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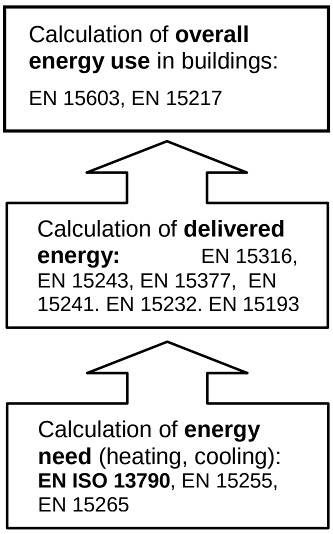

Figure 1: The series of CEN standards offer different types of calculation methods for different steps of the building's energy assessment. EN ISO 13790 includes passive heating and cooling, influencing the energy need.

The effects of passive heating and cooling on the energy performance of buildings – CEN calculation procedures

In the discussion of global warming and the increasing costs of most energy carriers, the implementation of passive heating and cooling in all kinds of buildings has become more and more important, as these systems do not require the use of energy derived from fossil fuels. Passive heating means to minimise all avenues of heat loss from the building whilst maximising solar heat gains. Passive cooling includes the reduction of solar heat gain into the building, as well as removing heat from internal heat sources by passive (or natural) strategies, e.g. by night-time ventilation. Both passive heating and passive cooling rely on the site, structure and architectural design of the building and on the materials used in its construction. Their effect on the building's net energy performance is considered in the calculation procedures set out in EN ISO 13790 [1]. This paper first defines the methods and systems used for passive heating and cooling before the various ways of calculating these effects that are specified in the CEN standards are described.

1 > In general

Passive heating and cooling strategies were historically well understood by architects and builders and elements of what is now known as bioclimatic design were commonly used. In more recent decades, modern architectural trends departed from that type of planning and building, in order to increase a building's transparency, facilitated by modern heating and/or cooling systems fueled with cheap energy. Fully glazed facades, less compactness and sub-optimal orientation to the sun lead to increasing energy demands for heating and cooling and the need for technical systems in buildings. As the costs of all energy sources have increased, together with political interest in reducing primary energy and CO_2-emissions, many traditional passive design elements are again being incorporated into modern building design.

Existing studies show the high positive impact of passive systems. For example, in Germany in 2006, the contribution of passive solar gains in the existing residential building stock (83.200 GWh) was in the same range as the total amount of thermal energy obtained by renewable sources, such as biomass and solar or geo-thermal systems (89.500 GWh) within the country in the same year [2]. The contribution of daylighting to energy conservation is also considerable, as it generally reduces the need for electrical lighting by 50%. What is more, if a building is planned and built adequately, up to 80% of the lighting required can be provided by daylight (for buildings which are mainly occupied in the daytime). Today, political efforts to reduce fossil energy consumption unfortunately focus only on increasing active renewable energy sources, ignoring the passive contribution which should be taken into account explicitly. It would be easy to devise ways of quantifying and rewarding solar gains that were above average, for instance by defining a reference value that was based on the passive solar gains achieved by “normal” window design, construction and orientation.

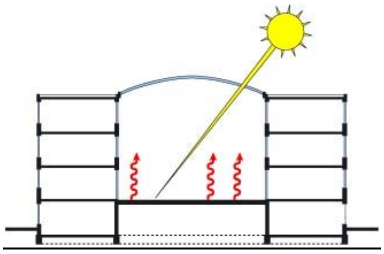

Figure 2: *Schematic illustration of direct solar heat gain in an atrium with a glazed roof, depicted by the red waved arrows illustrating heat.*

2 > Passive Heating

Passive heating techniques are usually based on solar energy, a thermal source available on most sites. Even though solar heating is sometimes equated with passive heating, the most commonly used ways of achieving solar heating must be regarded as active, since solar panels are usually involved, and mechanical systems are used to store, collect, and distribute solar energy in the building in the form of hot water.

