Existing technical solutions

for the improvement of the building's energy efficiency

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UNIT 0. Introduction

1. Why is energy renovation necessary?

Every day we give greater importance to the energy consumption of our buildings, either due to environmental interests related to the reduction of greenhouse gas emissions, economic goods, linked to the reduction of the energy bill first of the users and, in general, of the large countries, drivers of energy saving measures that allow them to alleviate the burden of importing energy from abroad, mainly from fossil fuels such as coal, gas, oil, etc.

In this framework, the European Energy Directive of 2002 set the guidelines to be followed by all EU member countries in terms of energy efficiency, but without establishing specific objectives, which were later presented in 2007 through the initiative 20 / 20/20, an ambitious plan that aims to achieve three great achievements by the year 2020:

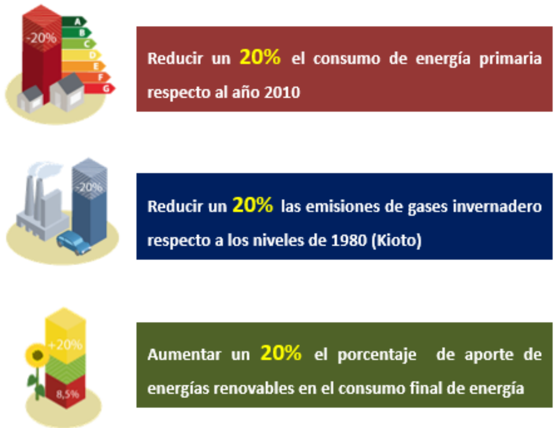

Image 01. Objetives 20/20/20

(Note: these objectives have been extended by the EU for the period 2020-2030)

The first of the objectives, to reduce 20% the consumption of primary energy, can not be carried out only with greater efficiency in new buildings, even more so if we take into account the fall of the construction sector in the first decade of the 21st century, which leaves us a real estate park with a large number of buildings previous to the current regulations (CTE 2006), built mostly between the 70s and 90s.

Within this group with the greatest potential for energy rehabilitation, we will also distinguish in those before or after the first Spanish legislation that required taking into account thermal losses in buildings (NBE CT-79)

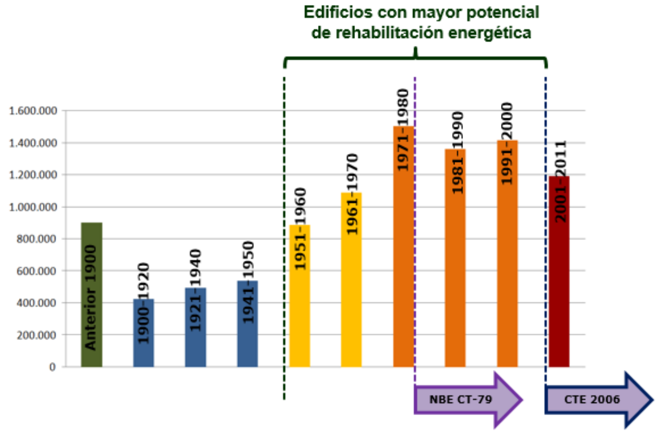

Image 02. Evolution of the real estate park in Spain

Remember:

If we intend to achieve the objectives set, it is not enough to build better in the present and future, we will also have to promote and bet on the energy rehabilitation of existing buildings.

2. The regulations as a driver of the evolution of our buildings

The current regulatory framework guides our buildings to three general objectives:

-Lower energy consumption

-High efficiency of air conditioning equipment

-Increase in the use of renewable energies

> *Remember:*
>
> *The regulation in matter of power impels to our buildings to a lower consumption, greater efficiency of the equipment of air conditioning and increase of the employment of renewable energies.*

Setting the objectives, improving our buildings from the energy point of view involves different actions:

a) First of all it is necessary to establish what is your current state, compared our building with those around it.

This system is none other than the energy certification of the buildings, in which the building is considered a consumable rather than, as if it were a household appliance, when purchased by its owner must report the monthly expenditure that will mean keeping it in a condition habitability For this purpose, a scale of letters between A and G is used, being a class A building the most efficient.

The energy certificate is regulated by RD 253/2013, being mandatory for the purchase or rental of a property from April 14, 2013.

It is currently composed of a first document that summarizes the construction characteristics and breakdown of consumption of the building, and a second in which are presented a series of measures that informatively indicate which actions are the most convenient for the energy improvement of our building, all of them susceptible to access to different subsidy plans.

b) In the second place, it is necessary to orient the improvements that are made in a way that responds to reasonable minimums, thus preventing the investments made from reaching the global objectives established by the regulations.

With this purpose the Technical Building Code, in its document CTE-HE energy saving, establishes maximum values of energy loss associated with each element of the building in which it is intervened, always depending on its nature and importance of the rehabilitation carried out . The greater the intervention and with it the associated budget, the greater the requirement.

In a specific intervention (for example, changing windows), only the rehabilitated element will be required to meet minimum efficiency values. If the rehabilitation exceeds 25% of the thermal envelope of the building, we will be required a minimum efficiency of the overall building.

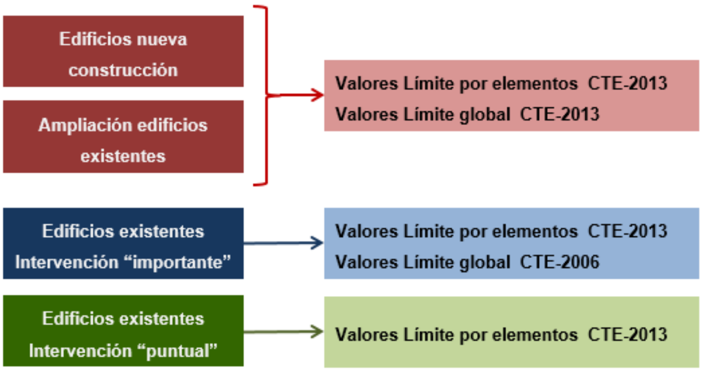

Image 03. CTE-HE1. Application according to building typology and intervention

If the CTE-HE regulates the constructive part of the building, the Regulation of Thermal Installations in Buildings (RITE) ensures that the air conditioning or sanitary hot water production equipment that we incorporate comply with a minimum level of efficiency, complementing in this way a correct energy renovation of our building.

Remember:

The regulations are presented as a means of promoting the energy evolution of our buildings, indicating their current situation, how we can improve it and limiting the efficiency of the measures we adopt to reasonable minimums.

As a whole, the current regulatory framework has evolved, responding to the various European Directives on the subject as major drivers of the regulations of each country, and we can see summarized in the following scheme for the case of Spain where there are three large documents in matters of energy efficiency:

1.- Código Técnico de la Edificación (CTE)

2.- Reglamento de Instalaciones térmicas en Edificios (RITE)

3.- Real Decreto sobre la certificación de la eficiencia energética de los edificios (RD 253/2013)

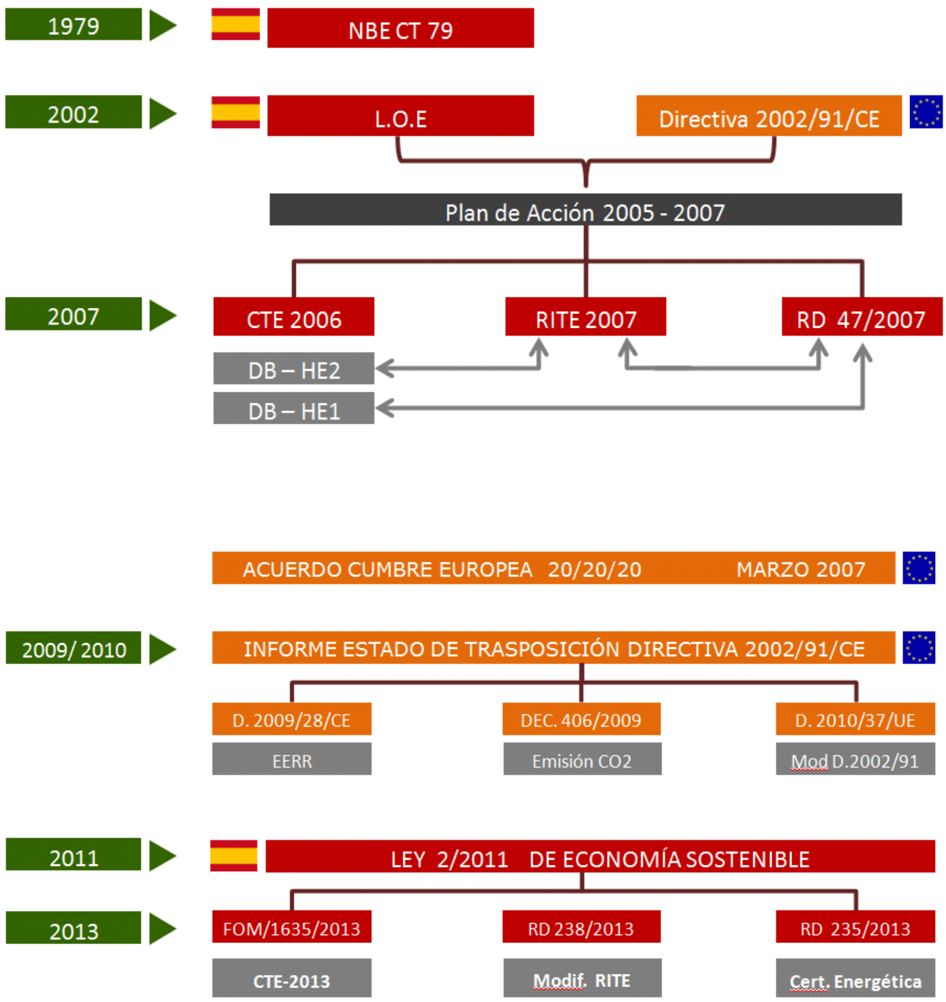

Image 04. Evolution of the Spanish regulatory framework in energy efficiency

3.-Thermal envelope, passive and active systems

Before beginning with the description of the different rehabilitation techniques, it is convenient to familiarize yourself with some terms that will help us understand the functioning of our building.

