POLITECNICO DI TORINO

Facoltà di ingegneria

Corso di laurea Magistrale in Ingegneria Edile

Tesi dilaurea in:

Energy efficiency in the building refurbishment: construction solution, materials and energy certification

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alla fiducia,

al sostegno.

Index

ABSTRACT

Il seguente lavoro di tesi è stato svolto presso l'università dei Paesi Baschi (Universidad del País Vasco – UPV), Spagna, con relatore Jesús Cuadrado Rojo, professore della ETSI di Bilbao (UPV/EHU) del dipartimento di meccanica e in collaborazione con il Politecnico di Torino, con la supervisone del vicedirettore del Dipartimento di Energia – DENER Marco Perino, nonchè professore ordinario e membro effettivo del Collegio di Ingegneria Edile.

Per il costante interesse rivolto all'edilizia e all'ambiente, ho deciso di focalizzare il lavoro verso la sostenibilità edilizia nonché sul consumo energetico degli edifici prima e dopo la loro riqualificazione energetica. Nello specifico, l'edificio di studio prevederà la riqualificazione energetica della facciata.

L'edificio, oggetto di studio, è una scuola elementare ubicata in Getxo, Paesi Baschi, Spagna. Di questo, verrà effettuata la certificazione energetica prima e dopo la ristrutturazione della facciata, con lo scopo di confrontare i risultati ottenuti e mostrare la riduzione della domanda e consumo energetico ed infine di emissioni di CO_2.

Sarà possibile prendere visione delle differenze climatiche e normative tra i due luoghi, Getxo e Torino, poiché la 'Azkorri Ikastetxea', nome della scuola oggetto di studio, verrà virtualmente spostata a Torino, della quale si effettuerà nuovamente la classificazione energetica.

I software utilizzati saranno 2:

- Edilclima, usato per la classificazione energetica in Italia;
- CE3X, usato per la classificazione energetica in Spagna.

La tesi verrà suddivisa in diversi capitoli e sottocapitoli; riguarderà l'efficienza energetica, gli edifici sostenibili e le relative strategie passive ed attive, fino a giungere alla parte pratica dell'utilizzo dei software, ottenimento dei risultati e stesura delle conclusioni. Non mancherà la descrizione dell'edificio con le relative piante e prospetti (non in scala), stratigrafie dell'involucro edilizio e i relativi impianti.

1 Introduction

Produrre energia significa soddisfare i bisogni delle generazioni presenti ma allo stesso tempo tutelare quelle future insieme al benessere del pianeta. Un obiettivo che porta con sé una costante analisi delle risorse e una altrettanto costante ricerca tecnologica, che punti a unire prestazioni e sostenibilità, come fissato anche dal protocollo di Kyoto prima e dai più recenti accordi di Parigi (Cop 21) poi.

Tradurre questo assunto nel contesto odierno vuol dire quindi ripensare il modo di produrre ***energia, ridimensionando in modo importante l'uso di combustibili di origine fossile e la*** *conseguente emissione di gas clima-****alteranti, come l'anidride carbonica, e*** *studiando soluzioni sempre più innovative. In due parole: riconversione energetica.*

Il passaggio dalle due parole ai fatti richiede organizzazione, pianificazione e investimenti. ***wrote Marco Cosenza in 'Wired'(22 August*** *2016).*

The Kyoto Protocol is an international agreement, adopted on 11 December of 1997 during the Kyoto Conference (Cop3) but it entered into force only on 16 February of 2005. To enter into force it had to be approved by no less than 55 countries of the Parties whose emissions sum was to represent not less than 55% of the total.

It borns for fighting the climate change, arguably the greatest and worrying environmental problem of the modern era, with its CO_2 emissions into the atmosphere caused by the human development. The Kyoto Protocol commits its Parties by setting internationally binding greenhouse gas emission reduction targets. The target has to be compared to 1990 emission levels (baseline). To do this, the parties