In passive solar heating, the direct heat gain of solar radiation on external wall and roof elements (the collection areas) is the source of energy, especially when they are glazed. (see figure 2) These heat gains depend on the solar radiation available at the location of the building, on its orientation and on the characteristics of the collection areas (their solar transmittance/absorption and thermal heat transfer) as well as on the use of shading devices. Most of these factors can be influenced to increase or control the solar heat gains of a building.

Maximising solar heat gain and minimising heat losses are the two most essential features of passive heating. Applying thermal insulation of high quality, installing multiple-glazed windows, avoiding thermal bridges and providing air tightness are the main factors reducing heat transmission and air infiltration, the main avenues for heat transport. These processes are important for passive heating in winter, and in summer, they contribute to passive cooling. In particular, highly insulated roofs and walls are beneficial at any time of the year, while high performance windows and air tightness are less beneficial in summer in Southern Europe.

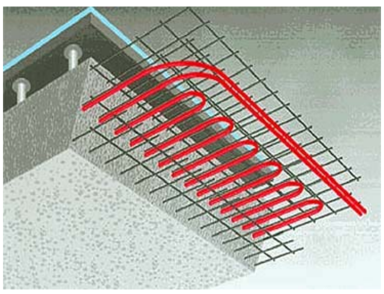

Figure 3: *Schematic illustration of a thermo-active ceiling. Cold water can be pumped through the red coloured pipe.*

3 > Passive Cooling

Thermal protection and airtightness of the building are essential aspects of passive cooling, as mentioned above. Passive cooling also implements technologies or design features which use the principles of physics to cool buildings without fossil energy consumption. As a result no or only very few energy-using mechanical components, such as pumps and fans, are required. Slowing the heat transfer into the building and removing unwanted heat from it, are important principles of passive cooling, which can for instance be realised by increasing the building mass.

The possibilities of removing unwanted heat from a building depend mainly on the climate. In climates with cool (dry) nights, ventilating at night-time is easy and effective, whereas it is counterproductive in hot humid climates. There, a thermoactive ceiling could be installed instead (see figure 3), which would however need a pump. As no energy for cooling is required, such systems are usually classed as passive cooling.

Also the intelligent use of daylighting directly reduces the energy required for cooling, as electrical lighting will otherwise contribute a large part of the internal thermal heat gain.

4 > Structural Measures

Figure 4: *South elevation of a perfectly orientated building. The main glazed façade area faces south and is provided with an overhang that provides shading in summer. Solar panels are also shown, although they are strictly speaking not entirely passive, as they require an electrical pump.*

In general, the implementation of structural measures to reduce power consumption by passive means needs to be evaluated carefully, as usually both heating and cooling are influenced, but not necessarily in the same way. The mechanisms that are relevant to energy conservation by passive means are thermal transmission, ventilation, infiltration and solar radiation. Reducing a building's heat transfer is usually beneficial in both cases, while solar shading, a typical element of passive cooling, may not be. Shading, which is absolutely essential in summer, may reduce passive solar heating in winter, thus the installation of dynamic shading devices (using a minimum of auxiliary energy) may be necessary to optimize the building's energy performance both in winter and in summer.

The following means are available for maximising passive heating in winter and passive cooling in summer. Regarding orientation, the building is assumed to be located in the Northern hemisphere. A rationale for the application of each approach appears in parentheses, in some cases illustrating how the different ways of passive heating and cooling are taken into account in the calculation procedures stipulated in the CEN-standard, which are described in paragraph 5.

- Orientating the building's main glazed façade area southward (to reduce solar radiation in summer, when the vertical angle of the sun is very high at midday, and to benefit maximally from solar radiation in winter, when the vertical angle of the sun is low), see figure 4
- Aiming for compactness (to reduce the transmission area of conditioned zones)
- Avoiding thermal bridges (to reduce transmission heat transfer), see figures 5-7
- Improving the building's air tightness (to reduce uncontrolled infiltration)
- Applying thermal insulation of high quality and multiple-glazed windows (to reduce heat transmission), see figures 6-7
- Increasing the building's thermal mass (to store and then shift solar gains from day- to night-time)
- Arranging the distribution of the rooms depending on the building's orientation (e.g. to locate rarely used rooms in the north)
- Avoiding overlaps of high solar heat gains with high internal thermal heat gains
- Effective planning and installing of ventilation devices