The final objective from the thermal point of view is to keep the user in comfort conditions (around 21ºC in winter and 25ºC in summer, with relative humidity in both cases of 50%), with the lowest possible energy consumption.

For this the building faces the external conditions of each locality by two means:

Passive systems, understood as those that do not require the consumption of energy to act. They are based on a correct architectural design and the use of suitable materials for each function. In turn we can divide them into:

• Thermal envelope of the building, that is, its enclosures with the exterior, terrain or unheated spaces, such as facades, roofs, floors, etc.

• Ventilation systems, responsible for maintaining the sanitary conditions inside the building

• Orientation and solar capture, that is, the way in which the building uses or protects itself from solar radiation according to the climate and time of year

Active systems. Although the desirable thing would be that a building does not require the consumption of energy to maintain its comfort conditions, in most cases the reality forces us to provide equipment, such as boilers or cooling systems, to complement the measures Passive insulation and control of ventilation with the generation of heat or cold when necessary.

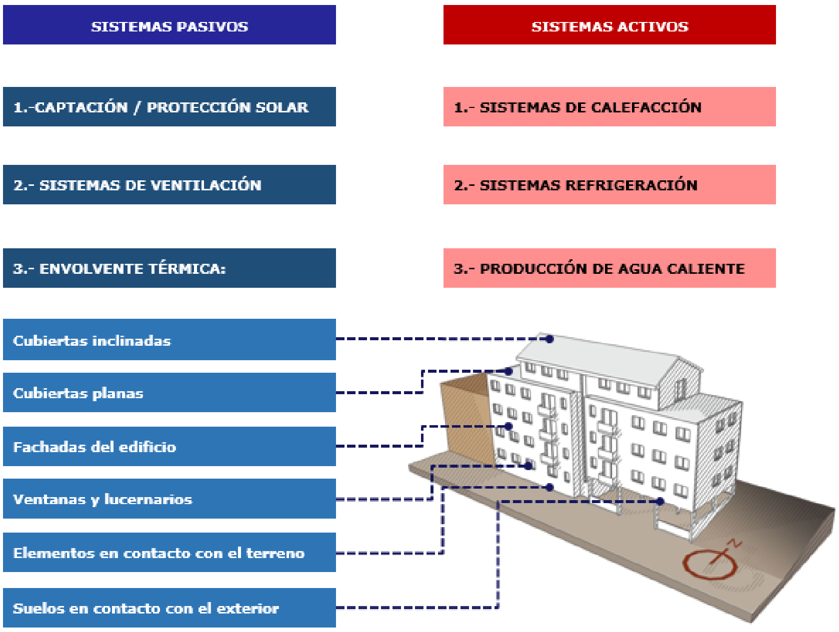

Image 05. Scheme of passive and active systems in a building

Remember:

After the above definitions, we can understand the building to be rehabilitated as a system that aims to keep us in thermal comfort, whatever the external conditions, using passive insulation systems in its envelope and control of ventilation, as well as generating the energy you need through active air conditioning systems.

4. Demand and energy consumption

If we consider that the heating, ACS or refrigeration systems try to supply or extract from the interior of the building a quantity of heat that allows us to reach the conditions of habitability, that amount of heat in a moment of time is called thermal load, and it is measured in watts (W).

However, the thermal load is variable since its value depends on the external conditions and the use of the building, so it is not representative of the energy that we need, or otherwise expressed "demand".

Therefore the concept of **energy demand** is used, which is the result of the sum of the thermal loads over a period of time, being able to speak of daily, monthly or annual demand, and therefore must be expressed in Watts over a period of time, for example 1 hour (Wh).

$$Demanda\ energía\ (t) = \sum_{i}^{t} Carga\ témica$$

However, we not only need the energy we demand, but also the energy consumed by our equipment (boilers, heat pumps) and even the one lost in the transport or emission of heat (pipes, radiators, etc.). It is what is known as system performance.

Demand and energy consumption are therefore united by the following expression:

$$\text{Consumo Energético} = \frac{\text{Demanda de Energía}}{\text{Rendimiento del Sistema}}$$

Example:

The boiler of a house is characterized by its power. A 25 kW boiler is therefore able to cope with a thermal load of equal value.

That same boiler will present short times during the year in which it requires 100% of its capacity (25 kW), for example during a cold wave with a simultaneous DHW consumption, while the usual is to use only a part of its power or even be off, so its annual consumption is not associated with the nominal power of the boiler (25 kW), but the sum of the actual energy demand that requests hour by hour, which may vary between 0 and 25 kW. The sum of the power generated over a period of time will be the energy demand it faces. For example 150 kWh / year

If that same boiler declares a yield of, for example, 90% during that same period of time, the energy consumption would be 150 / 0.9 = 166.66 kWh / year.

Note that the consumption is higher than the demand because the yield is less than unity, that is, the system assumes energy losses in its generation, transport or emission.

Remember

Energy demand *expresses the amount of energy we need to maintain comfort conditions in a building over a period of time.*

Energy consumption *implements the efficiency of the energy system based on its performance, so that:*

$$Energy\ consumption = \frac{Energy\ demand}{System\ performance}$$

5. ¿Which intervention is the most appropriate?

Selecting properly the rehabilitation techniques that we will use in the improvement of our building depends mainly on three factors:

• The objective we intend to achieve. The lower the energy consumption we intend in the building, the more means we will need to achieve it

• The type of building we face, generally marked by its constructive typology

• The presence of tenants at the time of the intervention, which will set the guidelines to follow depending on whether the work should be done with or without eviction from the property.

The objective can be either the improvement of the building from the point of view of heating, cooling or both, which in turn depends on the climate of the locality.

Facing a continental or atlantic climate imposes isolation needs to reduce consumption in heating, while in a Mediterranean climate the solar collection of the building must be controlled to reduce its consumption in refrigeration.

On the other hand, the year of building construction usually indicates its constructive typology, and with it the base on which to work, being the buildings before the 80s those that have a greater margin of improvement, since as a general rule, they lack of specific insulating materials, with presence in all cases of air chambers in facades and roofs.

These types of buildings are also those that represent an opportunity for intervention, since their age often lend themselves to conservation and maintenance works that can easily be directed towards an energy improvement.

Finally, we must assess the presence of tenants in the building during the course of the works, which may determine the choice of rehabilitation method to be used and the time of year to do it.

Example:

A building that must carry out conservation works in its façade can take advantage of the auxiliary means provided (scaffolding, cranes and operators) in the improvement of the insulation on the outside of the façade.

However, if the same building did not have to carry out works on its façade and was not inhabited at the time of rehabilitation, it would be feasible and more economical to make the insulation inside the rooms.

After the previous premises, the rehabilitation techniques that we will use in turn can be divided into three main groups:

- Rehabilitation of the building envelope (facades, roofs, windows, floors, etc.)

- Control of solar radiation (sun protection, glass replacement, etc.)

- Improvement of facilities (boilers, thermostats, refrigeration equipment, etc.)

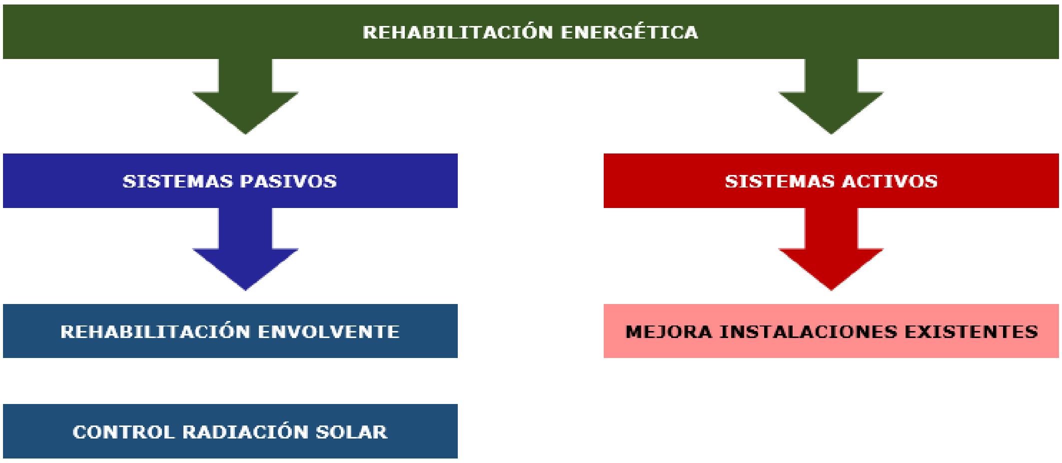

Image 06. Outline typologies of energy rehabilitation

6. Management and use of energy

Any energy rehabilitation that we perform in any of the aforementioned elements will not have the desired effect without proper management of the building by the user.

In their hands lies the decision to establish an adequate temperature in their home, according to the season and clothing, being in the work of technicians just to convey that each degree of heating temperature is around an additional 8% of energy consumption, while each degree that we discount to the internal temperature of cooling supposes a 10% of consumption on what really is needed.

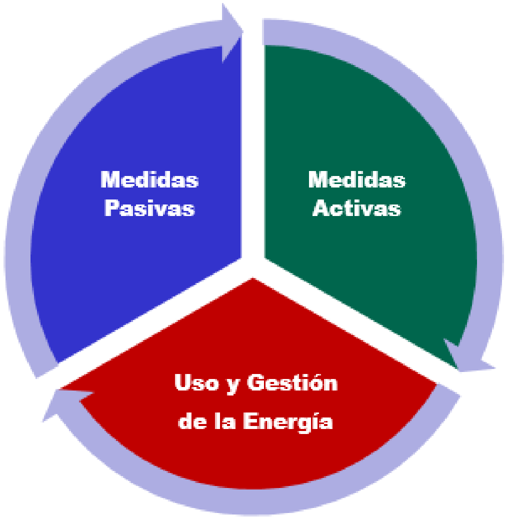

Image 07. Importance of management in building energy efficiency.