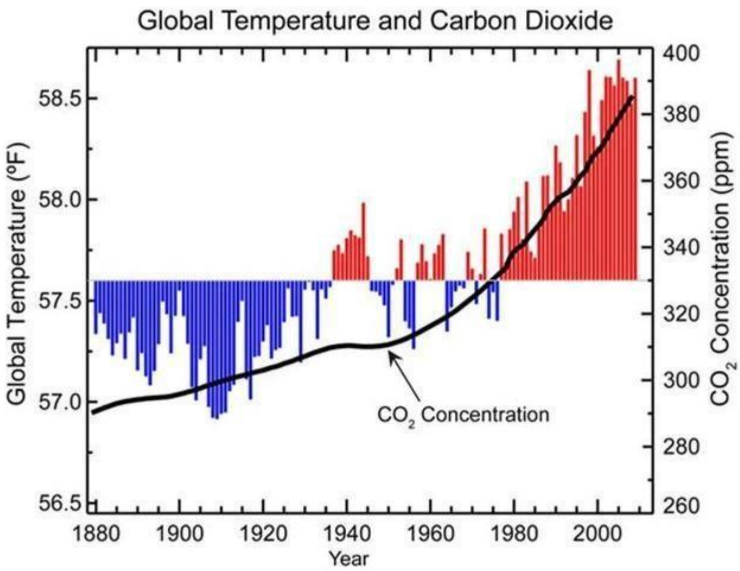


Figure 1.1 - Global temperature and CO_2

have to implement a national system for monitoring of greenhouse gasses emissions. It will be updated annually. Figure 1 shows us the CO_2 increase during the years.

The GreenHouse Gases - GHG that have to be reduced are:

- CO_2 (carbon dioxide) produced by the use of fossil energy sources and industrial activities as well as in transport;
- CH_4 (methane), produced from landfill of waste, livestock farms and rice crops;
- N_2O (nitrous oxide), produced in the agricultural and chemical industries;
- HFC (hydrofluorocarbons), used in the chemical and manufacturing industries;
- PFC (Perfluorinated Chemicals), used in the chemical and manufacturing industries;
- SF6 (sulfur hexafluoride), used in the chemical and manufacturing industries.

The CO_2 currently is the most relevant greenhouse gas that has the main power on the climate (accounting for more than 55% to the greenhouse effect today's).

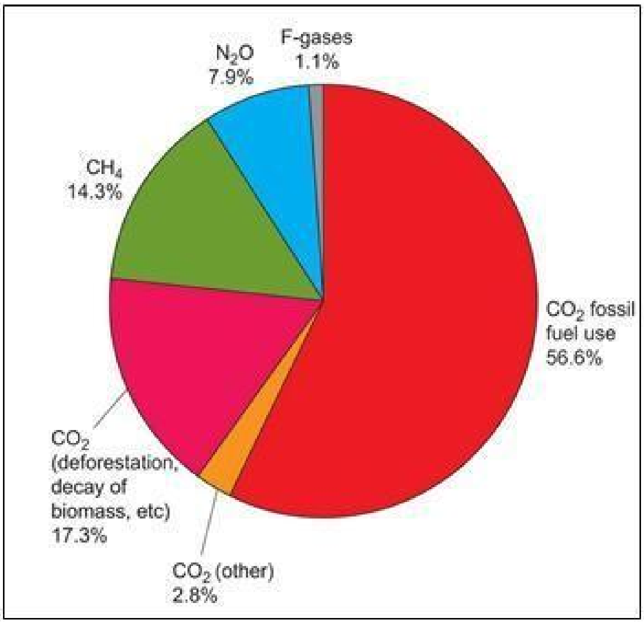


Figure 1.2 – Greenhouse gases

The Kyoto Protocol was an important treaty, even if it is just a first step, insufficient to contain climate change. However, it was an important beginning.

We will briefly review the conferences that took place during the years. None of these led to an agreement:

- Cop 15, December 2009 - Conference of Copenhagen;
- Cop 16, December 2010 - Conference of Cancun;
- Cop 17, December 2011 - Conference of Durban;
- Cop 18, December 2012 - Conference of Doha;
- Cop 19, November 2013 - Conference of Warsavia;
- Cop 20, December 2014 - Conference of Lima;

Arriving at the Cop 21 held in Paris, concluding a climate agreement, very important and ambitious, to be implemented by 2020. It provides an increase in global temperature of not more than 2°C.

The main causes of CO_2 production come from:

-  Transportation sector;
-  Energy industries;
-  Building sector;
-  Industry sector;
-  Agriculture sector;

➢ Waste sector.

The aim of the thesis work is focused on the building sector. A school building in Getxo, Bilbao (Basque Country) will be studied and the following steps will be executed:

- Study of its envelope (type of construction, materials used, detecting diseases);
- The facade will be reformed with new construction techniques and materials that reduce energy loss;
- The building energy loss will be identified using a Spanish software, after and before the refurbishment;
- The building energy loss will be identified using also an Italian software;
- The two energy certificates will be compared.