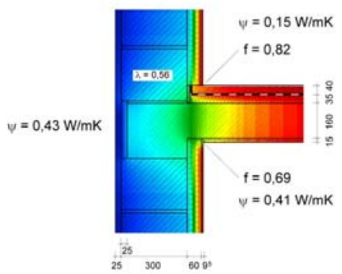

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Figure 5: *An example of a thermal bridge, illustrating the heat distribution and its potential transfer by different colours (red: warm, blue: cold), which should be avoided*

5 > Consideration of passive heating and cooling in the calculations of the CEN standard

The CEN-standard EN ISO 13790 covers the calculation of energy use for space heating and cooling, as introduced in Information Paper P92. It offers definitions and calculation procedures, together with example applications and standard data. Passive heating and cooling affect these calculations of the energy balance of a heated zone in different steps and ways, depending on the kind of aspect, as mentioned above in parentheses. Both systems influence the heat transfer calculation procedures, which are described in clauses 8, 9 and 10 of the standard: "8: Heat transfer by transmission", "9: Heat transfer by ventilation" and "10: Internal heat gains". Dynamic effects, covered in clause "12: Dynamic Parameters" are also influenced by passive solar gains, especially via the thermal mass of the building. These four aspects are explained below in paragraph 5.1. Clause "11: Solar heat gains", which is described in 5.2, presents a calculation procedure, explicitly covering the main

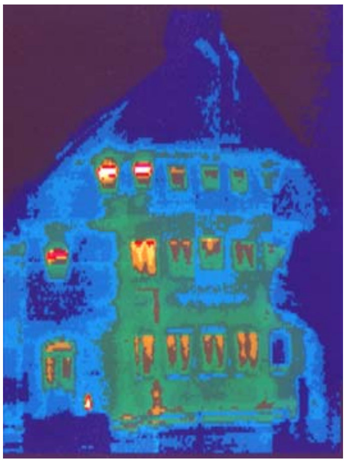


Figure 6: *A thermographic picture of a badly insulated façade with thermal bridges.*

Figure 7: *A thermographic picture of the façade from figure 6 after the building's retrofit (the upper left window is tilted).*

characteristic of passive heating. All of the quantities described in the following paragraphs influence the energy balance of the building, which determines its energy performance.

For special elements, such as (unconditioned) sunspaces, opaque elements with transparent insulation, ventilated solar walls and ventilated envelope elements, Annex E of CEN-standard EN ISO 13790 covers the calculation of heat transfer and solar heat gains. The first two of these special cases can be considered as passive heating systems. They are therefore described in paragraphs 5.3 and 5.4.

5.1 Calculation of heat transfer and dynamic effects

Heat transfer by transmission

Transmission heat transfer is driven by the difference between internal and external temperature. It is expressed as the overall transmission heat transfer coefficient, which depends on the area of the building's envelope, its specific thermal transmittance (U-value) and on thermal bridges. Thus, minimizing the heat transfer area, by improving the compactness of the heated volume, reducing the U-value, typically by applying better or thicker insulation on walls and roofs, and avoiding thermal bridges, which generally requires accurate planning and careful building, all reduce the heat transferred by transmission and consequently support passive heating and cooling.

Heat transfer by ventilation

Ventilation heat transfer is driven by the difference between the internal temperature and that of the supply air, which in the case of natural ventilation is the ambient air temperature. It is expressed by the overall ventilation heat transfer coefficient, in which the airflow rate is the only manipulable factor. Intentionally influencing the airflow leads to a typical method of passive cooling: night-time ventilation. This can easily be covered, when applying a dynamic calculation method or small time steps, such as hours. Monthly and seasonal calculation methods tend to overlook the effect of night-time ventilation. In these cases an additional factor must be included, which depends on the time fraction of night-time ventilation per day and is explicitly covered in clause 9.4.3 of the standard.

