new4old

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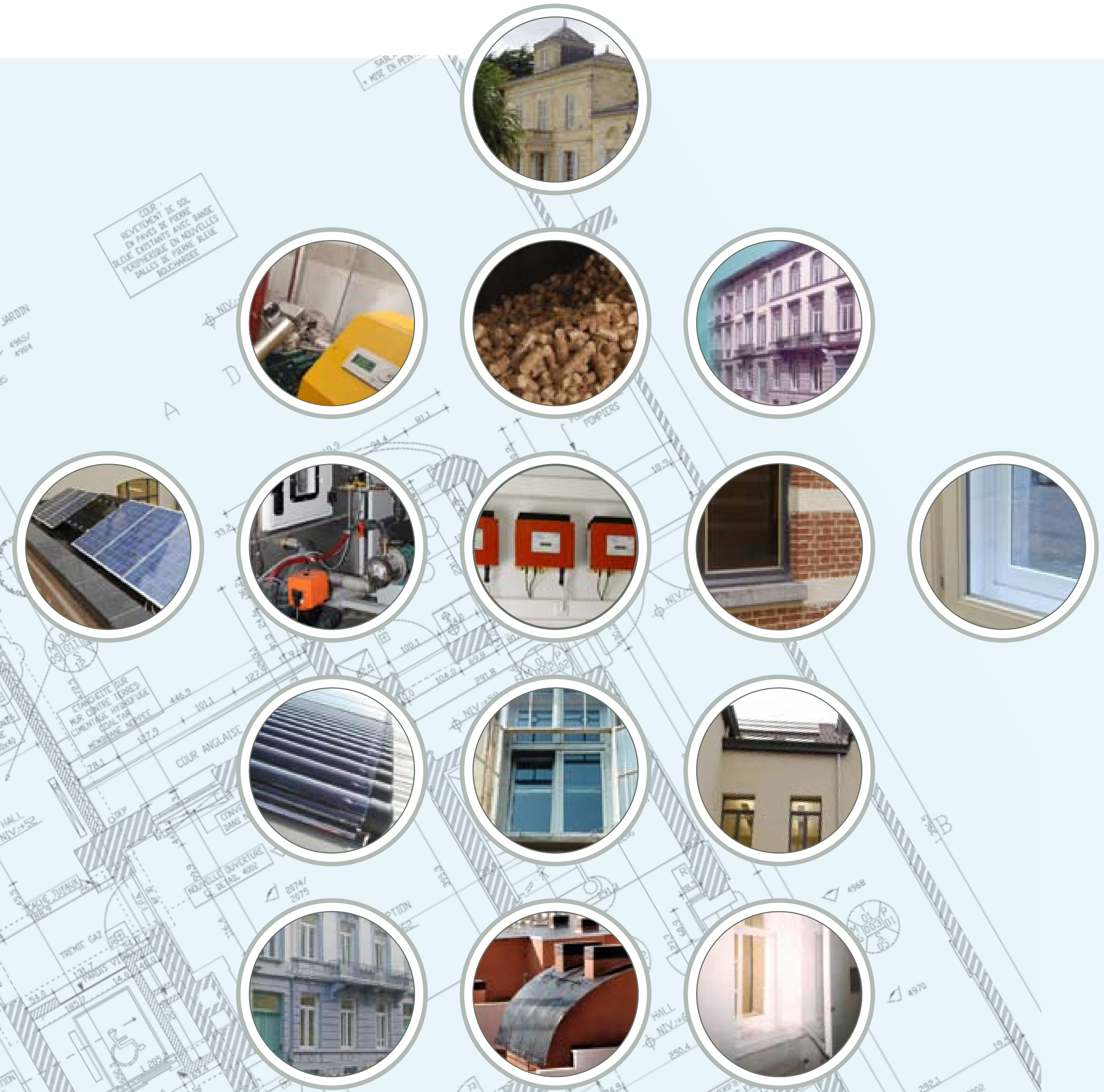
TECHNICAL GUIDELINES FOR BUILDING DESIGNERS

new4old



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In the Renewable Energy House in Brussels, elements were conserved and completely restored during the refurbishment of the building.

