided guidance for balancing energy efficiency interventions and heritage preservation. However, such guidance is not necessarily reaching those who ultimately inhabit and manage historic dwellings and are not taking into account future change of values and technological developments.
This deliverables aims to afford that gap and offer basic info and data as well as suggestions, in order to improve the awareness of buildings owners and HBAs managers and enhance the balance between historic value and sustainable performances of the heritage buildings.

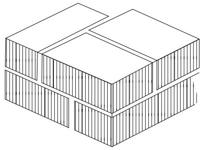
According to the previous results on the Bhenefit project, we would underline that traditionally, historical architecture is the complex and stratified product of a building culture, necessarily careful to environmental conditions and characters, to natural materials, to building morphologies that dialogue and safeguard with the territory (water regulation and storage, oversight of the slopes, soil erosion protection, governance of forest resources and agricultural etc..)
Nevertheless, the relation between Sustainability and Heritage is often reduced to the mere Energy Efficiency of the buildings, simplifying a complex problem into the exclusive item of energy saving. Consequently, technical innovation remains still largely a process of the application of products and technologies. This often leads to a greater emphasis on the technical components that do not correspond to effective cultural advancement. Neither do they improve the capacity to assimilate and modify the technology to achieve higher long-term objectives. A new and different approach can then be investigated and practiced in the relationship between Heritage and Sustainability, to help overturning objectives and cultural references almost exclusively of technical nature, returning to consider the technique a mean and not the end of our actions.

Within this framework, the assessment of environmental sustainability of historical buildings, in an early stage of the energy improvement design, may help to recognize potential ways of enhancement As in the sustainability protocols, in general, the energy aspects weights account for about 30%, the score improvement of the energy sustainability may not be particularly relevant. However, since the energy improvement interventions can also affect issues related to other sections of the assessment method, there can be positive impacts on a larger part of the criteria, according to the indications and constraints of the Cultural Heritage official body that guarantee the protection of the historical features.
Moreover, the growing interest given to the energy efficiency could increase also the attention to renewable energy adoption in historical contexts and valuable landscape. The support of renewable energy sources is often difficult to be considered, as their impact on the ancient structures may be not allowed, even if, in some cases, also photovoltaic systems have been incorporated in old structures, effectively supporting the energy-efficiency improvement. Although the contribution of renewable energy sources can be, in the case study, very small, it could be nevertheless useful to a demonstration level, such as to show a greater sensitivity to energy conservation and renewable energy exploitation.

Sustainable conservation principles

High energy and environmental performances may lead the preservation of a building, but each action on historic and listed heritage gives attention to the matter of vulnerability, physical alteration, and decreasing of immaterial and material value. The most important principles for sustainable conservation regard:
- Compatibility: modern materials tend to be harder, less flexible, and less moisture permeable than traditional ones. For these reasons when are used in direct conjunction with historic fabric can greatly accelerate decay in the original work;
- Aesthetic integration: history and authenticity of historic building should be respected as essential to its significance;
- Reversibility: the unavoidable changes of the building should wherever possible be made to be fully reversible. Adopting this principle, the valuable historic fabric can be returned to its original state without damaging the building;
- Emphasis on effective maintenance: care, planned conservation, and management should include regular inspections so that defects can be discovered whilst still small and easily fixable. This permits to preserve historic fabric, minimize cost and disruption to the building's owners and users.

The retention of older buildings or the re-using of components in-situ and allowing for their energy upgrading in benign and sympathetic ways, can provide excellent finished results which are fully in accordance with the principles of building conservation and sustainability.
Energy efficiency and environmental sustainable programs should be developed on the basis of a thorough knowledge of the property, blending technological and landscape requirements. This means understanding original construction, alterations, actual conditions, qualities, material and immaterial values, lacks, and retrofitting opportunities. The suggested process is structured in the following phases:
- *Historical analysis of city, urban site and heritage building;*
- *Analysis of functions, performance and needs of users;*
- *Building energy audit;*
- *Evaluation of environmental performance;*
- *Individualization of energy and environmental lacks;*
- *Definition of possible retrofitting actions;*
- *Evaluation of the compatibility, the integration and the reversibility of each action.*



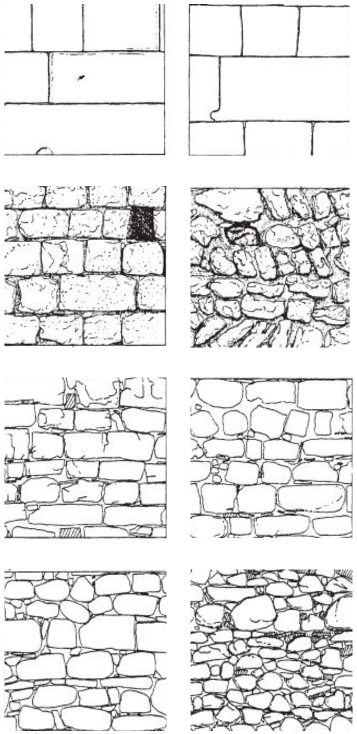
1.Construction's materials
1.1 Brick

Energy performance

The brick is a material with excellent thermal insulation performance. In the case of load-bearing brickwork with a high thickness (40-50 cm), the thermal insulation layer may not be necessary, since the high thickness of the brick acts as a thermal mass. Insulation is necessary if the brick walls are thin.
Solid bricks are the first brick elements used for load-bearing structures. They have a parallelepiped shape and a size of 5.5x12x25, with a minimum percentage of holes (less than 15%).
The value of the thermal conductivity is affected by the reciprocal influence of the physical characteristics (density, imbibition, impermeability, uniformity), varying as a function of:

- specific gravity, the value of the thermal conductivity decreases proportionally to it;
- porosity and alveolation, the value of thermal conductivity decreases as they increase;
- composition of the mixture, the value of thermal conductivity is low in those rich in limestone;
- forming, the value of thermal conductivity decreases where the internal texture of the product has greater porosity;
- moisture content, the value of thermal conductivity decreases proportionally to it.

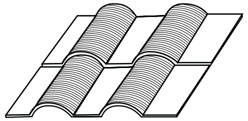
Brick arrangement typologies



Barbara Frascari
Engineer

Which aspects should be taken into account when dealing with this type of material?