Internal heat gains

Internal heat gains generally result from persons or active systems, for instance from appliances, lighting devices, hot water systems or heating, cooling ("negative heat gains") and ventilation systems. As these heat gains may either remain in the building (as in passive heating) or be rapidly rejected (as in passive cooling), they influence the required capacity of effective passive heating or cooling.

Thermal mass - Dynamic effects

In the standard, a dynamic method is used to model the thermal resistances, thermal capacitances and heat gains from solar and internal heat sources. Several methods are available, varying in complexity from simple to very detailed. Being directly coupled, the building's thermal mass is especially relevant in the standard's simple hourly method. In the monthly and seasonal methods, the dynamic effects are taken into account by introducing the gain utilization factor

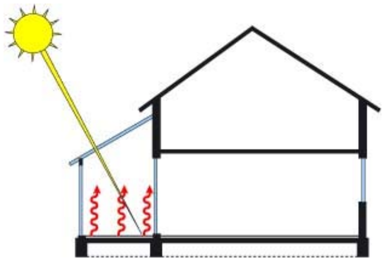


Figure 8: *Schematic illustration of direct solar heat gain in an attached but unconditioned sunspace, a conservatory, depicted by the red waved arrows illustrating heat.*

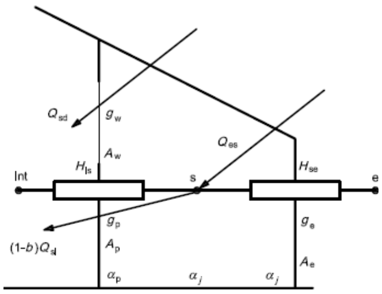


Figure 9: *Sketch of an attached sunspace, illustrating direct (Q_{sd}) and indirect solar heat gains (Q_{si}) and input parameters required for the calculation*
(A: area, g: solar energy transmittance, H: transmission heat transfer coefficient, a: solar absorption factor;
with subscripts: e: sunspace external envelope, w/p: transparent/opaque parts of the partition wall)
Also showing electrical equivalent network
(int: internal, s: sunspace, e: external; H_{is}/H_{se}: resistance internal-sunspace/sunspace-external)

for heating and the loss utilization factor for cooling. The effect of inertia in the case of intermittent heating or switch-off is taken into account separately, by the building time constant. Due to its robustness and transparency the monthly method is the option chosen in many EU Member States, at least for residential and simple commercial buildings.

5.2 Calculation of solar heat gains in the standard

Clause 11 of EN ISO 13790 covers passive solar heat gains, which can be direct (e.g. through windows) or indirect (e.g. via absorption in opaque building elements). Controlling and effectively using these gains is the main objective of passive heating. In general, the overall solar heat gain is determined by the heat flow rate from solar heat sources over time. Generally, two main types of heat flow exist: those by solar gains through building elements (glazed-ones as well as opaque-ones) and those due to thermal radiation to the (cold clear) sky. The latter needs to be subtracted from the former to arrive at the overall value.

The heat flow by solar gains through building elements is determined by multiplication of a shading reduction factor for external obstacles (e.g. due to other buildings, topography or overhangs), the solar irradiance (depending on the location of the building's site and on the orientation and the tilt angle of the building element) and the effective collecting area. The determination of this area depends on the type of facade element, glazed or opaque:

› **Effective collecting area of glazed elements**

The effective solar collecting area of glazed envelope elements, such as windows, is the product of:

- the total solar energy transmittance (g-value; equivalent to the time-averaged fraction of energy passing through) of the element's transparent part (product property)[-]
- a shading reduction factor for movable shading provisions (function of g-values with and without solar shading and the time the shading is in use; determination depending on method used (seasonal/monthly/hourly)) [-]
- a factor expressing the frame area fraction [-]
- the projected area of the glazed element (e.g. the window area) [m²]