READING GUIDE

The project New4Old is a European funded research, implementation and dissemination project in the framework of the Intelligent Energy – Europe programme. The project consortium is composed of EREC, GRECT, 3E, AEE, ITW, NUID and NKUA with the aim of integrating energy efficiency and renewable energy in historic buildings while respecting the cultural and architectural heritage of these buildings.

Inspired by the success of the Renewable Energy House (REH) in Brussels, it is the intention to lay the ground for the creation of publicly accessible renewable energy houses, which will serve as a basis for further stimulation of the market replication of Renewable Energy Sources (RES) and Rational Use of Energy (RUE) technologies in historic buildings.

The project New4Old is committed to significantly contribute to RES and RUE market penetration through a two-fold approach:

a. Creation of a network of Renewable Energy Houses which will serve as focal points for the sustainable energy policy discussion in the different EU Member States and contribute to the commercialisation of RES & RUE equipments
b. Capacity building among architects and planners through guidelines and training activities in the field of building integration of renewable energy and energy efficiency into historic buildings.

As part of the second goal, this document is an introductory brochure for the technical guidelines that have been developed in order to give an overview of the possibilities of integrating RES and RUE in historic buildings.

Respecting the historical elements of buildings the guidelines are divided in 3 parts with a clear distinction between exterior and interior changes of the building. The third part consists of the monitoring and controlling of energy and comfort aspects.

- PART I: The outside of the building
- PART II: The inside of the building
- PART III: Regulation and control

The full version of the technical guidelines is available on the project website (www.new4old.eu) as a pdf report and in the form of a virtual library in html. This introductory brochure is also available in digital format on the project website.

Front facade of the Renewable Energy House, Brussels, before and after refurbishment

TECHNICAL GUIDELINES FOR BUILDING DESIGNERS

INTRODUCTION

Today, the EU is challenged to use and produce energy in an efficient and sustainable way to ensure both security of supply, environmental protection and competitiveness for the benefit of all. In this context, the 27 European Heads of State and Government agreed to a binding 20% share of renewable energy by 2020, together with the agreed 20% energy efficiency target and the 20% greenhouse gas reduction target, which forms a sound basis for a sustainable policy focusing on both demand and supply measures. Buildings are at the core of the sustainable energy policy as long as the sector keeps accounting for 40% of the EU's energy demand.

An example is the 140 years old Renewable Energy House (REH) in Brussels. This former mansion was refurbished in order to minimize energy consumption and to explore different methods for integrating renewable energy technologies, making it a 100% renewable energy office building.

In the REH different parts were protected and a lot of decorative features have been preserved. The allowed measures of the building that would change the appearance of the building were conceived after planning consent.

It is perfectly possible to integrate renewable energy technologies in our historic building patrimony.

Of these 40% there are a number of historic buildings in Europe and many of them are wasting large amounts of energy. This architectural heritage deserves very particular attention within a sustainable architectural approach, with regard to sustainable energy development and historic buildings protection.

As a general rule, any project that is considered to significantly change the appearance of a listed building will require planning consent. It is also essential to demonstrate that the project will not alter the elements that make up the special character and interest of the building, including features such as decorative elements, internal layout, decorated plaster surfaces, archaeological or technological interest of the surviving structure and surface, etc.

Back facade of the Renewable Energy House, Brussels, before and after refurbishment

PART I: THE OUTSIDE OF THE BUILDING

External adaptations like external insulation, solar panels on walls and roofs, new types of windows or additions to windows etc. change the visual aspects of the outside of a building. In this part the possible problems, (dis)advantages, limitations, optional changes of the envelope are mentioned, with the goal to optimize those parts of the building's envelope that are not protected and thus can be changed on the outside. Other outside building features, like geothermal drillings, air source heat pumps etc. are also discussed in Part I.