The opaque vertical closures, generally composed of massive walls in stone or brick, combine in a single component the structural function and the barrier between the inside and outside of the building. The requirements they must satisfy are the containment of dispersions in winter and the dissipation of excess heat in summer.
Brick is a material with different types of composition to which different performance characteristics of the material are linked. In general, the main characteristics to be taken into consideration if you want to intervene on opaque components in terms of energy efficiency are transmittance, thermal capacity and vapour permeability.



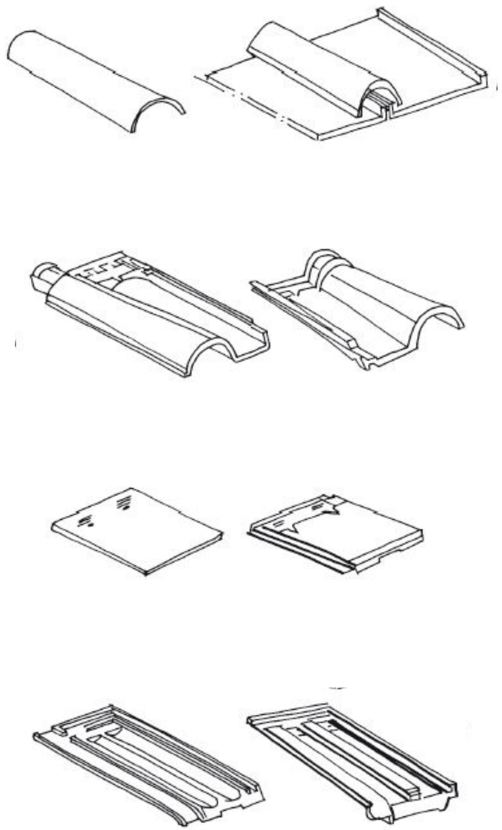
1.Construction's materials
1.2 Roof tile

Energy performance

The tile is an artifact made of resistant and at the same time light materials (the most common is the brick). The tiles are usually used as a covering for roofing (or sloping pitch).
The main purpose of roof tiles is to prevent rain from entering the building, so roof tiles must be frost-proof and water-proof. There are various types of tiles depending on their shape.
The energy efficiency of a roof is linked to the hydrometric behaviour of the cladding brick, a hygroscopic material capable of absorbing part of the water vapour contained in the air. Curved tiles are the ideal solution for buildings with high historical and architectural value. The double layer installation allows the circulation of air in the chinstrap, damping negative effects related to the wind.
Some of the main technical features are:

- Waterproofing
- Shock resistance
- Resistance to loads
- Thermal shock resistance
- Chemical stability
- Acoustic insulation
- Thermal insulation

Traditional roof tiles typologies

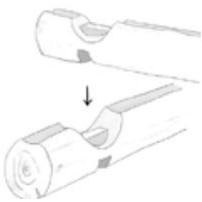


Barbara Frascari
Engineer

Which aspects should be taken into account when dealing with this type of material?

From the energy point of view, the opaque horizontal closures represent a thermohygrometric limit between inside and outside: they are used to control the methods of accumulation and release of heat flows in and out through the building.
The tiles do not have particular characteristics in terms of energy performance, their function is to prevent water infiltration that can cause deterioration of the existing waterproofing.
Often the interventions for the recovery of the roof in historical buildings concern the system of permeability to the vapour to which a ventilation of the roof is added.

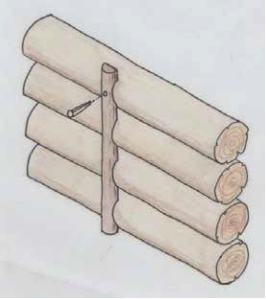
1.Construction's materials
1.3 Wood

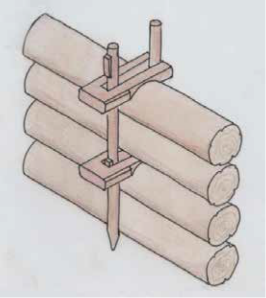


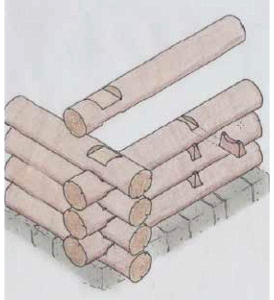
Energy performance

Wood is a porous-capillary material. Depending on the density of the wood, the percentage of pores is on average 50-60%. The wood therefore has a large internal surface area.
This system, which consists mainly of cavities, like all porous materials, absorbs water vapour from the surrounding air and can soak in water or other liquids (e.g. solutions of wood preservatives, adhesives) through capillarity. The moisture content of the wood influences practically all its physical, mechanical and technological characteristics.
Due to its high percentage of pores, wood is a poor heat conductor.
Wood material consists of woody substance, water and air and therefore its thermal conductivity is function of: λWood = f (density, humidity, structure, temperature).
For wood with a moisture content of about 20%, the thermal conductivity perpendicular to the grain assumes values λ = 0.10 ÷ 0.20 W/(mK).
It is therefore about 15 times smaller than in reinforced concrete and about 10 times smaller than in normal unreinforced concrete.

Costruction typologies



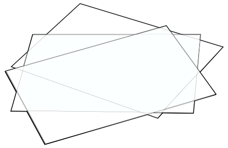




Which aspects should be taken into account when dealing with this type of material?

The lower opaque closures allow the control of the thermal exchanges with the ground.
For opaque components, it is important to underline the issue of vapour permeability of materials, as air exchange is often difficult in historic buildings.
It is important to intervene in order to ensure good permeability and not to create condensation through the addition of materials with good permeability to steam.
For insulation, it is important to use non-rigid materials, as historical buildings are more flexible and deformable.