Remember

The use we make of our buildings is a fundamental part of their energy consumption.

UNIT 1. Techniques for improving the building envelope

1. Facades

The facade intervention techniques consist of providing an insulation layer on the outside, inside or in the intermediate chamber. Each of them has advantages and disadvantages that we must analyze and take into account.

a. Improved insulation on its outer face

It is undoubtedly the most effective method and with a lower incidence in housing, since all the work is done from the outside of the facade.

It involves not only the improvement of insulation of the surface of the walls but also the elimination of the so-called thermal bridges, that is to say, energy losses related to the constructive joints of the buildings, such as the facade with the structure or the perimeter of windows and blind boxes.

On the contrary, this type of interventions requires auxiliary means such as scaffolding or cranes that make the action more expensive, as well as the need to disassemble both own façade elements (clotheslines, antennas, air conditioning equipment, etc.) and alien elements (power lines, lampposts, etc.).

http://www.acuatroarquitectos.com/rehabilitacion-de-fachadas-evaluacion-de-sistemas/

Image 01. Intervention on exterior facades.

b. Improved insulation on its inner side

It involves creating a chamber inside the rooms of the building, either by plasterboard or brick factory, in which to house the insulation layer.

Its main advantage lies in the fact that it does not require specific auxiliary resources, the whole work being developed from inside the building. However, for the same reason, it presents the need to evict the tenants in the areas affected by the rehabilitation, so it is used when we face buildings without occupation at the time of the works.

Image 02. Intervention in facades in the interior.

c. Improvement of the insulation in the air chamber

In those buildings that have air chambers, their performance can be improved by filling them with injected insulating materials.

It is a non-invasive technique in which the work is done from the inside by means of small perforations at different levels of the wall, thus guaranteeing a homogeneous filling of the chamber.

On the contrary, its level of isolation is very limited by the size of the existing chamber, which is usually between 2 and 4 cm, and by its conditions, having to carry out previous inspections that guarantee that they are not clogged with debris or materials from work that prevent its proper filling.

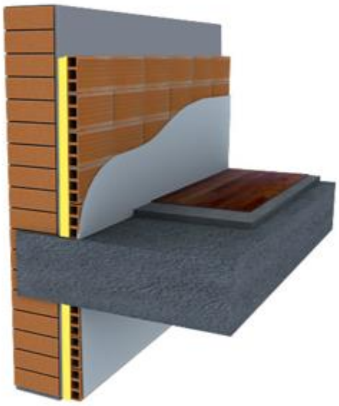

Image 03. Improvement of the insulation in the interior chamber of facades.

d. Thermal bridges in the intervention of facades

In a building, the existence of constructive joints between its main components is inevitable. Thus, the structure of the building, both pillars and horizontal slabs, come into contact with the facades and enclosures generating points in which energy losses are concentrated due to a reduction in the insulation conditions. It is what is known as thermal bridges.

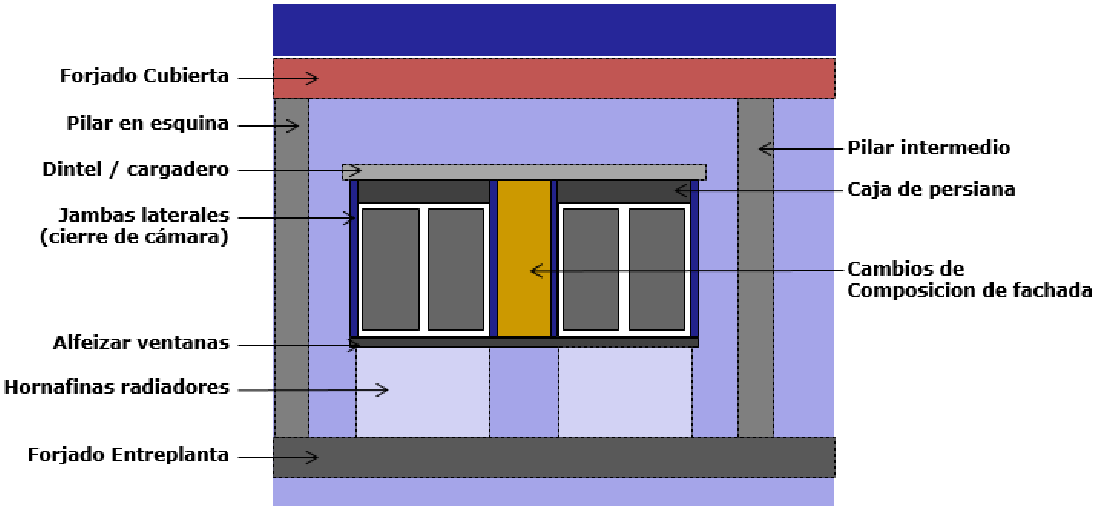

Image 04. Typology of thermal bridges.

We must understand a thermal bridge as an area compared to the rest of the building: if a building has bad insulation, thermal bridges are minimal, since in reality the whole building loses energy in a homogeneous way.

Therefore, the importance of its treatment increases with the insulation level of the building, that is, the percentage losses in thermal bridges are greater the greater the insulation of the façade.

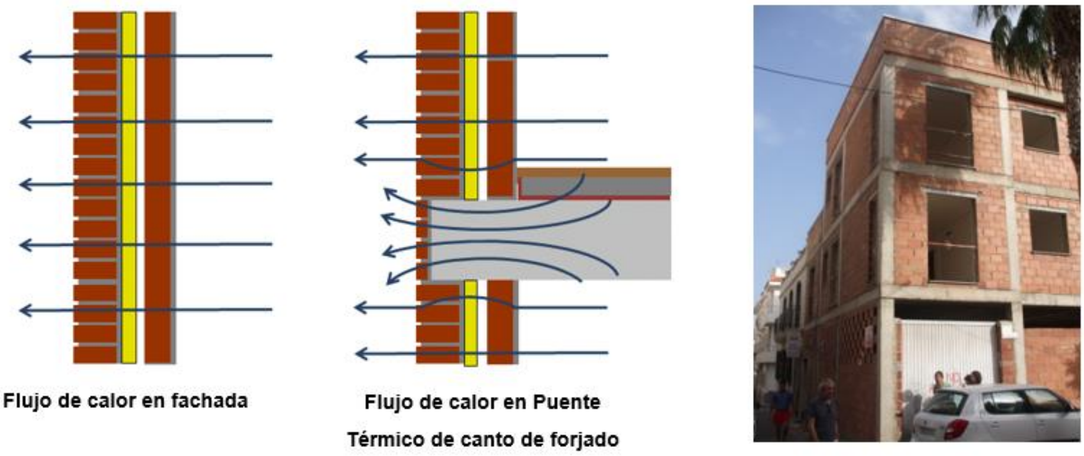

Image 05. Heat flow compared between conventional facade and thermal bridge of slab edge.

The type of intervention in the façade directly affects the thermal bridges generated. Therefore, having an insulation layer on the outer side contributes to its almost complete correction, while interventions on the inside or the filling of cameras practically do not affect them, and even increase their importance in the context of the building as shown in the previous graph, since they become uninsulated areas of a rehabilitated façade.

The following image compares the thermal losses between two façade and floor slab meetings. In the first case (left), a double-leaf facade with an air chamber is analyzed, without other isolation. In the case of the right of represents a rehabilitated facade with external insulation of 8 cm. In both cases, the color code represents the temperature variation between the interior and exterior.

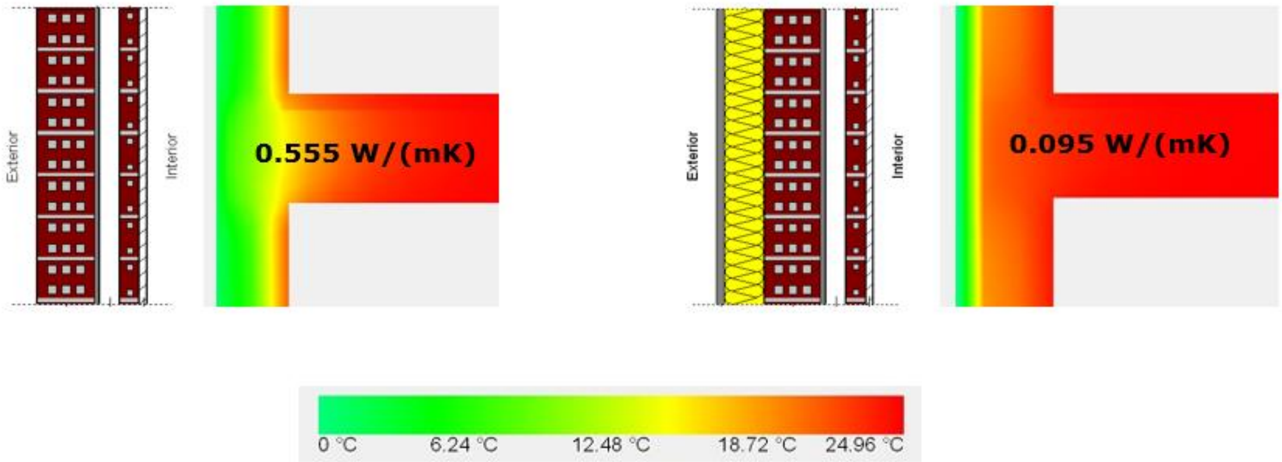

Image 06. Lost thermal comparisons in a thermal bridge of forged edge.

2. Roof covering

Again the main difference between the rehabilitation techniques that we can find is in the arrangement of the insulation layer, as well as the type of cover that we face, whether it is flat or inclined.

a. Sloping roofs

We can consider it as the traditional cover that evacuates the waters by simple slope towards its perimeter, expelling it directly or collecting it in gutters.