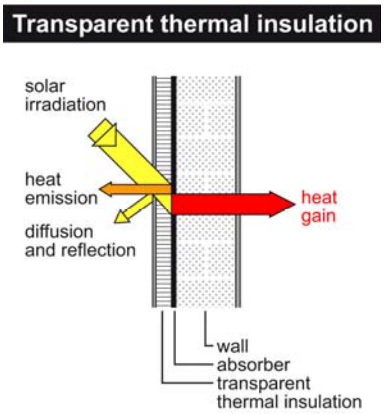
› **Effective collecting area of opaque building elements**

The effective solar collecting area of an opaque part of the building envelope is the product of its:

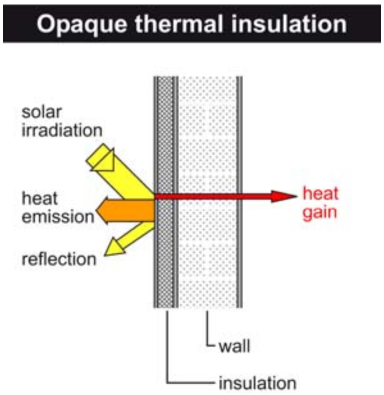
- absorption coefficient for solar radiation [-]
- external surface heat resistance (standard value: ISO 6946) [(m²K)/W]
- thermal transmittance (U-value) [W/(m²K)]
- projected area [m²]

In most conventional buildings, the influence of opaque elements on the overall solar heat gains is insignificant, except for large (flat roof), dark and/or poorly insulated surfaces.

Similarly, the extra heat flow due to thermal radiation to the sky for a specific building envelope element is determined by multiplication of its external surface heat resistance, its thermal transmittance (U-value), its projected area, the external radiative heat transfer coefficient and the average difference between the external air temperature and the apparent sky temperature. Again, the contribution to the overall value is normally small, unless the surface facing the sky is very large.



<u>Figure 10:</u> Transparent thermal insulation is not only a good thermal protection, it also allows heat flow of solar energy through the wall (solar heat gains).



<u>Figure 11:</u> The sketch illustrates the functionality of opaque thermal insulation. Comparison of figures 10 and 11 shows the difference in heat transfer of opaque and transparent insulation.

5.3 Unconditioned sunspaces (conservatories/ greenhouses)

The calculation procedures provided are to be applied for unconditioned, particularly unheated, sunspaces that are adjacent to a conditioned space but separated from it by a partition wall, as are most conservatories and greenhouses.

In the case of old existing buildings, where gathering the full required input dataset would be highly labour-intensive, a simplified method or default values defined at national level may be used instead.

When considering the heat transfer by transmission and ventilation, an unconditioned sunspace is handled like any unconditioned space, using an adjustment factor, as covered by clauses 8 and 9 of the standard.

The solar heat gains entering the conditioned space from the sunspace are the sum of direct solar heat gains, via the sunspace through the partition wall and indirect heat gains through the partition wall from the sunspace heated by the sun (see figure 9). The latter is given by a lower value for the above mentioned adjustment factor for transmission and ventilation, resulting in reduced transmission and ventilation losses from the conditioned space. The calculation method quantifies the positive effect during the heating season. However, the same procedure must also be used to calculate the negative impact of the solar gains for the cooling (summer) mode, taking into account any extra (seasonal) solar protection and ventilation provisions, if present. Note also that in the calculation method it must to be taken into account that the direct solar gains via the sunspace into the conditioned space are reduced due to the shading caused by the sunspace envelope (reflection, absorption, frame fraction). Depending on the design, the net effect of the sunspace may thus be found to be less than expected.

Input parameters

The following input parameters are required (see figure 9):

For the sunspace envelope as well as for transparent and opaque parts of the partition wall:
- area [m²]
- effective total solar energy transmittance [-]
- frame area fraction (for transparent elements only) [-]

For each surface in the sunspace, absorbing solar radiation:
- area of the surface [m²]
- solar absorption factor [-]

In addition:
- shading correction factor accounting for external obstacles [-]
- heat transfer coefficients for transmission from internal spaces through the sunspace to the external environment [W/K]

Conservative approximation and simplified method

Instead of applying the detailed method, a conservative approximation can be used, if this is approved at the national level. The sunspace is then treated in the same way as for any kind of unconditioned adjacent space, meaning the additional indirect gains via the sunspace are ignored while the direct solar transmittance through the partition wall, which will be reduced by the sunspace envelope, is taken into account.