Barbara Frascari
Engineer



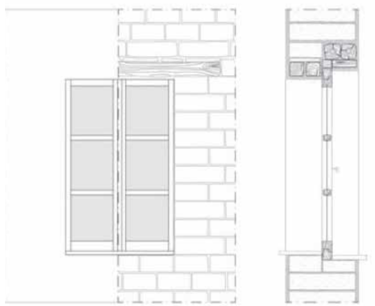
1.Construction's materials
1.4 Glass

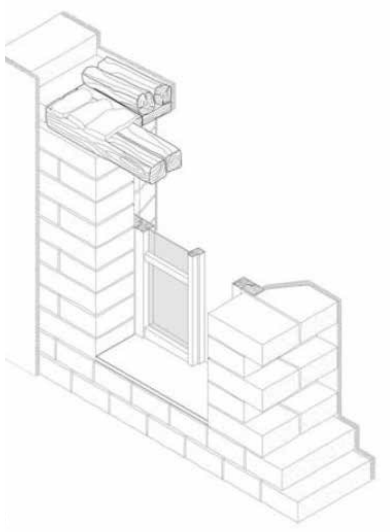
Energy performance

Traditional glass does not have good heat transmission resistance properties, as it has a very high thermal conductivity of 1.00 W/mK (ISO 10077-1:2006). It is not an insulating material. Replacing it with glazing with higher thermal resistance improves the energy performance of the casing by reducing transmission losses.
However, the thicknesses used are limited, 4-6 mm, so the resulting thermal resistance is low, 0.04-0.06 m2K/W. The resulting U-transmittance for a simple sheet with the usual values for the induction coefficients [hi=7.7 W/(m2K) , he=25 W/(m2K)] around 5.7 W/(m2K).
The main characteristics of glass are:

- transparency
- chemical and biological inertia
- very smooth surface
- compactness and structural homogeneity
- impermeability to liquids, gases, vapours and micro-organisms
- inalterability over time
- sterilizability
- perfect ecological compatibility thanks to the possibility of recycling an infinite number of times

Window with traditional glass typology

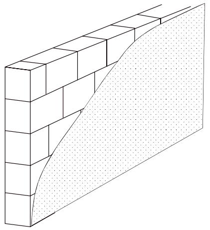




Barbara Frascari
Engineer

Which aspects should be taken into account when dealing with this type of material?

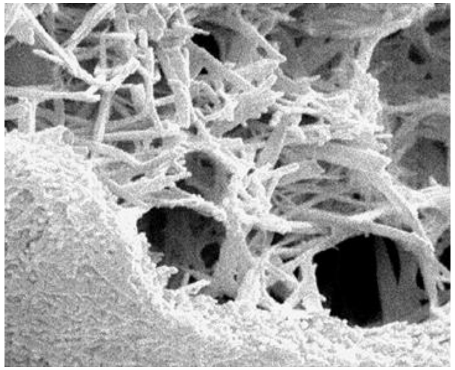
In the energy balance of a building envelope, the window and door frame represents a critical point for its construction characteristics (element of heat dispersion) and for its functional characteristics (air exchange and ventilation); in fact,the window and door frame controls the exchanges between inside and outside in terms of heat dispersion, capture of solar and light energy, acoustic comfort, etc.
The main characteristics to be evaluated for transparent components are thermal transmittance and solar factor.
Especially in historic buildings it is important to maximize natural lighting without penalizing thermal comfort.



1.Construction's materials
1.5 Plaster

Energy performance

Masonry walls are often protected externally and internally by plaster. However, the composition of external and internal plasters is different. Looking back, the most common mortars and plasters in historical buildings in all countries are made of plaster and lime. At different times, plasters have been modified with additives to improve their quality.
For this purpose, both inorganic and organic materials were used. Among the inorganic additives, the most common were natural and technical materials with a pozzolanic character, such as volcanic rocks, burnt ceramic clays with a high content of clay minerals, dust from bricks and various ashes and fly ash.
Plasters can be characterized by numerous properties, depending on the binder used, the type and structure of the aggregate, the method of application, external changes.
They can also be assessed from the point of view of their mechanical properties, resistance to degradation and its durability, optical properties and aesthetic footprint.
For example lime has hydraulic properties due to the presence of impurities in the limestone, such as silica and alumina.



Structure of calcium silicate: widely used insulation material for historic buildings.

Application of thermal insulating plasters that provide insulating properties.

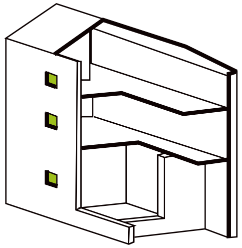
Which aspects should be taken into account when dealing with this type of material?

The preservation of cladding plasters or their reconstitution is of primary importance for the proper maintenance of the building and their restoration, especially with regard to historical buildings.
It must be respectful of the original materials and colours identified through the analysis of the structure and the layers of the plasters.
The restoration of architectural surfaces and therefore plasters must be assessed on a case-by-case basis, taking into account the historical value of the building, the time of execution, the original style and colours that once characterized it.

Barbara Frascari
Engineer

2.Construction's components

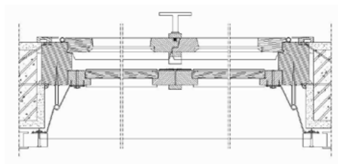
2.1 Window

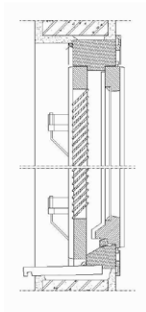


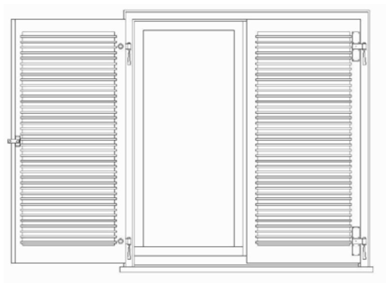
Energy performance

In the energy balance of a building envelope, the window and doorframe is certainly a critical point in the choice for its construction characteristics and for its functional characteristics.
In historical buildings, windows and doors are often made with a wooden frame and single glass, as well as having high transmittance values, they often have cracks that, allowing the passage of air, help both to promote the phenomenon of radiant asymmetry and to generate annoying air currents. They are a weak element, characterized by high heat losses in the winter season and solar accumulations in the summer. The requalification intervention must reduce losses by transmission and ventilation and, at the same time, encourage the accumulation of heat from solar radiation at certain times of the year.
It is important to consider whether the intervention on the windows and doors alters the original appearance of the building, but it is also important to manage the relations between the parts that change and those that remain, especially when working on buildings with a high thermal mass, whose energy functioning could be easily altered by the choice of components that regulate the ventilation.

Traditional window typology







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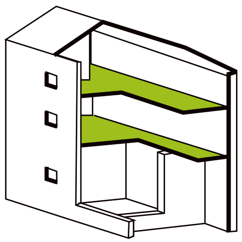
Micaela Goldoni
Architect and Engineer

When is it possible to intervene on the component to improve the energy performance of the historic building?