2 Energy efficiency

2.1 Introduction

It is becoming increasingly clear that energy efficiency needs to be central in energy policies around the world. All of the core imperatives of energy policy – reducing energy bills, decarbonisation, air pollution, energy security, and energy access – are made more attainable if led by strong energy efficiency policy. Efficiency is the keyword for the world transitions to clean energy. It can make the transition cheaper, faster and more beneficial across all sectors of our economies. Indeed, there is no realistic or affordable energy development strategy that is not led by energy efficiency, despite it is far from fulfilling its potential: globally, two-thirds of it's potential remains untapped. About the 70%, of the world's energy use, takes place outside of any efficiency performance requirements. For example, during the building construction, there is no codes or standard applied to it. It increases the pollution emission.

Can the world can achieve more? Energy efficiency is the one energy resource that every country possesses in abundance. The greatest efficiency gains have been led by a good policy. The worst efficiency gains have been led by an absent or inadequate policy.

Global trends in energy intensity

Data from the *'International Energy Agency (IEA)'*, tell us that amount of energy used per unit of gross domestic product (GDP) decreased by 1.8% in 2015 and 1.5% in 2014, and tripling the annual rate (0.6%) seen in the previous decade (figure2.1).

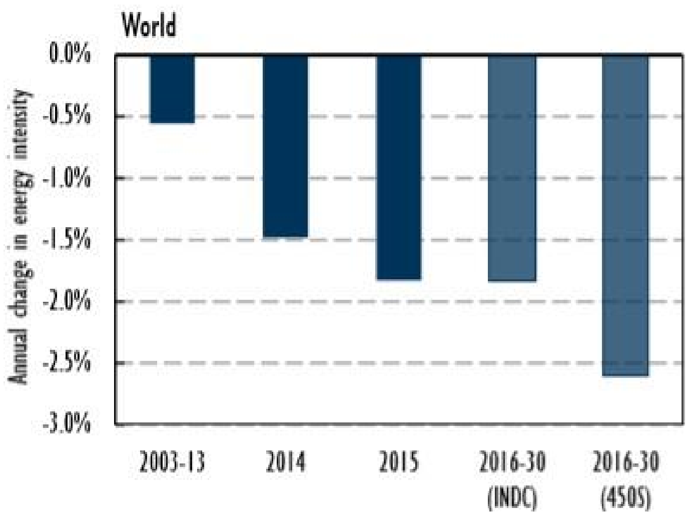


Figure 2.1-changes in Energy intensity from 2003-30

Despite these gains, the pace of intensity improvements is too slow to reach the established goal of limiting global temperature increase to 2°C, as expected in the Paris Agreement (COP 21). The analysis of International Energy Agency (IEA) shows that annual energy intensity improvements need to rise immediately to at least 2.6% in a trajectory consistent with our climate goals.

At the country level, the trends are more mixed. China achieved the greatest improvement in energy intensity (Figure 2.2). The Chinese economy consumed 5.6% less energy per unit GDP in 2015 than it did in 2014, marking the second consecutive year in which the rate of energy intensity improvement surpassed the annual average over the previous decade. In the picture below it can see the different countries' improvement.