REDUCING THE ENERGY DEMAND

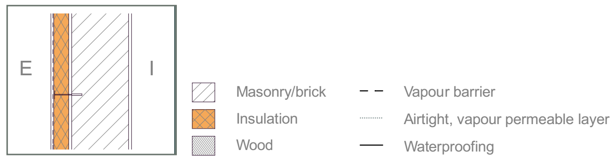
The reduction of the energy demand in buildings is the first logical step. To reduce the energy needs of a building it is possible to reduce the heating, cooling, ventilation and the lighting demands without losing comfort.
The different chapters in the guidelines cover the different possibilities for reducing the energy demand by improving walls and roofs from the outside (U-value, air tightness, …), windows (U-value, entering daylight, solar screens, …), but other innovative measures that are integrated in the building's outside are also treated.

Improving opaque elements

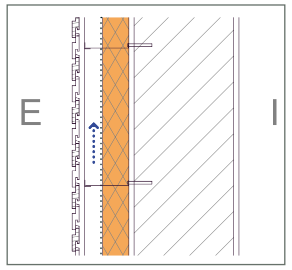
Adding insulation on the external side of opaque elements like facades and roofs is one of the most straightforward and efficient measures to reduce heat demand. The first few centimetres of insulation have a dramatic effect on heat demand reduction.

Exterior insulation reduces the additional heat losses caused by thermal bridges, preserves the thermal mass, contributes to thermal comfort as the mean radiant temperature of the surfaces in the room increases, etc. Also, it is possible to reduce ventilation heat losses, since higher surface temperatures allow higher relative humidity, so a lower air change rate is sufficient.

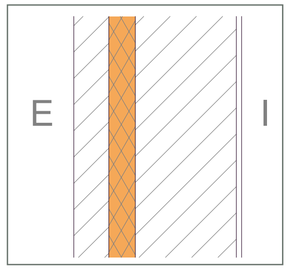
Adding exterior insulation is not possible on protected facades, limiting the possibilities for historic buildings to a large extent. However, placing external insulation does not necessarily change the outside appearance of a building. With a special technique it is possible to insulate the facade after carefully removing the historical features. After placing the insulation the historical elements of the wall are replaced or reproduced.
Other techniques exist of which some do not alter the outside appearance of a building: composite systems, transparent insulation or cave filling. In the guidelines these techniques are explained and a detailed approach for pitched roofs, cellar floors, flat roofs etc. is included.



External insulation with a composite system



Cladding with ventilated cavity



Insulation of a cavity wall

Improving transparent elements

The main functions of windows are to create a sight connection from the inside to the ambient environment and to provide the premises with sufficient daylight, which are both essential for the well-being and health of the users of the building. In old buildings the large windows ensure the illumination of typical generous rooms and in the winter the solar gains help reducing the heat demand.

However, windows do not only have positive effects on the indoor environment of a building. Since windows have higher U-values than wall constructions, they rate among the weak points of a building envelope from a thermo-technical point of view. Especially in winter months, old and leaky windows in historic buildings cause energy losses through transmission and infiltration. These energy losses have a big influence on the thermal comfort for the users of the building due to cold radiation and draught. In summer times, large solar gains can lead to the overheating of the building. Despite the fact that historic buildings usually have a large thermal mass, overheating is a frequent problem. Especially in warm climates with long hot periods it is important to avoid overheating in summer by limiting incoming light by shading or radiation screening.

Generally the restoration of historic windows should be preferred to their replacement. After a physical evaluation of the windows concerning their soundness and thermal qualities, different solutions to integrate high efficient glazing and frames into historic buildings can be implemented in consultation with the local monument protection authorities.

Another solution to improve single-glazed windows is to create a box-type window by presetting an additional

Reconstructed window in the balcony of a historic building

Box-type window with high efficient interior sash

window with high efficient glazing and frame inside the original historic window. With this measure the outside appearance of the building front will not be changed, though the thermal and soundproofing quality of the building will be improved considerably.

Other options

Apart from changes related to insulating the envelope and improving different aspects of windows, other aspects are included in the guidelines like the implementation of necessary penetrations of the envelope. The integration of new techniques in existing elements like the use of present chimneys for natural ventilation and cooling are treated.

INTEGRATING RENEWABLE ENERGY

The second step is the integration of renewable energy. In the guidelines the use of solar, biomass, geothermal and wind energy in historic buildings are handled. Most of these technologies have a big impact on the appearance of the building although this does not necessarily mean they cannot be integrated in protected buildings.