Being able to intervene on the doors and windows is a great advantage as it allows you to regulate and control the heat flows in and out. To reduce the building's energy consumption, it is possible to operate on the window and doorframe according to different degrees of invasiveness and reversibility, depending on the binding constraints and the need to respect the building's materials:
-replacement with high-performance energy models
-replacement of glass with insulating models
-installation of a second pane of glass on the inside
-insulation and airtightness of the frame
-application to glass of special insulating films
-use of shielding

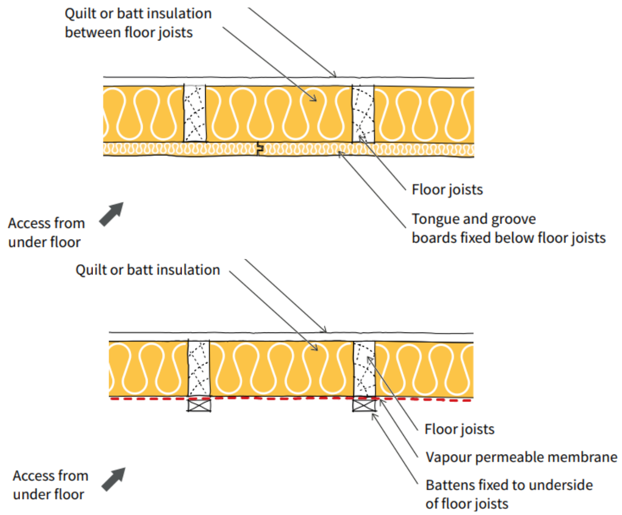


2.Construction’s components
2.2 Floor

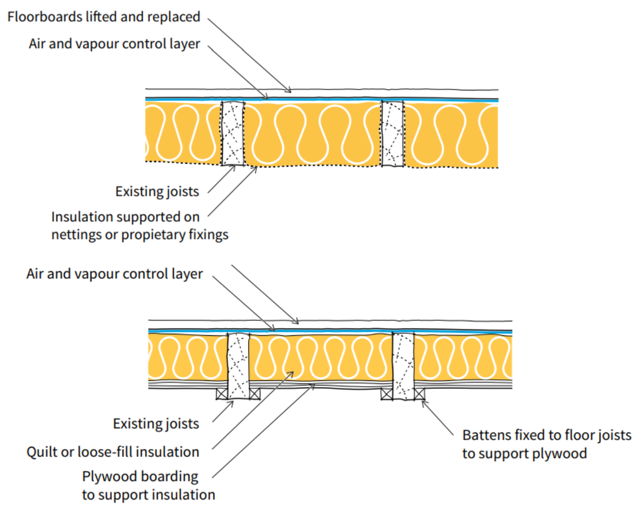
Energy performance

The floors of historic buildings allow the control of heat exchange with the ground, which is subject to less fluctuation than the outside environment. In order to optimise winter heating, it is possible to limit dispersion through the adoption of an insulating layer; in summer, excess heat can be dissipated through radiative cooling towards the ground.
In addition, the lower closures must guarantee resistance to water infiltration that can derive from the rising of moisture from the ground; it is a good idea to lay an impermeable layer under the insulating material and, if compatible with the hygrometric behaviour of the envelope, a vapour barrier towards the inside of the room to prevent surface condensation.
If the room in contact with the ground is inhabited, the insulating material must be walkable and have good mechanical resistance; in addition, it is necessary to provide a surface finish or a floor on a layer of bedding screed.

Fixing insulation from below floor



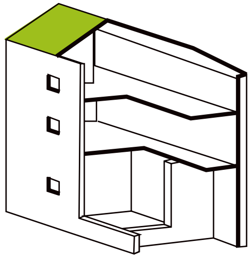
Fixing insulation from above floor



Micaela Goldoni
Architect and Engineer

When is it possible to intervene on the component to improve the energy performance of the historic building?

It is not always possible to intervene on these components due to the invasiveness of the work to be carried out to improve the energy performance of the building, which in most cases involves the remaking of the stratigraphy of the floor. Where permitted to optimise winter heating, it is possible to limit dispersion through the application of an insulating material on the extrados of the floor. In summer, excess heat can be dissipated by means of radiative cooling towards the ground. In addition, the lower closures must guarantee resistance to water infiltration: it is a good idea to lay a waterproof layer under the insulating material and, if necessary, a vapour barrier to prevent surface condensation.

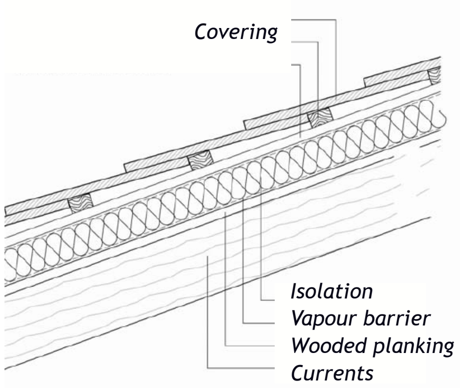


2.Construction's components
2.3 Roof

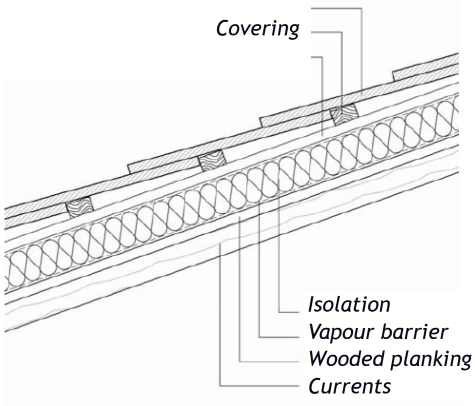
Energy performance

In historical buildings, roofs are often made with pitched roofs, usually on a wooden structure, or with flat roofs. From the point of view of energy performance, they are used to control the spatial and temporal modes of accumulation and the release of heat flows in and out through the building.
In order to obtain an optimization of passive heating, this control is mainly expressed in the containment of dispersions; for the purposes of cooling, instead, in the minimization of the incident radiation and in the dissipation of excess heat.
Roofs represent the portion of the envelope most subject to chemical, mechanical and physical stresses due to atmospheric agents, especially solar radiation, steam and rain. It is possible to envisage interventions that improve the passive functioning of the building, for example through the construction of skylights or ventilation chimneys, or interventions that involve the integration of active energy production systems.
In almost all interventions involving the removal of the roof covering to improve the performance of the underlying layers, such as the introduction of an insulating layer or a ventilated cavity, it is possible to envisage the restoration and reintegration of the existing finishing elements maintaining the appearance of the factory.