It usually consists of a board or support on which a waterproof layer is available, usually loose pieces such as curved or flat tiles, although sometimes we will find pieces of greater surface such as metal plates or bituminous sheets.

In general, the intervention can adopt two paths:

1. Improved insulation inside

It involves creating a false ceiling inside the building that allows the insulation layer to be housed, generally using suspended plasterboard.

The work is executed inside the rooms so, although it is not essential, usually assume their temporary eviction.

In addition, before the intervention, it must be considered which facilities will be affected, such as lighting points, air conditioning ducts, water distribution pipes, etc.

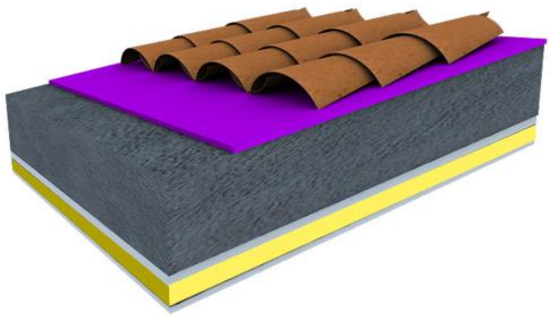

Image 07. Inclined roof. Improved insulation inside.

2. Improvement of insulation under tiles

The exterior appearance of this type of roof tile is undoubtedly an element to be conserved, so it is usually decided to disassemble it to incorporate the layer of insulation under them.

This type of intervention is usually motivated by waterproofing problems in which the dismantling of the tiles is used to incorporate insulation in the roof.

It requires more auxiliary means and a correct planning of how and at what time of the year the works on the roof will be carried out. On the contrary, it does not involve intervening inside the building, although it may be affected according to the state of the rehabilitated roof.

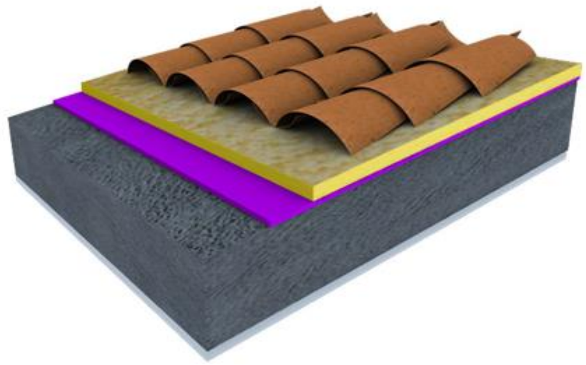

Image 08. Inclined roof. Improvement of insulation under tile.

3. Improved insulation in cameras

Sometimes the sloping roof rises on a horizontal slab through brick factory partitions, generating an air chamber between the support (forged structures) and the roof (inclined plane containing the impermeable layer).

In these cases you can take advantage of this space to incorporate layers of insulation that improve the performance of the air chamber, combining low cost in auxiliary media with high thermal performance. On the contrary, its effectiveness is limited by the dimensions and conditions of geometry and access to the camera.

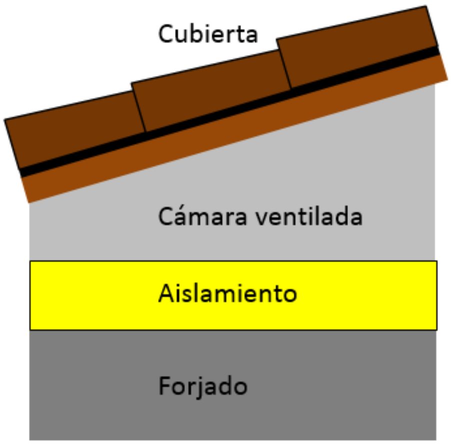

Image 09. Inclined cover. Improved insulation in cameras under cover.

b. Flat covers

In a flat roof, the collection of water is carried out in its interior by means of sinks that divide its surface into zones with gentle slopes (1 to 3%).

The traditional flat roof is built on a structural board or slab that serves as a support to the waterproof layer, usually of bituminous material, on which the finish is disposed, well passable (for example, mortar and screed) or non-passable (gravel or Similary).

A variant of the above composition is widely used is the ventilated flat roof, which on the support or forged has an air chamber raised on a brick factory that gives the whole a certain insulation.

1. Improved insulation inside

Similar in procedures, advantages and disadvantages to the techniques used in inclined roofs, with the exception that the support is usually flat, which facilitates the work to be done.

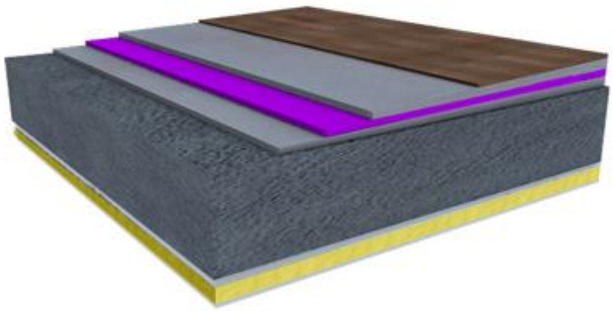

Imagen 10. Flat roof. Improved insulation inside.

2. Improvement of insulation from the outside

It is based on providing an insulation layer on the existing roof, which adds to the building's energy improvement other constructive advantages:

• Prevents the deterioration by solar radiation of the exposed waterproof sheets

• Protects the waterproof sheet from mechanical damage, such as crushed gravel, roof anchors or inadequate maintenance work that could damage it

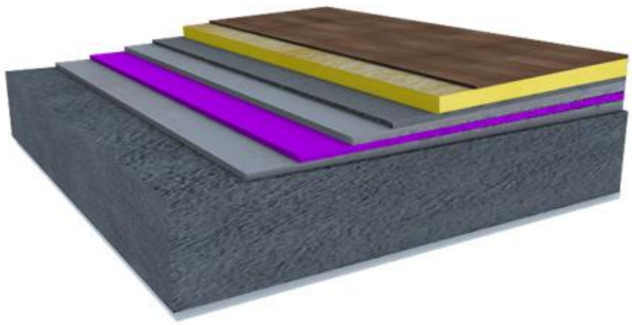

Image 11. Flat roof. Improvement of the insulation on the outside.

3. Floors

Faced with the exposed facades and roofs, the floors of the building can be well in contact with the outside, such as balconies or arcades, or in contact with the ground.

In this second case, the advantage lies in being in contact with an element whose temperature is much more stable than that of the outside air, and therefore offers some insulation.

On the other hand, the land can be a source of humidity leaks in the building that, if not properly treated, reduce the conditions of healthiness of the rooms. The latter is usually the main cause of their rehabilitation, which can be used for energy improvement.

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a. Insulation of floors in contact with the outside

Its arrangement offers the opportunity to act on its lower face, without intervening inside the building, simply adding a layer or insulation that can be protected by various finishing (mortar, false ceiling, etc.)

The intervention is simple in terms of the use of auxiliary means and offers few problems to the tenants of the property.

Image 12. Insulation of floors in contact with the exterior.

b. Insulation of floors in contact with the ground

In this section we must include not only the floors, but in general any enclosure in contact with the ground (such as walls or roofs).

In these cases, the energy improvement must respond equally to the conditions of space sanitation, avoiding moisture infiltration.

From the point of view of the intervention, in general, the options are limited to actions inside the rooms, again through a layer of insulation, or walls, such as ceilings or floors.

In this case, the use of water-repellent insulation is mandatory, that is to say, those whose properties are not affected by the presence of humidity.

Image 13. Isolation of soils in contact with the ground.

4. Windows

So far, opaque building components have been evaluated, and therefore do not allow direct passage of solar radiation into buildings.

A window is a mixture of transparent part (glass) and opaque (frame or carpentry that supports the glass), so that its intervention responds to criteria of both isolation and radiation control.

The Sun is a necessary source of heat in buildings to control indoor temperatures on winter days without the need for energy consumption.

However, in southern locations, their excessive presence in summer leads to overheating problems that we should also avoid.

To understand the operation of a window we must resort to what is known as the "greenhouse effect", based on the properties of glass and solar radiation.

From the Sun we get heat in the form of high energy waves, which are able to pass through the glasses due to their properties. However, when they reach the interior of our buildings, they reheat walls, floors, ceilings and any object or person inside, turning it into a generator of heat.

In this case, the heat generated by these objects is made by low energy waves (infrared), which are not able to pass through the glass, being "trapped" inside the building and, thereby, increasing its temperature.

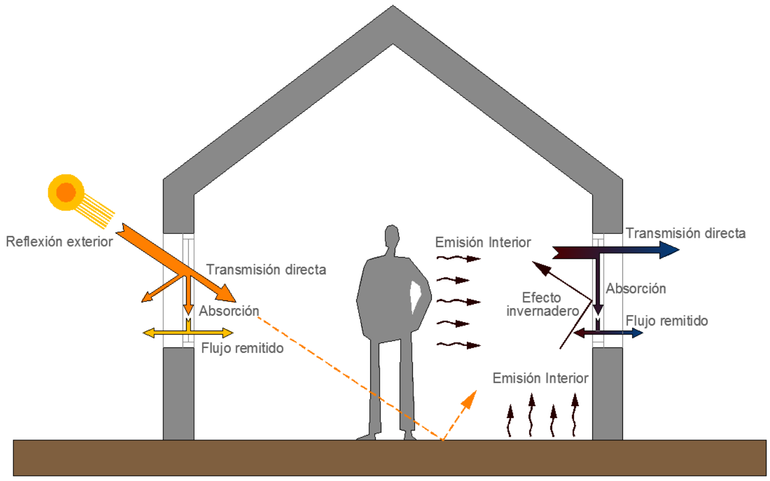


Image 14. Scheme of operation of the "greenhouse effect" in buildings.