For solar and photovoltaic panels a good orientation should be chosen to generate a significant yield of energy. Typically all orientations facing between east and west can be considered as appropriate. In this context it should be assured that no trees, chimneys or dormer windows cast shadow on the collector.

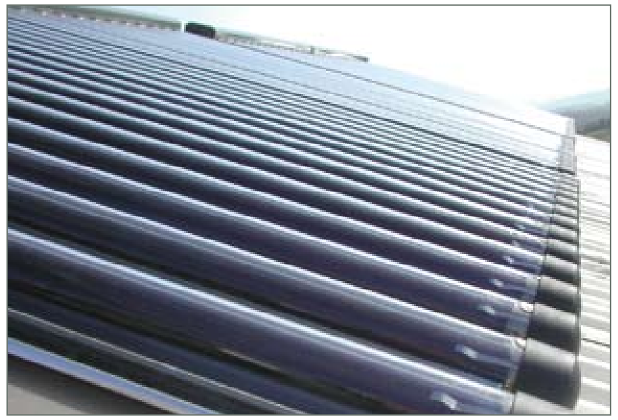
In general, solar thermal technology is used to convert the solar radiation from the sun into heat. This heat can be used for the heating of domestic water, for space heating, for industrial processes or in combination with a thermally driven cooling process for solar thermal cooling. Many different collector types exist: with liquid or air as heat transfer medium, glazed or unglazed, flat plate or vacuum tube collectors, in different shapes and in different integrations (facade, in-roof, on-roof, free standing).

Unglazed collector using liquid transfer medium

For photovoltaic (PV) panels photovoltaic cells are used that convert sunlight into electrical energy. The produced power can be transferred to the conventional electricity grid and/or connected to the building.

Mostly solar and PV panels are placed on roofs. It may occur that roof tiles and slates get broken during the installation of the panels and replacements for roofs with stone or old handmade tiles can be expensive and difficult to find. Therefore it is advisable to investigate what type of roof covering is present and how to get replacements before undertaking any work.

Next to positioning the collectors on the roof, solar collectors can be placed on the ground, away from the building, or integrated in walls and/or glazing. The integration in opaque surfaces of the (non protected) facade has advantages like a more even radiation of sunlight during the year or the improvement of the building's thermal insulation and they can become an element of architectural design in facades. Also the integration of PV panels in the transparent parts of the wall can be part of architectural design.