Thermal insolation above the currents



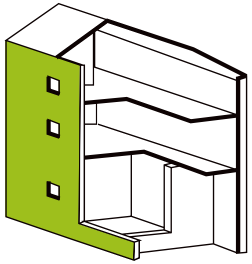
Thermal insolation between the currents



Micaela Goldoni
Architect and Engineer

When is it possible to intervene on the component to improve the energy performance of the historic building?

In order to obtain an optimization of passive heating, the control is mainly expressed in the containment of the dispersions; for the purposes of cooling instead in the minimization of the incident radiation and in the dissipation of excess heat.
Where possible, it is possible to envisage interventions that improve the passive functioning of the building through, for example, the construction of skylights or ventilation chimneys, or through the introduction of an insulating layer or a ventilated cavity.
It is also important to ensure watertightness as even small infiltrations can lead to thermal bridges and surface and crevice condensation.



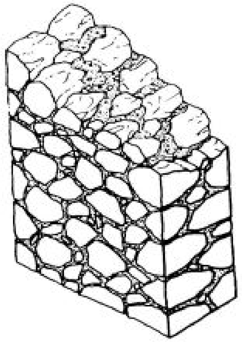
2.Construction’s components

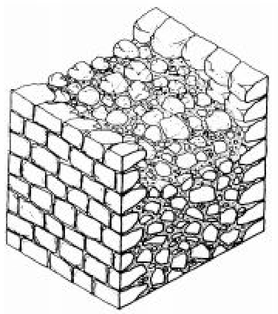
2.4 Masonry

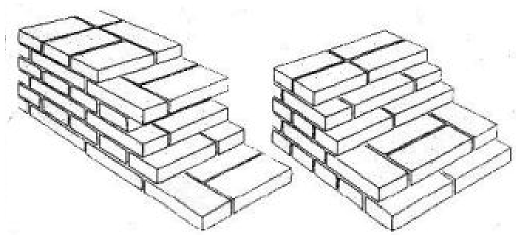
Energy performance

The traditional masonry of historical buildings is made of building materials with high transmittance values. The walls that generally characterize historical buildings have a good level of insulation for the high thicknesses and an average level of thermal conductivity. If the thickness of the masonry package is reduced, it is possible to integrate it with special layers of insulating material. Their very low thermal conductivity allows a considerable improvement in thermal performance. In fact, the thermal insulation is obtained by applying insulating material on the external or interstitial surfaces of the walls, in order to reduce heat losses by transmission and to have homogeneous performance. The energy objective is to reduce transmission losses and diffuse thermal bridges.
The choice of thermal insulation must comply with the permeability and breathability of the existing masonry system, or be counterbalanced by alternative measures for the dissipation of excess moisture.
Among the various insulating materials on the market, therefore, natural fibrous materials, both organic and inorganic, are particularly suitable for the redevelopment of historical buildings.

Traditional masonry ypologies







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Micaela Goldoni
Architect and Engineer

When is it possible to intervene on the component to improve the energy performance of the historic building?

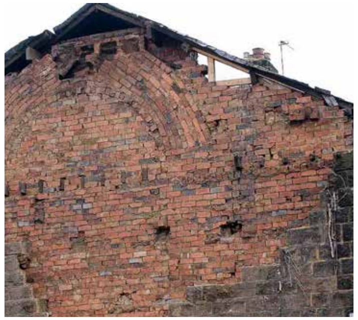
The thermal insulation capacity can be achieved through an internal insulating layer or a thermal insulating plaster outside or inside, depending on the historical-architectural character of the building and its conservation needs.
As far as cooling strategies are concerned, the walls of historic buildings have a high thermal storage capacity and also good thermal inertia thanks to their mass. The possible presence of superimposed finishing elements that separate the internal surface of the wall from the environment can cancel out the positive effect of traditional masonry. In this case, it is possible to consider bringing the thermal masses back to sight, eliminating any improper additions.

Appendix
Main wall types of Historical Buildings

Massive walls

The typical material used in historical buildings for masonry structures was brick and lime mortar masonry.
Some walls were also made of bricks and limestone or sandstone.
Massive natural stone walls differ greatly due to local availability and building know-how.
In all countries, stones have mostly been combined with brick walls for reasons of structural stability.
The most used stones in historical buildings are sandstone, limestone, gneiss and granite.
gneiss, granite. Less popular types of stones used for the historical buildings are dolomite, schist, tuff.

Cavity walls



The cavity wall is made up of two leaves of masonry linked together, but separated by a continuous air space. The leaf has a protective function against the weather. The two leaves must be tied together for structural stability. The cavity keeps the two leaves separate, preventing moisture from passing from the outside to the inside of the wall, ensuring a more uniform temperature inside the building.The cavity can therefore protect any internal cladding. It also allows for the evaporation of any condensation or rainwater that penetrates into the external door and guarantees a more uniform than the temperature inside the building.

Rubble walls

In the type of two-leaf masonry, the inner leaf can be made up of rubble from fragments of bricks and mortar.
The masonry of rubble consists of rough and irregular stone bound with diseased cement or lime. Raw, uncut stones are piled one on top of the other without mortar, and are often laid in irregular horizontal courses. Sometimes they are regularized by horizontal layers of bricks.
The masonry of rubble can also be used as the outer surface of a wall, particularly common in medieval cathedrals and historic buildings, and as a nucleus of plugging between outer walls andd interior (multi-sheet walls with a core of rubble).

Timber frame

A particular type of masonry is composed of stock bricks in combination with timber framing and a thin layer of lime-mortar or lime.
The wooden frame is a traditional method of construction with heavy timber, creating structures that use squared structures. It is a commonplace in wooden constructions of the nineteenth century and earlier.
The load-bearing wooden structural frame could be left exposed outside the building so that the infill between timbers could be used for decorative effect.