The use of another simplified procedure is also possible, again if approved at the national level. The adjustment factor used for unconditioned spaces is corrected, to reflect the beneficial or negative effect of the additional solar gains in the sunspace during the heating and cooling periods. This is a refinement of the conservative approximation introduced above.

Further development of this procedure

Within the European project “BESTFACADE” (www.bestfacade.com), an appropriate calculation procedure for double skin facades was developed, based on the approach explained above. For this purpose, the methodology was modified and extended. Additional objectives of the project were to present an information database, a design guide and default values for typical applications, in order to promote the concept of double skin facades.

The German standard “DIN V 18599” [3] already contains a calculation procedure for double skin facades that is based on this method, which could serve as model for future CEN procedures concerning double skin facades.

5.4 Opaque elements with transparent insulation

For the purpose of collecting solar energy, transparent insulation material has been designed. Annex E of the standard EN ISO 13790 provides a calculation method covering its positive effect during the heating season as well as the unwanted solar gains during the cooling season, taking into account whatever seasonal solar protection and ventilation provisions are present.

Input parameters

The following input parameters are required for the calculation:

- the total area of the element [m²]
- the area of the element covered with transparent insulation [m²]
- the thermal resistances of the opaque element behind the transparent insulation and of the transparent insulation itself [(m²K)/W]
- the total solar energy transmittances of the transparent insulation for both cases: normal and diffuse-hemispherical incidence [-]
- the thermal resistance of the air layer (enclosed) between an opaque element and the transparent insulation [(m²K)/W]
- internal and external thermal surface resistances [(m²K)/W]
- the shading correction factor [-]

Output parameters

The following properties can be derived, serving as further input for calculation of the energy need for heating and cooling:

- the thermal transmittance of the element (internal-external) [W/(m²K)]
- the external thermal transmittance of the element (from the surface in contact with the transparent insulation product to the external environment) [W/(m²K)]
- the effective total solar energy transmittance of the transparent insulation product [-]
- the reduction factor due to non-transparent frame area of the transparent insulation (frame area fraction) [-]
- the effective collecting area [m²]

For the calculation of heat transfer by transmission, the transparent characteristic of the insulation is not relevant, and it must be treated in the same way as any other kind of opaque construction element.

6 > FAQ

Why use passive heating or cooling?

The main advantage of passive systems is that they do not use energy even though they facilitate thermal comfort and good indoor air quality. Nowadays, as public awareness of the importance of ecological considerations, sustainability and pollution control increases and as the costs of all forms of energy rapidly rise, passive systems become more and more attractive.

Can passive systems be implemented in existing buildings?

The use of passive heating and cooling depends mainly on features that are generally decided before a building is built. These are for instance the location of the building, its orientation, the choice of materials and the quality of planning and building. This means it is difficult to implement passive systems in existing buildings. Nevertheless, there are components, which can be added later, for example (automatic) shading devices or a sunspace.

Are passive systems explicitly covered by CEN-standards?

Apart from solar heat gains, the main factor of passive heating, which is covered in a specific chapter of the standard EN ISO 13790, passive systems are not explicitly covered by CEN-standards. But as these systems essentially influence several aspects of heat flow, they are also indirectly covered by different parts of this standard and by those standards dealing with thermal and solar properties of building components.

Are there ways to account for the contributions of passive heating and cooling as part of the renewable contributions for buildings' energy use?

Being highly relevant, the contributions of passive heating and cooling systems should definitely be taken into account explicitly or rather be seen as part of the renewable contributions, where already minimum requirements are demanded in several countries. This could for instance be implemented by the definition of standard solar heat gains used in reference building calculations, making it possible to reward above-average gains.

7 > References

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