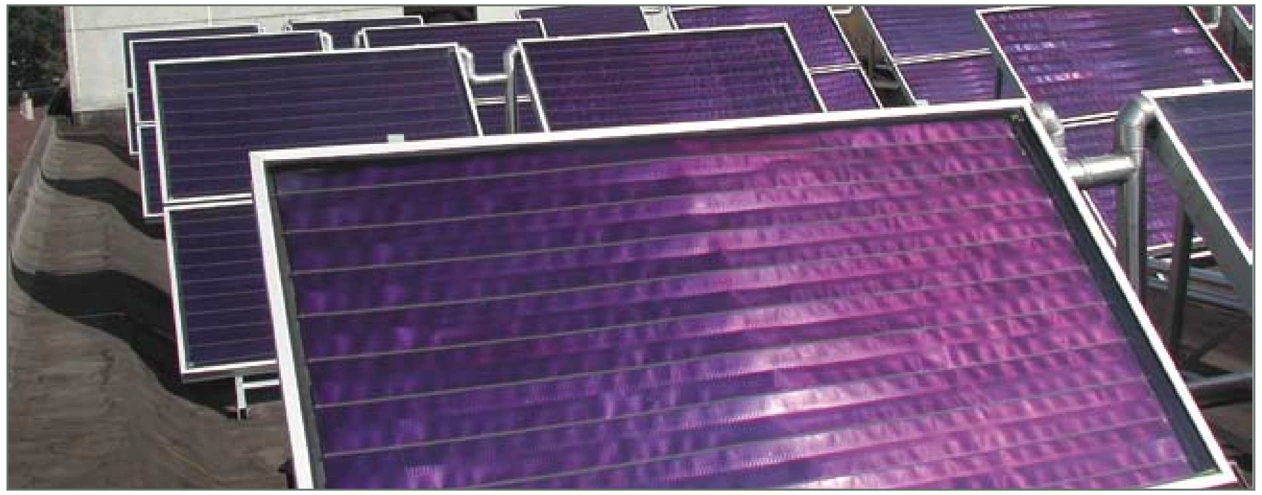
Evacuated tube collector

However, the profitability of the solar and PV panels placed on walls or vertical transparent parts of the wall decreases due to the non-optimal inclination of the collector.

It is difficult to integrate wind power systems in or around protected buildings. Modern conventional grid-connected wind turbines are intentionally sited away from buildings due to the fact that in an urban area, as compared with an adjacent rural area, the wind speed will be generally lower, the turbulence and wind shear greater and there will be more specific local flow effects. Conditions thus seem unfavourable regarding both power output and turbine lifetime. However, the integration of wind turbines in built areas allows produced energy directly fed into the client's electrical circuitry and so avoids the overheads and losses associated with separate connection to the local electrical utility distribution network.
The economic value of this energy is then equal to that otherwise charged by the client's electrical supplier, which is considerably higher than that produced in a remote area.
However, there are issues of integrating urban wind turbines in historic buildings or on their site. These are discussed in the guidelines.

Another source of renewable energy treated in the guidelines is biomass. Biomass used as fuel can be divided into the following two main categories: solid biomass and liquid biomass.

This guide only covers biomass that is commonly used in buildings, such as pellets, wood chips and wood blocks as solid biomass and pure plant oil as liquid biomass. Other forms of biomass are generally not used in buildings.



Flat plate collectors installed on a flat roof

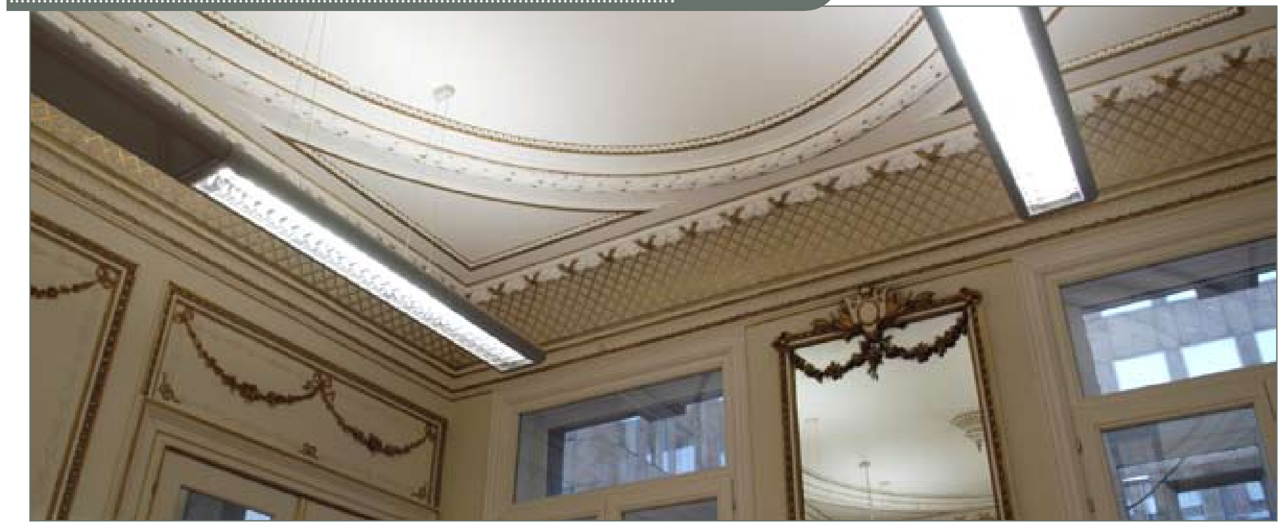
Wood pellets

One major concern is to keep biomass protected from moisture. If it is not absolutely dry, loss of energy may occur or even moulds may be formed of which the spores may be dangerous if inhaled. Geothermal energy can be conversed in different ways. A typical outside feature of balanced ventilation systems is an earth to air/water heat exchanger. This is a buried pipe, through which a fluid (this may be air or a water solution) circulates by means of electric fans or pumps. It is a simple solution with low to medium construction cost. Earth-heat exchangers can also be used in combination with a heat pump system for pre-heating or -cooling the working fluid.