3. Technical systems

Energy performance

The ancient buildings were developed from a close link with the natural environment. With the advent of the industrial era, the microclimatic well-being has always been more guaranteed by the presence of air conditioning systems, with a constant departure from the traditional constructive culture.
The old building works by exploiting the thermal inertia of the walls, is built with materials that retain a high percentage of moisture, is designed to be breathable to steam and uses natural ventilation for cooling. The new building is based on systems, insulation and total impermeability. For this reason, energy efficiency measures suitable for a newly designed building may be inadequate for an old building. The realisation of the distribution networks of the systems in the historical buildings requires an in-depth analysis of the routes and the encumbrances of the circuits, carried out in function of the available technological spaces and of the required operating requirements, in contexts often characterized by a lack of technical rooms.
A solution successfully pursued, which ensures greater optimisation of the distribution networks, consists in intervening on the temperature values of the thermovector fluids: increasing the temperature difference between the circuits of hot/chilled water in the hydronic systems allows both a significant reduction in the size of the pipes and the use of reduced and more efficient pumping systems.
One of the major difficulties encountered in the renovation of historic buildings is the choice and location of the heating and cooling plant, which should be placed inside the building, so as to hide its location.
This design practice can be easily pursued when the plant is made up of boilers and small mechanical components, but if the objective of the redevelopment is to achieve high energy classes, it is necessary to adopt more complex and efficient design solutions, which also include the use of renewable sources.
A key role is played by heat pumps which allow compact and indoor machines with very high energy performance.
It should also be considered that the presence of massive structures can cause problems especially in summer, because the energy accumulated during the day, could cause excessive overheating of the interior with a consequent feeling of thermal discomfort, so it is appropriate to provide ventilation systems, natural or hybrid.

Thermographic mapping of an historic building's facade

Ferdinando Sarno
Environmental Engineer

What are the main urgencies to be addressed in the installation of air conditioning systems in historic buildings?

According to the current legislation, historic buildings are not excluded from achieving minimum energy performance. The first step in improving the energy performance of an historic building is to intervene to make the building envelope more efficient. The constraints of protecting historic buildings are very restrictive and finding solutions to improve their performance is often reduced to a punctual action that is not very effective. Instead, strategies would be needed to find a compromise between the protection of the good and performance and to do so it is also important to find a guideline between actors.

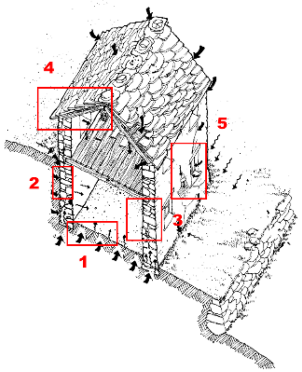
4.Innovative solutions

4.1 Minimization of transmission losses through opaque surfaces

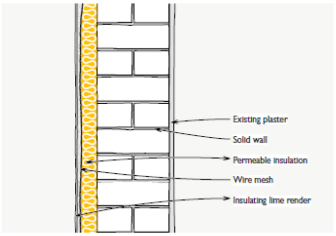
Application of external or internal insulation

A first form of energy efficiency concerns the application of external or internal insulation of opaque surfaces. This technique is difficult to apply on historical walls, as it modifies the image, the statics and the material consistency, resulting irreversible and difficult to compatible with the mechanical seal and the chemical-physical characteristics of the original wall.
In general, it is convenient to reduce energy consumption related to heating in winter, eliminate the thermal bridges of matter, take full advantage of the characteristics of thermal inertia of massive structures and reduce the risk of condensation.
The insulation from the inside, although more easily applicable, has a lower energy benefit as it does not eliminate thermal bridges and does not allow to fully exploit the inertia of massive walls.
The insulation of slabs, bases and roofs requires the insertion of material in the cavity or the application of an insulated counter ceiling.
In the first case, the waste material used to strengthen the slabs can be replaced with loose insulation (vermiculite, perlite, expanded clay), which guarantees its lightness and statics, while increasing its soundproofing power. In the second case, when there are no special decorative devices, it is possible to insert an insulating false ceiling.
The covers can also be insulated on the extrados with mats and continuous panels.
Renovation of the roof, on the other hand, should be considered an opportunity only in the presence of heavily degraded roofs, where it is no longer possible to improve performance through insulation or maintenance. In all cases, the insulators must have good thermophysical properties and steam transmission.

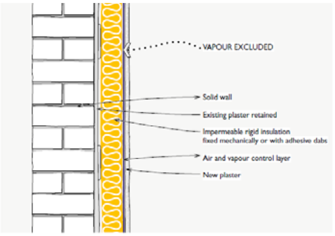
Isolation from the inside of an historic wall.



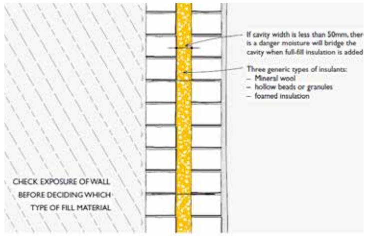
Solidwall: external insulation



Solidwall: internal insulation



Early cavitywall with insulation



4.Innovative solutions

4.2 Improvement of window performance in terms of dispersion by transmission and ventilation

Improvement of thermophysical performance, air permeability and solar shading

A second form of energy efficiency concerns the improvement of the thermophysical performance, air permeability and solar shading of existing windows and doors. The possibilities of intervention must always be balanced with the loss of the asset and include:

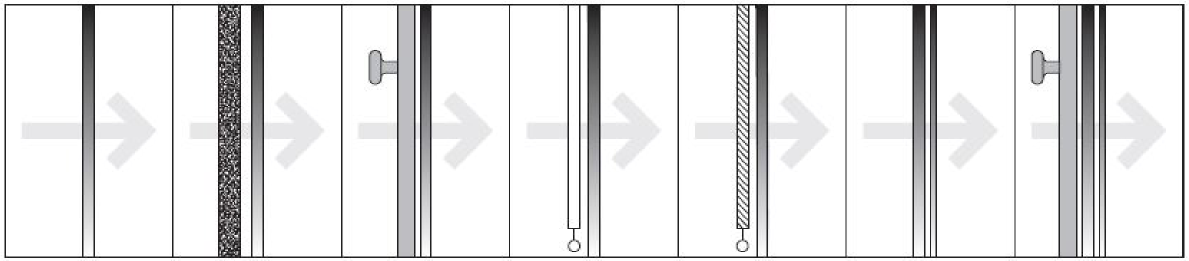
- replacement of glass only;
- application of low-emission films;
- addition of a counter-glazing or a double window;
- replacement of degraded windows and doors;
- insertion of heavy or dark curtains;
- repair or rebuilding of gaskets and seals.