> *Remember:*
>
> *A correct rehabilitation of windows must take into account the locality in which it is located and its thermal needs, putting in the balance the capture and solar control in its proper measure.*

a. Improved window insulation

The improvement of the insulation affects the control of the loss or gain of temperature in the same way that happens with any of the opaque elements so far analyzed.

As is logical, in carpentry and window glass, we can not provide layers of insulation as we have been doing so far, so we will have to resort to supplement existing (double windows) or change it by more advanced materials and technologies.

- **Double window**

It is the most economical way of thermal improvement, since it does not require investment in carpentry or glass of high quality, but only generates an air chamber between the existing window and the new one. This camera will be more effective the lower the air filtration from the outside, and by itself will provide thermal and acoustic insulation to the whole.

Its intervention does not require major works, just take into account that it is considered as façade modification, and as such is subject to current legislation and approval by the rest of the building's neighbors.

Image 15. Improvement through double windows.

- **Change of windows. Materials**

Sometimes the deterioration of the carpentry or the preferences of the users lead to the complete replacement of the same.

In these cases, from the energy point of view, we must base our choice on those windows that allow a lower energy loss, comparing for this the thermal transmittance value U (W / m2K) provided by the manufacturer, so that a lower transmittance value, lower thermal loss.

secciones:	marco 60 mm. hoja 65 mm.
espesor medio teórico:	ventana 1,5 mm. puerta 1,7 mm.
longitud de poliamida:	24,8 mm.
acristalamiento:	de 14 a 40 mm.
transmitancia térmica / zonas CTE:	perfiles nudo lateral **U = 2,9 W/m²K** según norma UNE-EN ISO 10077-2 2008
zonas de cumplimiento del CTE *: A B C D E * en función de la transmitancia del vidrio	

Image 16. Carpentry technical sheet in which the associated thermal transmittance value is declared.

Within the possibilities of carpentry we will distinguish depending on the material:

Wood. These are the traditional frames whose thermal behavior depends very much on the density of the wood (the higher the density, the less insulating) and the maintenance conditions. The transmittance value is about 2.3 W / m2K, and we must pay special attention to its permeability and closure system, as well as to the maintenance tasks that it will require in the future (sanding, varnishing, etc.).

Aluminum. The aluminum is a very resistant material against the aggressions of the external climate, hardly flammable, relatively economic and with a wide range of possibilities in terms of colors and designs. For all these reasons, gradually in Spain it has been used as a preferred material in windows since the 1960s.

However, its main thermal problem lies in the material that composes it, since aluminum is a highly conductive metal, so the thermal losses of traditional aluminum joinery are placed on 5.4 W / m2K.

At present, intermediate plastic elements are used between the interior and exterior aluminum sides of the carpentry, reducing the thermal transmittance to values above 2.8 W / m2K. These are the so-called carpentry with thermal bridge break (RPT).

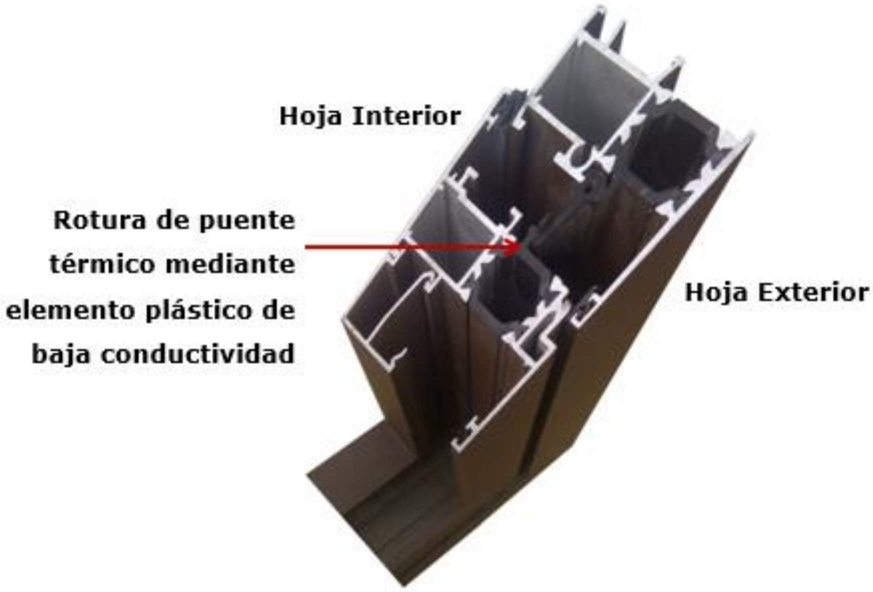


Image 17. Comparison of materials for window carpentry.

PVC. Used mostly in northern Europe, it is the carpentry with the greatest reduction in thermal losses, with values around 1.5 W / m2K, even lower. PVC profiles are based on creating an internal structure of air chambers as insulation, and although its price is usually higher than aluminum, so are its benefits.

In contrast, its variety of designs and colors is lower, as well as its tolerance to fire and continued resistance to solar radiation.

Image 18. Comparison of materials for window carpentry.

Regarding the glasses, we will establish 3 groups:

Monolithic. Traditional single-layer glass, with thermal loss values around 5.7 W / m2K. Currently in disuse, but very used in buildings before the 80s.

With camera. Composed of two or more sheets of glass between which an air chamber or an inert gas is available as insulation. The size of the chamber and the gas it contains depend a great part of its thermal properties, oscillating between values of 2.8 to 2.2 W / m2K.

Low emissives. Emissivity is the property of every body with a temperature of emitting heat. When the sun warms the glass of our windows, they emit part of that energy to the outside.

Imagine now that we have a layer capable of not emitting heat outside but "bounce" into the interior of the building. In this way we would be reducing the thermal losses of the windows, placing this type of glass in values above 1.8 W / m2K, according to its type and composition.

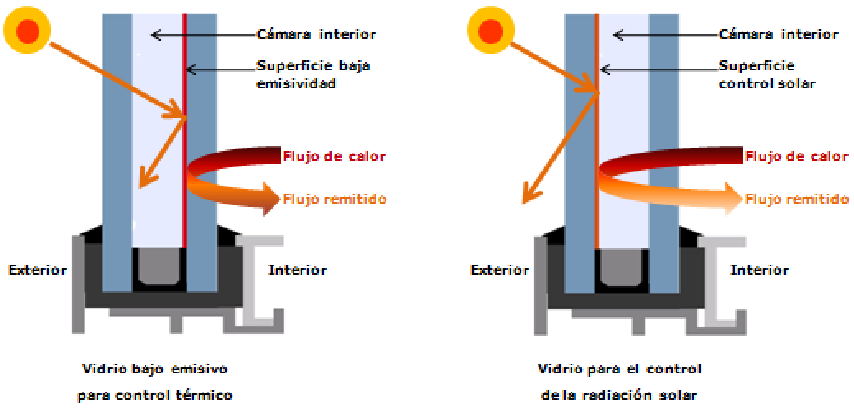


Image 19. Comparison of glass typology in windows.

b. Closure and permeability systems

Much of the thermal and acoustic performance of the windows depends on the choice of the closure system, with two large groups: sliding or folding windows. Here are some indications to consider in your choice:

- **Sliding windows.** They allow a greater air passage (they are more permeable), so thermally and acoustically their benefits are lower.
  To his favor, his thickness is smaller allowing greater surface of glass and do not need of space in the interior of the building for his abatement.

- **Folding or swing windows.** Its permeability is much lower, almost nil in the current windows, which sometimes can suppose a condensation problem in the rehabilitation of existing buildings poorly insulated or with thermal bridges in the contour of the windows, since the reduction of ventilation is encouraged the appearance of condensations.

In favor, its greater thermal and acoustic insulation, as well as eliminate the discomfort of air leaks in the vicinity of the windows.

Image 20. Comparison of type of closing systems in windows

c. Treatment of thermal bridges (perimeter and blind drawers)

As it happens in the case of the joints between structure and façade, in the contour of the windows joint constructions are produced, prone to generate the already exposed thermal bridges, both in the lateral jambs as inferior sill or blind drawer in the upper part of the window.

Contorno de huecos y lucernarios	70% del total de perdidas por puentes térmicos
Jambas de ventana	30%
Alfeizar de ventana	15%
Caja de persiana sin aislar	25%
Interacción envolvente - estructura	30% del total de perdidas por puentes térmicos
Pilares embebidos en fachada	10%
Cantos de forjado	20%

Image 21. Importance of thermal bridges in the contour of windows.

In each of these cases we must analyze the pre-existing situation, which results in various intervention techniques:

1. The sides of the window lack insulation, usual case of buildings with an air chamber. The appropriate way of acting is not to limit oneself to the change of carpentry, but to take advantage of it to inject insulation around the possible perimeter, even at the expense of a small masonry work. In this way the thermal bridge is eliminated and annoying surface condensations are avoided in the walls of the window contour.

This situation occurs in more recent buildings when the pre-frames for the installation of the window have been received only with mortar, being the way of operating similar to the previous one, by means of projected insulation in the perimeter.

Image 22. Intervention in contour of windows with facades with air chamber.

2. The drawer of the blind is in poor condition or not insulated. Let us think that the blind box by its own definition is open to the outside, which is why it supposes a point of uncontrolled entry of air. In these cases the best way to act is to install a new box with perimeter insulation, usually around 2-3cm thick.

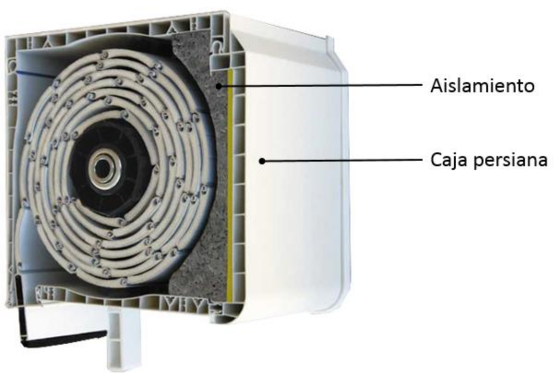


Image 23. Blind drawer with interior insulation.