Heat pumps (for heating applications) can also be considered as a renewable energy conversion technology as long as the auxiliary (primary) energy consumption is deducted from the heat production. Heat pumps always need a heat source outside the building from which heat is extracted at a low temperature to be upgraded to a high temperature by the heat pump. Different types of heat sources exist: air source heat pumps extract heat energy from the surrounding air, water source heat pumps are presented in open or closed systems, ground source heat pumps with a horizontal capitation grid or vertical borehole heat exchangers move heat from the underground into the house for space heating and domestic hot water, etc.

The integration of solar energy in buildings can become an element of architectural design.

In general, when compared to fossil fuels, biomass fuels are of relatively low energy density. Therefore, large volumes of biomass are needed to be stored. This storage can be done above ground or underground, where the primary purpose for the storage will be to retain the biomass in good condition in a convenient place before being transferred to the next stage of processing, combustion or energy conversion.



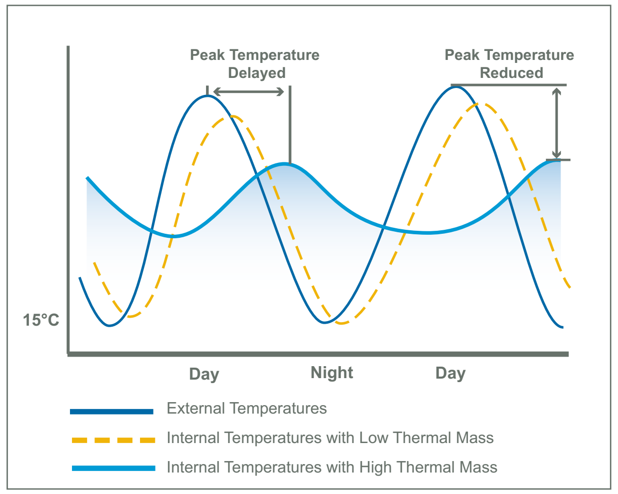
In historic buildings, it is not always allowed or suitable to apply some or more of the measures mentioned before. Even if it is possible, those measures are normally not enough to refurbish the old building into an energy efficient and highly comfortable building. Additional measures that do not affect the (protected) building's outside have to be foreseen. This section handles all the measures that affect the inside of the building.

REDUCING THE ENERGY DEMAND

The energy demand can be reduced by several measures that do not affect the outside of the building like placing internal insulation to reduce the heat demand, adding sun screens on the interior to reduce the cooling demand or the optimisation of lighting. The importance of thermal mass and its effect on comfort and energy demand has to be recognised.

Thermal mass moderates internal temperatures by averaging diurnal extremes and it delays the time at which peak temperatures occur. Preserving thermal mass can be done by keeping thermal contact between the mass and the interior (by increasing air flow, avoiding insulating layers or cavities around thermal mass, …), while increasing thermal mass can be realised with innovative measures like Phase Change Materials (PCM) that increase the heat storage capacity of a building without adding a lot of extra weight to the structure.

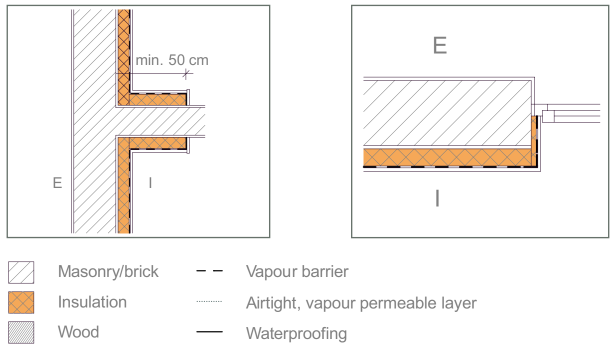
In historic buildings, external insulation of walls is generally not possible if the facade is under monument protection and the original appearance containing stuccos and sculptures has to be preserved. In this case there are two possibilities when retrofitting the building: applying interior insulation or not insulating the wall at all. If no insulation is applied but the windows are changed or sealed, or if the heating system is modernised, there is a risk of mould growth on the cold surfaces. Even driving rains might cause mould problems. Interior insulation has advantages, but careful planning and execution is necessary as its installation is not risk-free.