Among the technologies that offer the best yield:

- the most effective traditional system is a combination of dark and double glazing (>70%);
- external shutters (>60%);
- reflective blinds and insulating interior shielding (50-60%);
- heavy curtains (40-50%).

Moreover, the double window has performances that reach almost those of a double glass, while the dark ones double the efficiency of a single glass. It is not advisable, however, to replace traditional frames with frames made of contemporary materials (aluminum or PVC) which, in addition to distorting the aesthetic image of the facade, generates environmental emissions during the production cycle higher than the resulting energy benefits.

Showing how timber single glazed windows can be upgraded without altering their character by installing draughtproofing, secondary glazing, internal timber shutters and slim double glazing.

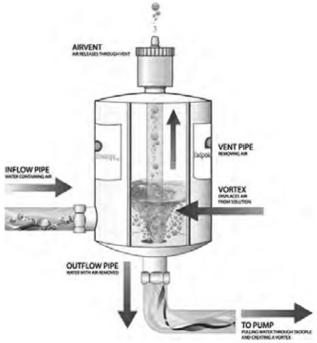


4.Innovative solutions
4.3 Thermal and electrical systems

Plant system temperierung in phase of installation.

Replacement or installation of new air conditioning systems

Another form of energy efficiency is linked to the replacement or insertion of new winter air conditioning systems. In this case, in addition to the main objective of energy improvement, there are those of well-being of people and limitation of the thermo-hygrometric excursions to have the best conservation conditions of materials, finishes and artifacts. More than the heat generator, located in a specific place of the historical building, it is important to choose a suitable heating terminal.
Since ancient times, the most common systems are radiators, fan coils and hot air heating, which can be recovered and replaced with new generation systems more efficient.
An interesting device in this sense is a device that reduces the air in the heating systems, increasing their performance.
A system particularly suitable for historical buildings is the *temperierung*, which consists of the installation of circulating hot water pipes at one or more different heights below the surface of the wall, so as to form a heated band of about the same height as the human one.
Experiments have shown that temperierung consumes 20% less energy than radiators. In some cases it also leads to a reduction in the water content of the masonry (in bricks and mortar) and, consequently, to an increase in thermal transmittance of up to 25%.
Radiant skirting boards are not very invasive systems and can be inserted on skirting boards, benches or radiant carpets (the latter two can also be removed). Finally, it is possible to recover the existing chimneys (by inserting high-performance boilers) or by coupling the existing heat generators with modern fans to exploit the cooling effects associated with hybrid ventilation.



Operating scheme of the Tadpol device installed in a residential building.

4.Innovative solutions
4.4 Inclusion of renewable sources

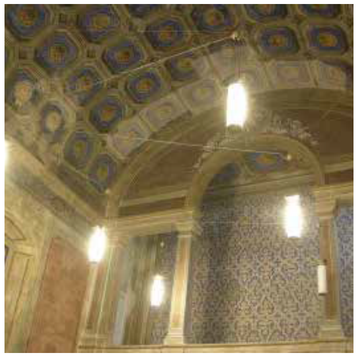
Replacement or installation of new air conditioning systems

In the introduction of renewable energy sources, it is necessary to encourage the architectural, mechanical and technological integration of photovoltaic, thermal and wind solar systems.

In these cases, some European countries (Germany, Austria, Italy) have developed common guidelines, which explain the principles to be adopted to achieve maximum integration with the landscape and the building. In general, the principles concern flatness, respect for the lines, regular and orderly form, reduced aesthetic and chromatic impact and precision in installation.

Finally, it is necessary to intervene with continuous controls and maintenance that make it possible to evaluate the response of the building, to know the new methods of intervention and to correct the problems that arise.

Integration of photovoltaic panels into the roof of historic buildings



Energy-efficient luminaires perfectly integrated into a historic building.

Ferdinando Sarno
Environmental Engineer

What are the main criticalities to be solved in the use of renewable energy in historical buildings?

The current constraints of protection in historic centers do not allow to implement typical solutions (photovoltaic panels - heat pump) due to problems of space and impact. The fragmentation of the users is an other important critical point in historic areas which makes it more complex to implement a trigeneration system. The application of this system to the historical areas would allow to reach good performance requirements with less impact through the use, even if minimal, of renewable energy. I believe that a political will on the part of the public administration and a concerted strategy with citizens are necessary in order to achieve performance objectives in historic areas.

5. Existing protocols
GBC Historic Buildings

GBC Historic Building certification is a rating system aimed at evaluating sustainability level of restoration and refurbishment, combined with the skills of the LEED international protocols.
This is an innovative standard in which the recovery needs of the most precious and historical part of the national building set coexists with the indications of the European targets on environmental impact reduction and existing energy redevelopment.
The GBC HB rating system evaluate the sustainability in overall refurbishment activities starting from the design phase, till the construction phase and the evaluation of the efficient operation and maintenance of the building.
Buildings that may fall within the scope of application of the GBC Historic Building protocol must be built before 1945 with artisanal and pre- industrial techniques or after 1945 if a pre-industrial building process is detached and there are historical and cultural recognized features.
It applies to conservation, rehabilitation or recovery/integration processes, which must implicate major renovations, defined as actions that involve significant elements of HVAC systems and the renewal or functional reorganization of interior spaces, evaluating the possibility of the building envelope performance improvement, consistent with preservation of the typological and construction features of the existing building.
Credit categories
The rating system is organized into environmental categories that help projects to achieve improvements in energy and environmental performances.
Sustainability in the restoration process is then measured through categories of analysis that translate into requirements applicable to the existing building.

Historic Value
This thematic area aims at preserving what is recognized as material witness having the force of civilization, encouraging high level of sustainability by taking advantage of the positive qualities of pre-industrial buildings.

Sustainability of the Site
This topic concerns the environmental aspects related to the place where the historical building is situated, with particular reference to the relationship between the building itself, the surrounding environment and the potential impacts that the building is capable of generating.

Water efficiency
Through the credits of this topic, in addition to the reduction of water consumption for civilian use, it is possible to enhance the contribution of pre-industrial devices for stormwater collection and management, through their restoration or renovation.

Energy and Atmosphere
One of the innovative aspects of GBC Historic Building® is the consideration that energy efficiency and retrofit process represent a form of protection of the historical building and not necessarily a change in the building's original material consistency.