5. Solar control techniques

In severe summer climates the radiation conditions lead us to the need to control the solar radiation to avoid excessive overheating of the building, which would entail a greater use of cooling systems.

There are two factors that we must analyze in this case:

1. **Orientation of the building**, it is logical that the solar protection is made on the facades that receive more radiation, especially the West, facing North orientations.

2. **Solar height**, which determines the angle at which the radiation hits your building. The more horizontal the sun's rays are, the more easily they penetrate our building. The more vertical, the easier it is to protect yourself from them with eaves, awnings or similar.

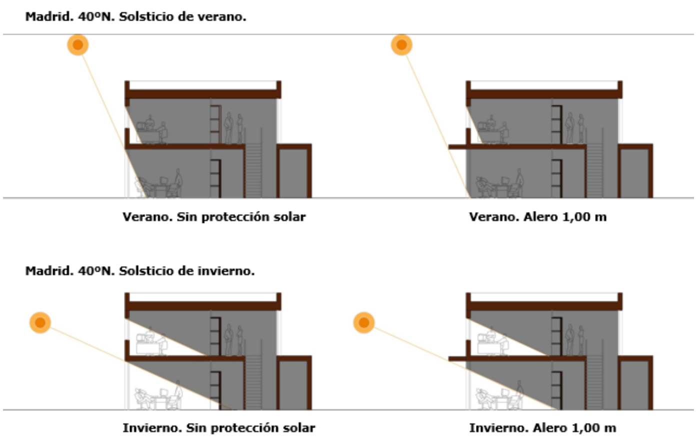


Image 24. Influence of solar height on radiation on a window in summer and winter.

For this reason, the West orientation is the one that gathers the highest temperature in summer, since it combines the horizontal solar radiation (late afternoon) and the overheating of the air during all the previous hours.

Remember:

We can say that an adequate solar control is one that allows the building to warm up in winter and protects it from the sun's radiation in summer.

To control the effect of solar radiation in our building we can choose several techniques:

a. Solar control glasses

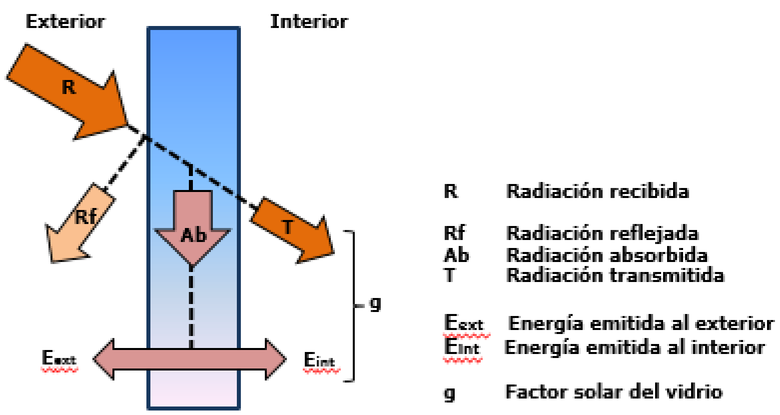
Similar to the aforementioned glasses under emissives, but with a layer of metallic particles on its outer face.

If in the case of thermal properties we relied on the value of the transmittance provided by the manufacturer, to assess the solar protection offered by a glass, we will use the solar factor symbolized in the letter "g".

A value of g = 0.60 indicates that, of 100% of the radiation received by glass under standard conditions, 60% reaches the interior of the building.

We can quickly deduce that a glass that offers us solar control should be placed at the lowest possible g values, generally around g = 0.4, when a standard low emissive glass usually has values g = 0.6.

In any case, using solar protection glasses leads to an increase in the demand for heating, since it is a fixed measure that acts in the same way in summer as in winter, so it is only recommended in warm climates and building with large glass surfaces.



Tipo de vidrio	Factor g
Vidrio simple	0,85
Vidrio doble	0,75
Vidrio doble bajo emisivo	0,6
Vidrio control solar	0,4

Image 25. Values of the solar factor in common glasses.

b. Fixed solar protections

In this section are the eaves, lattices, mullions, and in general any fixed element that interposes between the received radiation and the interior of the building.

In its design, it must again take into account the collateral effects that depriving of solar radiation may have on the heating consumption of the building.

Image 26. Fixed solar protections.

c. Mobile solar protections

They allow to adapt the degree of protection to each time of the year.

We include in this section both the manual mobile protection elements (awnings, shutters, blinds, curtains, etc.), as well as the automated ones, which by means of sensors are able to be regulated throughout the day and throughout the year.

UNIT 2. Intervention in the building facilities

The energy rehabilitation techniques that we have dealt with in Unit 1 cover the constructive part of the building, which at the beginning of the course we have called a passive part. It remains to analyze how to improve the efficiency of the most common air conditioning equipment.

1. Improvement of ACS (Sanitary Hot Water)

Reduction of DHW consumption to consume less energy

Although the following measure can be considered a passive system, we have included it in this section because of its relationship with energy consumption linked to the ACS. Since energy consumption depends directly on the flow of water that needs to be heated, reducing water consumption is an indirect way of saving energy.

Always under the premise of not reducing the comfort of use, the use of pearlizers or aerators allow mixing air with water thanks to the supply pressure, thereby reducing water consumption and, consequently, also the energy needed for heating .

It is therefore low cost devices and easy to implement in taps kitchens and bathrooms, especially indicated in showers and hot spots of ACS.

Figure 1. Aerator ring. Source: http://www.latiendadelahorrodeagua.com/blog/es/diferencias-entre-perlizadores-y-aireadores/

Energy improvements in centralized ACS installation

In broad strokes in blocks of houses we can find two schemes of generation of hot water:

-Individual, that is, a heating equipment in each house

-Centralized, with a system of generation and accumulation of ACS for all dwellings located in a technical room of the building

In the second case, the energy saving measures that we can implement are divided into two large blocks:

> -Improvement of the **accumulation systems**, increasing the thickness of the accumulation tanks and adjusting their volume to the real demand of the building, so that the necessary amount of water is heated and in its accumulation it loses the lowest possible temperature

-**Employment of pumping equipment** with frequency or speed variator, which allows to adjust the electricity consumption of the impulse pumps to the flow really demanded at every moment, avoiding unnecessary starts and stops, and with this increase the mechanical life of the engine.

With its use, the centralized pumping equipment consumes at any moment only the energy needed depending on the number of housing that at that moment requires hot water.

2. Improvement of boilers

The greatest consumption of a house, even in a warm zone, occurs in the sum of heating and domestic hot water production, and the most efficient way to generate it is through equipment that uses different fuels to heat water, either for consumption, to use it in heating.

Simplifying its operation, we can distinguish the following components in a boiler:

- **Fuel**
  Whether from renewable sources (solar panels, biomass, etc.) or fossil (natural gas, coal, propane), your choice is linked to the amount of CO_2 produced, and thus directly to the energy rating of our homes.
  In this case, the improvement lies in a change of fossil or electric type fuels towards the use of renewable energies (solar, geothermal or biomass) or simply to achieve a lower CO_2 production index (for example, change of coal by gas oil or diesel fuel by natural gas), avoiding as much as possible the use of electricity

directly, that is to say, by means of electrical resistances that heat the water, as it is the case of thermos and electric accumulators for heating.

Tipo de combustible	Kg CO_2 por kWh de energia	
Carbón	0,472	Menor emisión
Electricidad (Península)	0,311	
Gasóleo	0,311	
Propano	0,254	
Gas natural	0,252	
Biomasa	0,018	
Energía solar	0,000	

Figure 2. Comparison of production of Co2 associated according to fuel according to CTE-HE.

- **Generator equipment or boiler**

  It has a burner in which gases are produced at high temperature that circulate through the exchanger to heat the flow of water needed. Later the gases are evacuated by a chimney.

  Its mission is to "extract" the energy from the fuel, which is known as the calorific value of the fuel, its higher yield being the greater percentage of it able to obtain. Here lies the difference between traditional boilers of standard type and condensing boilers.

A standard boiler can only work in a high temperature range, with return water above 50 ° C, otherwise the gases used by the fuel burning, condense in acid and affect its internal parts. Its performance can never be higher than 100%, and it is generally above 85% depending on the age and maintenance of the equipment.

A condensing boiler, on the other hand, is prepared to assume that acid condensation thanks to the materials in which it is built, but even more, it is capable of taking advantage of it by generating an additional heat input, so that its performance can reach the 1.09% yield (100% on the calorific power + 9% extra by condensation), with values of 98% of yield being common.
The advantage of a condensing boiler not only lies in higher performance, but in working with water at low temperature, allowing the heating system to adapt at any time to the demand instead of being forced to work always above 50ºC return.

Let's give an example to explain its operation:

In a conventional house we turn on the heating until the thermostat detects that we have reached the indicated temperature. At that moment the boiler of standard type stops and later, when it is requested, it will start again, with the energetic loss that implies.

A condensing boiler, on the other hand, works by coupling its operation to what is requested, that is, it gradually decreases its performance by working at a low temperature instead of stopping completely, which prevents losses of successive start-ups.