Internal Temperatures with High Thermal Mass

Obviously, the most important advantage of interior insulation is that the appearance of the building does not change from the outside and no external scaffolding is necessary, hence the costs are lower. However, if the interior of the rooms is also of high value, like covered with frescoes for example, the option of interior insulation must be abandoned. Also, interior insulation has some disadvantages which require attention: creation of thermal bridges, risk of freezing of pipes in walls, reduction of thermal mass, risk of vapour condensation, etc.

The effect of thermal bridges should be minimised at wall and floor junctions and wall-window junctions. With interior insulation applied, the temperature of the external wall drops and it might be around or below the dew point on certain sections.



Junction of external and internal walls/floor with internal insulation and vapour barrier

Another risk that is coupled with interior insulation is moisture condensation in or behind the insulation layer. Installing a vapour barrier close to the internal surface can eliminate moisture-related problems. However, caution should be paid with the changed moisture movement because the outer wall might get damaged due to absorbed water. A vapour calculation will be necessary when placing interior insulation. The guidelines handle detailed solutions for specific building elements as well as the use of special materials like calcium-silicate insulating boards, which are suitable for handling moisture-related problems without installing a vapour barrier, and vacuum insulation panels, which are a good choice when space is scarce.

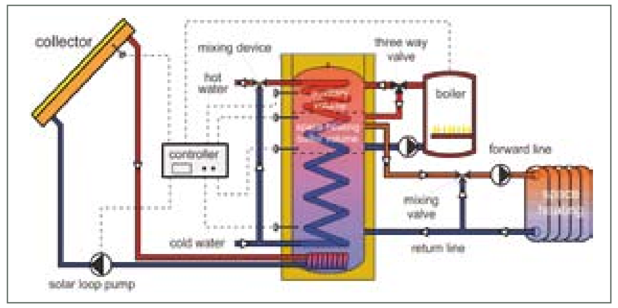
Other techniques treated in detail in the guidelines to reduce the energy demands of historic buildings are introducing internal sunscreen to reduce the cooling demand, replacing the interior lighting or by implementing automatic light controls, which reduce the electric needs and also influence the heating and cooling demand mostly in a positive way.

INTEGRATING RENEWABLE ENERGY

The following options are handled in the guidelines: active and passive solar thermal heating, the use of biomass and passive or solar cooling.

Active and passive solar heating

Active and passive solar heating techniques convert the short wave solar radiation in low temperature heat for heating or hot water preparation. For active solar thermal heating systems solar panels are needed to catch the solar radiation and produce hot air or hot water which



Scheme of a solar combisystem

can be used for the heating of domestic water and/or internal spaces. Beside the solar panels all components necessary for this technique are installed inside the building. For passive solar thermal heating different wall types with glazing can be used to catch the heat. With this principle there is no need for solar panels, because heat is caught behind glass in the room or between two layers of a (glazed) wall. This allows making only changes on the interior of the building if the windows are present, because a second (new) wall can be implemented on the inside of the building, so the outside of the historic buildings remains unchanged. Practical examples are a double skin facade, a trombe wall, etc.

Solar thermal cooling and passive cooling

It is possible to cool a building using solar thermal energy. For active solar thermal cooling a cooling machine is driven by heat instead of electricity, the heat being produced by a solar thermal system. These solar assisted cooling systems have the advantage that cooling of a building is needed when solar radiation is high. It's also possible to implement passive cooling techniques in buildings. These are not based on solar thermal principles but on natural driven processes. Examples of these techniques are night ventilation and free cooling. More information about all the possibilities can be found in the guidelines.