Materials and Resources
The Materials and Resources theme area aims to ensure that the project intervention is in continuity with the existing building, preserving as much as possible the historical material, in accordance with the principles of sustainability related to the reduction of the extraction of virgin materials and land consumption.

Indoor Environmental Quality
The area is structured into two possible paths: on the one hand the goal of conservation and preservation of historic architecture, on the other the fulfilment of occupants' conditions of comfort and indoor air quality.

Innovation in design
This area rewards aspects that are excellence in design in case of performance that greatly exceed those required by the protocol itself or the particular characteristics of the project which, although not related to any prerequisite or credit, guarantee documented benefits in terms of sustainability.

Regional Priority
The credit area Regional Priority aims to enhance the environmental aspects specific to the locality in which the building is situated, encourages design teams to focus on the aspects of regionalism.

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GBC Historic Building - Check list

Historic Value — Maximum score: 20

YES	?	NO			
YES			Prereq. 1	Preliminary analysisM	andatory
			Credit 1.1	Advanced analysis: energy audit	1 - 3
				I Level Analysis1	
				Advanced analysis: thermography	2
				Advanced analysis: thermography and thermic conductance	3
			Credito 1.2	Advanced analysis: diagnostic tests on materials and degradation	2
			Credito 1.3	Advanced analysis: diagnostic tests on structures and structural monitoring	1 - 3
				Diagnostic tests on structures	1 - 2
				Diagnostic tests on structures and structural monitoring2	- 3
			Credit 2	Project reversibility	1 - 2
			Credit 3.1	Compatible end-use	1 - 2
			Credit 3.2	Chemical and physical compatibility of integrated materials	1 - 2
				Compatibility evaluation with fulfillment of the basic requirements1	
				Compatibility evaluation with fulfillment of the basic requirements and at least two complementary requirements	2
			Credit 3.3	Structural compatibility	2
			Credit 4	Sustainable restoration site	1
			Credit 5	Scheduled maintenance plan	2
			Credit 6	Specialist in restoration of architectural heritage and landscape	1

Sustainable Sites — Maximum score: 13

SI	?	NO			
YES			Prereq. 1	Construction activity pollution preventionM	andatory
			Credit 1	Brownfield redevelopment	2
			Credit 2.1	Alternative transportation: public transportation access	1
			Credit 2.2	Alternative transportation: bicycle storage and changing rooms	1
			Credit 2.3	Alternative transportation: low-emitting and fuel-efficient vehicles	1
			Credit 2.4	Alternative transportation: parking capacity	1
			Credit 3	Site development: open spaces recovery	2
			Credit 4	Stormwater design: quantity and quality control	2
			Credit 5	Heat island effect: non-roof and roof	2
				Outdoor paved surfaces	2
				High reflentance roofs	2
				Vegetated roofs	2
				Combination of high reflectance roofs and vegetated roofs	2
			Credit 6	Light pollution reduction	1

Energy & Atmosphere — Maximum score: 29

YES	?	NO			
YES			Prereq. 1	Fundamental commissioning of building energy systems M	andatory
YES			Prereq. 2	Minimum energy performance M	andatory
YES			Prereq. 3	Fundamental refrigerant managementM	andatory
			Credit 1	Optimize energy performance	1 - 17
				Procedura semplificata per la determinazione della prestazione energetica dell'edificio	*1 - 3*
				S imulazione energetica in regime dinamico dell'intero edificio	*1 - 17*
			Credit 2	Renewable energies	1 - 6
			Credit 3	Enhanced commissioning	2
			Credit 4	Enhanced refrigerant management	1
			Credit 5	Measurement and verification	3

Materials & Resources — Maximum score: 14

YES	?	NO			
YES			Prereq. 1	Storage and collection of recyclablesM	andatory
YES			Prereq. 2	Demolition and construction waste management	Mandatory
YES			Prereq. 3	Building reuseM	andatory
			Credit 1	Building reuse: maintaining existing technical element and finishing	3
			Credit 2	Demolition and construction waste management	1 - 2
				Reduction of 75%	1
				Reduction of 95%	2
			Credit 3	Materials reuse	1 - 2
				Reused materials for the 15%	1
				Reused materials for the 20%	2
			Credit 4	Building product environmental optimization	1 - 5
				Third part certification2	
				Multicriteria certification1	- 3
			Credit 5	Regional materials	1 - 2

Regional priority — Maximum score: 4

YES	?	NO			
			Credit 1	Regional priority	1 - 4

Innovation in design — Maximum score: 6

YES	?	NO			
			Credit 1	Innovation in design	1 - 5
			Credit 2 G	BC Accredited Professional	1

Indoor Environmental Quality — Maximum score: 16

YES	?	NO			
YES			Prereq. 1 M	inimum indoor air quality performance (IAQ)	Mandatory
YES			Prereq. 2 E	nvironmental Tobacco Smoke (ETS) controlM	andatory
			Credit 1	Air monitoring	2
			Credit 2	Outdoor air delivery monitoring	2
			Credit 3.1C	onstruction IAQ management plan: during construction	1
			Credit 3.2C	onstruction IAQ management plan: before occupancy	1
			Credit 4.1	Low-emitting materials: adhesives and sealants	1
			Credit 4.2	Low-emitting materials: paints and coatings	1
			Credit 4.3	Low-emitting materials: flooring systems	1
			Credit 4.4	Low-emitting materials: composite wood and agrifiber products	1
			Credit 5	Indoor chemical and pollutant source control	1
			Credit 6.1C	ontrollability of systems: lighting	1
			Credit 6.2C	ontrollability of systems: thermal comfort	1
			Credit 7.1	Thermal comfort: design	1
			Credit 7.2	Thermal comfort: verification	2

Water Efficiency — Maximum score: 8

YES	?	NO			
YES			Prereq. 1	Water use reduction	Mandatory
			Credit 1	Water efficient landscaping	1 - 3
				Outdoor or irrigation water consumption reduction 50%	1
				Outdoor and irrigation water consumption reduction 50%	2
				No irragation required3	
			Credit 2	Water use reduction	1 - 3
			Credit 3	Water metering	1 - 2
				M ixed use building separated water meter	1
				High efficiency appliances and process water systems	1

Total — M aximum score: 110

100 points; 10 bonus points for Innovation in Design and Regional Priority

Certified 40 - 49 points **Silver** 50 - 59 points **Gold** 60 -79 points **Platinum** 80 and more