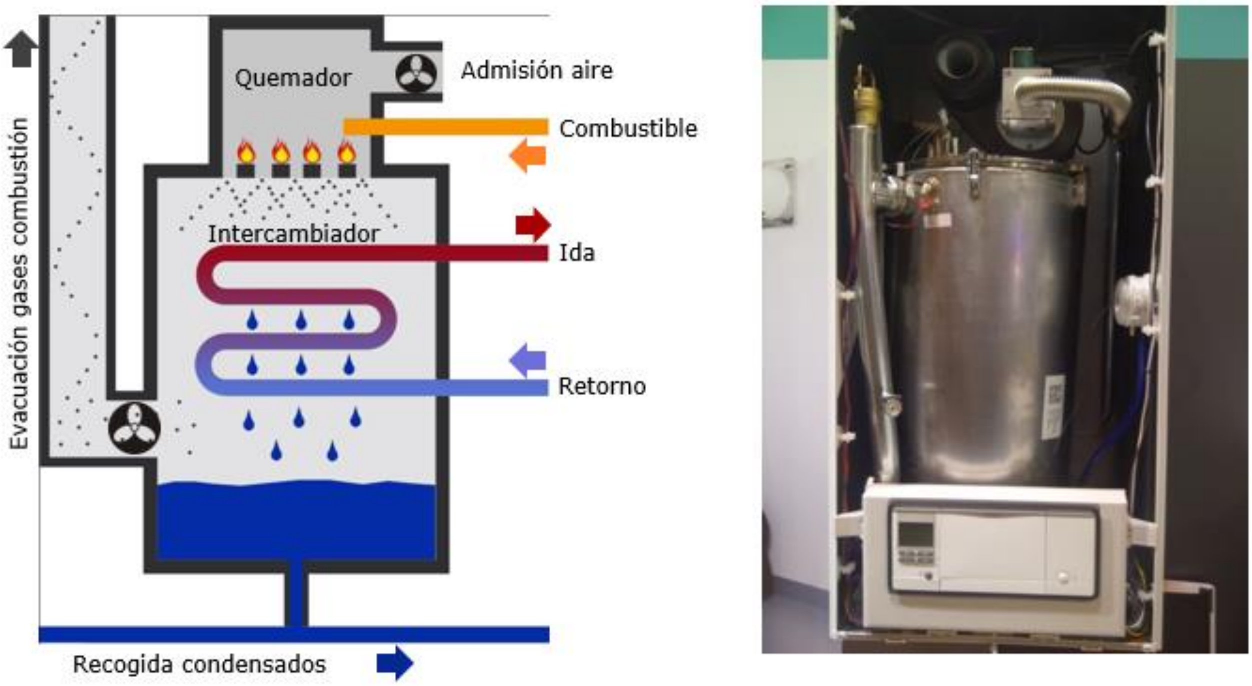


Figure 3. Scheme of operation of a boiler.

- **Distribution network.** Network of pipes in charge of joining the generator equipment with the issuers of each stay. Its efficiency is based on the choice of adequate insulation depending on where it is located.
  Indoors, insulation is not necessary, since the lost heat is directly contributed to the dwelling. However, in central boilers, with distribution sections in unheated or outdoor common areas, the isolation of the pipe network allows to minimize energy losses and that this is used to the maximum in the rooms.

Figure 4. Isolation and energy meters in centralized installation.

- **Issuing equipment.** Managed in each room to provide the heat that comes from the boiler. It is what we know as radiators, or in your case, underfloor heating. Its efficiency is based on correct regulation by the user, so that the temperature in the rooms is as homogeneous as possible.
  This implies the presence of regulating or thermostatic keys, either automated or manual, at the entrance of each radiator.

Remember

An efficient heating system is based on the choice of an adequate fuel, a high-performance generating equipment, the isolation of its distribution network and the correct regulation of its emitters.

Instantaneous, nominal and seasonal performance

By definition, the performance of a system is the relationship between the energy I obtain and the energy I consume in the process to obtain it:

$$\boldsymbol{Performance = \frac{Energy\ obtained}{Energy\ consumed}}$$

The maximum power that a device can offer is known as nominal power, which is what characterizes the boiler, heat pump or heater, and is the data that the manufacturer will give us.

Therefore, the performance of the equipment when working at maximum power is known as nominal performance, and takes into account the losses by combustion and heat dissipation on the surface of the boiler.

Example:

That the boiler of our house has a nominal power of 25 kW means that this is the maximum power it can develop.

In the manual of the equipment the manufacturer will establish, for that maximum power, the nominal performance of the equipment.

However, since our boiler does not always work at maximum power, it does not always have the same performance at all times.

The average performance over a period of time, or **seasonal performance**, is what really represents the performance of our team as it takes into account the energy losses associated with stopping and starting the boiler or service provision, and therefore depends on the typology of the boiler.

Condensing boilers are able to adapt their power depending on the needs, so they significantly reduce their stops and thus increase their seasonal performance.

Remember

The nominal performance of the equipment is offered by the manufacturer in its catalog for a load factor of 100%. Represents the maximum power that the team is capable of generating, but does not characterize the annual operation.

The seasonal performance expresses the efficiency of the equipment over a period of time, being superior in condensing boilers in relation to low temperature or standard type.

Since the seasonal yield incorporates a greater number of losses, it will always be equal to or less than the nominal of the equipment.

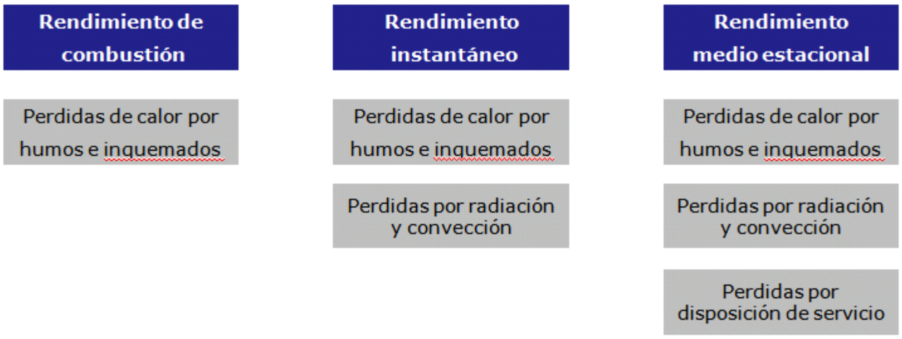


Figure 5. Combustion performance, instantaneous yield, seasonal average yield.

Reading the labeling of a boiler

Since the recent modification in 2013 of the Royal Decree of Thermal Installations in Buildings (RITE) determined that the type of boilers to be installed in new construction homes should be boilers whose performance increased when not working at full power, ie condensing boilers .

In a complementary way, the European Ecodesign Directive 2009/125 / EC (ErP Directive Ecodesing) establishes that from September 26, 2015, boilers, heat pumps and cogeneration equipment with powers between 0 and 70 kW, must incorporate a label energetic to report its main properties:

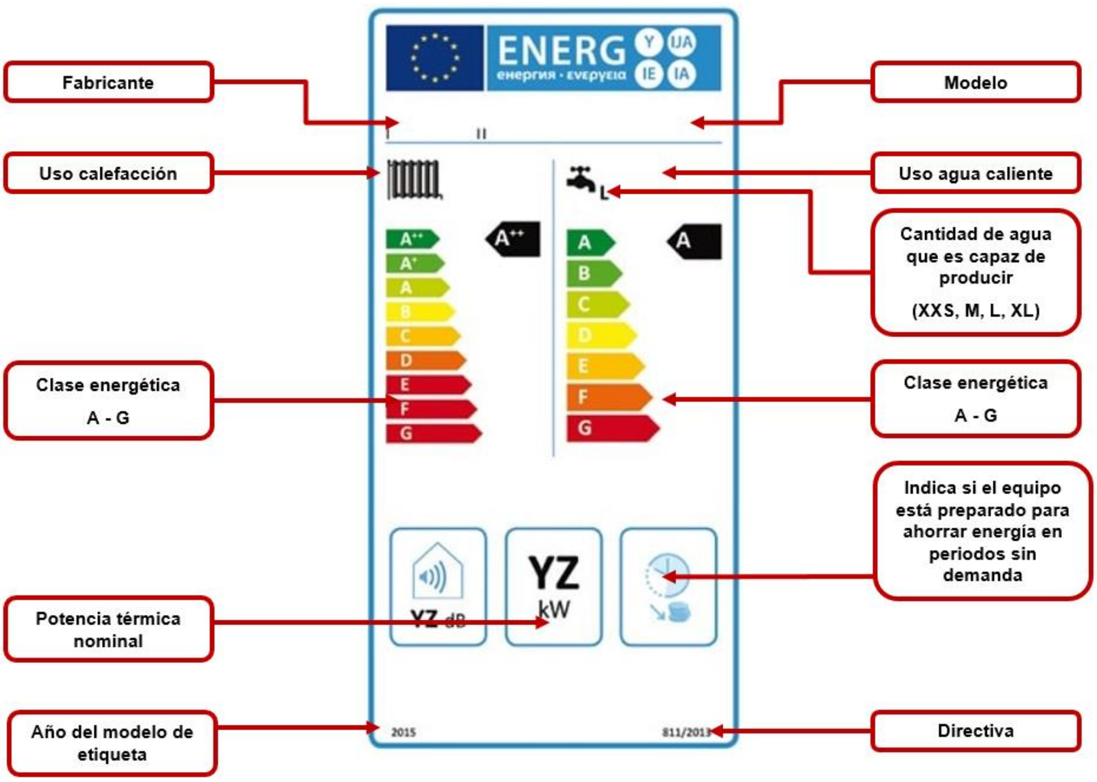


Figura 7. Boiler labeling.

3. Improvement of refrigeration equipment

The equipment that we usually use is of the compression-expansion type, with two exchange units, one housed inside the building and another outside.

It is important to understand that this type of equipment does not generate cold, but that they exchange heat, that is, they extract it from the rooms of the building to expel it to the outside. For this reason, their performance in the use of the electric energy they use is very high, around 3 kW thermal for each electric kW consumed (think that an electric heater for resistance only contributes 1 kW thermal per kW electric).