Heat pumps revisited

Heat pumps were already mentioned in the previous part, where they changed the outside appearance of historic buildings. This, however, is not necessary because the system can use geothermal energy, so only buried or drilled ducts will be present in, under or around the building. This allows foreseeing historic buildings with a high efficient production of heating and cooling without any visual impact. Another advantage of heat pumps is that they do not require a chimney, creating extra options for ventilation systems and/or space for cables and ducts.

Next to physical changes of the interior and the building's envelope, handled in the previous parts, there are other parameters and measures that can be undertaken to influence comfort and energy consumption. These measures include the monitoring of systems to validate if the performances of installations reach the set-up goals, the different controlling strategies to use energy in a more efficient way or thirdly by influencing (the perception of) comfort. Below a short introduction is given to the different topics handled in the guidelines.

Comfort

The concept of comfort has too often been confined to purely thermal phenomena, the whole range of sensory conditions involved being neglected. Genuine comfort is as much psychological as it is physiological. Human beings judge the quality of their environment, both indoor and outdoor, in a direct, interactive manner, altogether consciously, subconsciously and unconsciously.

Most of these technologies have a big impact on the appearance of the building although this does not necessarily mean they cannot be integrated in protected buildings.

This raises the broader issue of individual perceptions of comfort. Although the psychological parameters are extremely important, they are difficult to assess. They depend on a host of factors, including time, the specific background and the broader situation and the cultural environment. Not only temperature and humidity are thus involved here, but a whole range of variables.

Regulation and control

Regulation and control systems have the difficult task of maximising comfort for the building occupants while minimising energy consumption. There is no conflict between those two functions, but an issue of complexity: simple systems will most often focus on user comfort and leave room for energy efficiency improvements while more complex and elaborated systems can both increase comfort and energy efficiency.

Occupant behaviour

When considering the energy balance of a collective building, the influence of all the users' behaviour is capital. As a result, the implementation of energy-efficient techniques and systems must be complemented by actions fostering an evolution towards responsible behaviour regarding energy use.

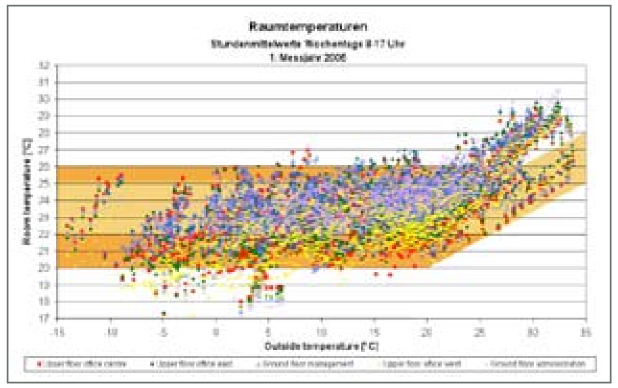
Occupants can have a positive or negative influence on the total energy consumption and comfort of a building, dependant on their behaviour with regard to heating, air-conditioning, lighting, ICT equipment and other electric appliances. So it is essential, for a good acceptance and an adequate use of any lighting and ICT systems, to inform the users and to encourage them to a responsible occupation of the buildings.

Responsible user behaviour is the cornerstone of a rational use of energy in buildings. Many awareness-raising programs showed this influence. Discussions with occupants coupled with measurement campaigns on heat consumption, room temperature and ventilation of the residences have provided qualitative and quantitative evaluations demonstrating this influence.

Monitoring

The monitoring of the energy consumption in different points of a building is a simple instrument to supervise and to document the performance of all energy consumers and the comfort parameters within an operated building.

In a well-considered monitoring concept the consumed amount of energy (heat, water, cold, …) and existing comfort parameters (temperature, humidity, CO_2-concentration) are permanently registered and documented in graphs and reports. Based on this information the energy consumptions can be analysed and evaluated. With the help of these monitoring results potential energy savings can be identified, improvement measures and superior activities (like improvements in the building management) can be initiated and supported.



Distribution of the mean room temperatures (ordinate) in offices as a function of the outside temperature (abscissa)