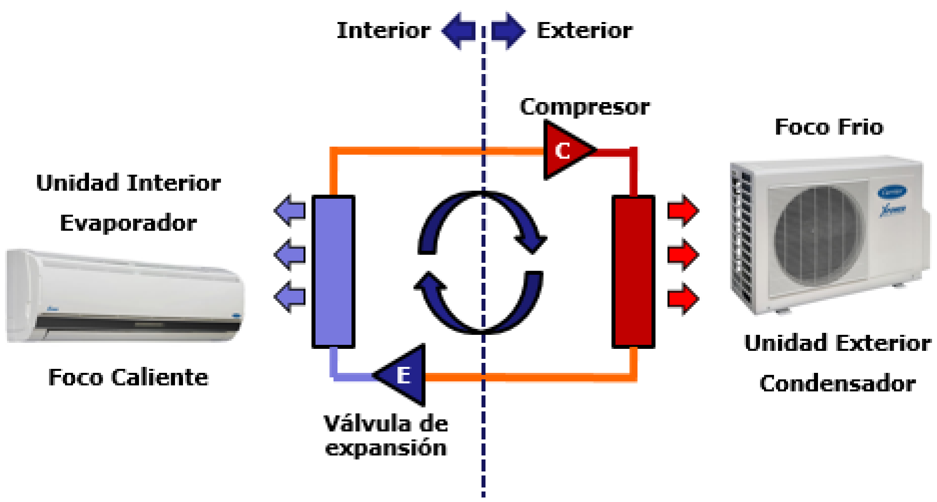


Figure 7. Diagram of operation of refrigeration system through two exchange units.

When planning a rehabilitation, you can choose different configurations, of which we will highlight the most common ones:

1. **Individual interior teams.** This is what we know as Split (if each indoor unit corresponds to an exterior) or multi-split (when several indoor units connect to a single exterior).
   The advantage of this system is that each room has its own equipment and therefore the temperature regulation is simpler, as well as its installation, since they can be arranged in any type of horizontal or vertical facing and allows to cool only the rooms that are desired, something usual in existing buildings.
   On the contrary, they require the evacuation of condensed water, so they must either be connected to a sump by gravity, or incorporate small pumps that can drive the condensate to drain.
2. **Duct network.** In this case, the equipment is unique and larger, usually located in the false ceiling of a wet room to take advantage of the proximity of evacuation points of condensed water.
   From the central equipment a network of pipes distributes the air through the house by means of insulated pipes to grids, which must have a regulation system, either manual or motorized, which allows to adjust the temperature of each room.ed de conductos.
   In this case, the control of the temperature is more complex, but the performance of the equipment is greater since the losses of a single equipment, although of greater power, are smaller than those of several dispersed equipment.
   The drawback is having to have a network of ducts in the house, which is not always possible, and that it is a comprehensive cooling system for the whole house, not a single stay.

Remember

We must select the highest possible performance equipment, and opt for individual systems or conduits depending on the possibilities offered by the building to be rehabilitated and the user's preferences.

4. Energy saving in residential lighting systems

Although electricity consumption for lighting does not count when establishing the energy rating of a home, does not mean that its value is negligible, and therefore it is interesting to use lamps and luminaires with the lowest associated energy consumption.

The criterion of choice should be similar to that established in thermal comfort: decrease consumption but without reducing user comfort.

En este aspecto, el valor más representativo de una lámpara es su eficacia luminosa, expresada como la **relación entre el flujo luminoso obtenido y la potencia consumida** para lograrlo

In this aspect, the most representative value of a lamp is its luminous efficiency, expressed as **the ratio between the luminous flux obtained and the power consumed** to achieve it:

$$\boldsymbol{Luminous\ efficiency\ (Lm/W) = \frac{Luminous\ flux\ (Lumens)}{Electric\ power\ (W)}}$$

For the same degree of illumination (luminous flux) a lamp with low electricity consumption will obtain a high efficiency value.

The usual commercial values in housing according to the type of lamps are:

Type of lamp	efficiency (lm/W)
Incandescent	10
Halogen	25
Fluorescent tube	60 - 90
Compact fluorescent	60 - 90
Led (punctual)	50 - 70
Led (bands or tubes)	70 - 85

From the above values it can be seen that the use of fluorescent or LED lighting supposes a remarkable energy saving compared to traditional incandescent or halogen luminaires.

5. The use of home automation as a means of energy saving

The rational use of energy is undoubtedly the basis of the reduction in its consumption.

In an idealized environment, the user should always adapt the operation of their equipment to the real needs they demand, but in practice it is not always possible because of their absence, lack of knowledge in the matter or complexity of the equipment they must administer.

Home automation systems save energy and resources because they rationally manage and program the operation of the facilities based on external factors such as temperature, time, light, the presence of people, etc.

They allow executing pre-established actions, automating procedures or exchanging information between different equipment in the home, adjusting and optimizing its operation.

The home automation implementation can go from the simplest systems, such as the use of presence detectors in corridors and common areas, to the most complex in which we can control each equipment of our home (air conditioning, lighting, irrigation, security, etc. .) from a smartphone or tablet

Everything depends on the degree of investment and complexity of the home automation system that is intended to be achieved.

6. The sun as a renewable source of energy

The European directives, and with it the Spanish regulation, not only promote the reduction of the consumption of energy, but the source from which it comes also has a renewable origin, fleeing as much as possible from the use of conventional derived fuels of the oil.

Within the range of renewable energies, taking advantage of solar radiation is undoubtedly one of the best options, especially in a country like Spain that enjoys numerous annual radiation hours.

We can choose two types of collection, depending on the needs of the building:

- Solar thermal system, if what we pretend is to heat water well for consumption or heating.

- Solar photovoltaic system, if we need to generate electricity.

The problems presented by its implementation in housing blocks are derived from three factors:

1.- **Necessary space**. These are multi-component systems that require a certain space for their location, so except for single-family homes, it is necessary to occupy common areas and the roofs of the building for their implementation.

2.- **Decoupler schedule between production and use.** Solar energy usually occurs at hours other than those consumed in most homes (19 to 23 h), so it must be accumulated during the day to be used at night.

This leads to the need for an accumulation device (deposits in the case of thermal energy and battery in the case of electricity) that make the installation more expensive.

Another alternative is the use of an auxiliary source of energy, such as a boiler in the thermal case or the connection to the electricity network in the case of photovoltaic, whose objective is to cover the periods in which solar radiation is not captured and besides, there are no accumulated reserves.

3.- **Normative compliance.** Although in the case of solar thermal energy its use is encouraged by the Technical Code (CTE-HE4), with minimum values of solar contribution for production of sanitary hot water according to the locality, in the case of photovoltaic systems, regulation current only allows the generated energy to be consumed by its owners, that is, if the photovoltaic panels are owned by the community of neighbors of a block, the generated electricity can only be used in uses of common areas of the building, not in the privately owned homes.

In any of the cases, the three factors above do not stop a sector, both thermal and photovoltaic, in strong boom that presents each year more efficient generation and accumulation equipment at a lower price.

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TESTS

Unit 0

The group of buildings with the greatest potential from the point of view of energy rehabilitation is:

a) Newly constructed buildings

b) Existing buildings prior to the 50s

c) Existing buildings between the years 70 to 90

The three main normative documents related to energy efficiency in Spain are:

a) Technical Building Code, Regulation of Thermal Installations and Urban Management Plan of each locality.

b) Technical Code of the Building, Regulation of Thermal Installations and Royal Decree of Energy Certification

c) Technical Building Code, Building Assessment Report and Thermal Installations Regulation

The current regulations on energy efficiency in buildings aims to:

a) Lower consumption, greater efficiency of equipment for air conditioning equipment and increased use of renewable energy

b) Lower consumption, greater efficiency in energy management and increased use of renewable energy

c) Lower consumption and greater efficiency of air conditioning equipment

The facade of a building corresponds to:

a) Its passive part

b) Your active part

c) To both

From the point of view of an energy rehabilitation, the most appropriate intervention in a building is:

a) The one that obtains the greatest energy improvement

b) The one that seeks the balance between the initial conditions of the building and the energetic objective that it is intended to achieve.

c) That in which the initial situation of the building prevails over the level of energy efficiency that it is intended to achieve.

Unit 1

From the point of view of the elimination of thermal bridges in a façade, the most convenient action is:

a) The insulation inside the facade

b) The insulation in the intermediate chamber

c) The insulation on the outside of the facade

One of the advantages of improving the insulation of a roof by its outside face instead of by its interior face is:

a) The auxiliary means necessary to execute it are reduced

b) It does not affect the life of the tenants of the building

c) It has no advantages

The so-called greenhouse effect

a) It implies that most of the solar radiation that affects the glasses is reflected

b) It implies that the solar radiation that passes through the glasses dissipates quickly

c) It implies that the solar radiation that crosses the glasses reheats the interior environment when it is "trapped"

From the point of view of thermal behavior, the material that causes the most losses in the carpentry of a window is:

a) Aluminum

b) Wood

c) PVC

For the correct control of solar radiation we can count on:

a) Active building systems such as heat pumps and refrigeration

b) Carpentry of reflective materials and sun protection eaves

c) Mainly solar control glasses, fixed and mobile protections

Unit 2

The choice of fuel used to heat our buildings influences:

a) The associated emissions of CO_2

b) The efficiency that we will achieve with our boilers

c) The relationship between heating consumption and hot water production

When changing a boiler, the most efficient equipment is:

a) Waterproof boilers

b) Boilers with microaccumulation

c) Condensing boilers

An efficient heating system is based on:

a) Adequate choice of fuel, high performance generator, isolation of the distribution network and regulation of emitters

b) High performance generator, isolation of the distribution network and regulation of emitters

c) Adequate choice of fuel and high performance generator

The refrigeration system that uses duct networks in its distribution:

a) Use individual equipment in each stay

b) Requires drive grilles in each stay

c) You can choose any of the two previous means

The heating and cooling systems correspond to:

a) The passive part of the building

b) The active part of the building

c) To both

Test's answers

Unit 0

1. c.

2. b.

3. a.

4. a.

5. b.

Unit 1

1. c.

2. b.

3. c.

4. a.

5. c.

Unit 2

1. a.

2. c.

3. a.

4. b.

5. b.