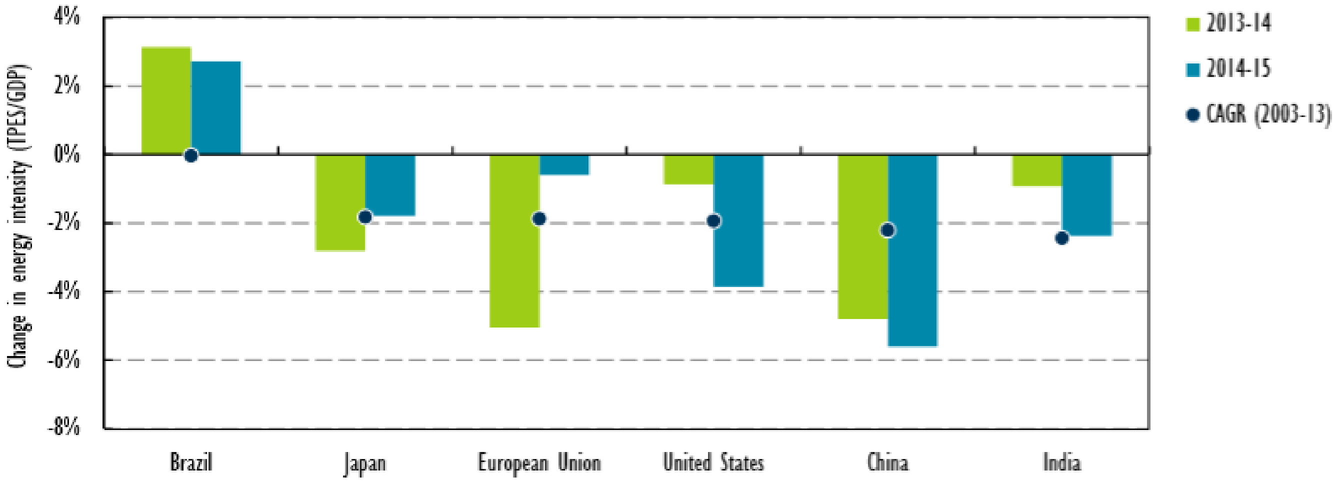


Figure 2.2 - Changes in primary energy intensity for selected countries

The energy production is undoubtedly higher in countries with emerging economies. These country fear that the reduction of energy demand can cause damage to economic developement (less energy consumption = less production). Under a productivity framework, policy makers in emerging economies could prioritize objectives to increase energy services and energy consumption, which would drive economic growth and achieve wider social objectives time, allow the achievement of objectives.

The improving of energy intensity

The greatest improvement in final energy intensity (TFC [1]/GDP) since 2000 has been in the services sector (Figure2.3), where economic growth outpaced energy demand growth. The Intensity in the services sector fell by 24% between 2000 and 2014, about 2% per year. Conversely, the energy intensity of passenger transport, increased by 15% globally between 2000 and 2015. This reflects the growing demand for personal vehicle transport, driven by rising per capita income. Energy use in personal transport has been growing annually five times faster than population. Industrial intensity is improving more rapidly. In OECD[2] countries between 2000 and 2014, industrial final energy use fell 0.9% per year on average while industrial GVA[3] rose 0.8%. Non-OECD industrial intensity was stable over this period. In services, GVA has grown 7.2% per year on average in non-OECD countries against 5.5% growth in energy use; in OECD countries, GVA growth has been 2% while energy demand growth has been only 1%.

[1] TFC is the sum of consumption by all end-use sectors: industry, transport, buildings (including residential and services) and other (including agriculture and non-energy use). It excludes international marine and aviation bunkers, except at world level where both are included in the transport sector [3].

[2] Organisation for Economic Co-operation and Development (OECD).

[3] Gross Value Added in given sector. Intensities are calculated as thousand tonnes of oil equivalent per billion 2010 USD using purchasing power parity. *Passenger intensity* is measured by passenger transport energy consumption per capita; *residential* is residential buildings energy consumption per capita; *industry* is industrial sector energy consumption per industrial sector GVA; *services* is services sector energy consumption per services sector GVA.

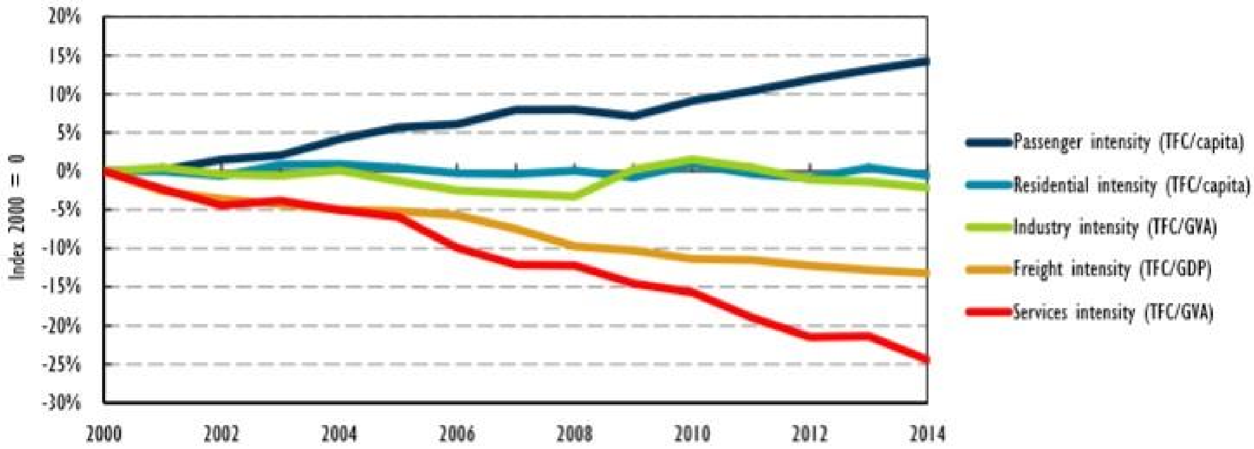


Figure 2.3 - Change in world TFC intensity by sector, 2000-14 [from International Energy Agency (IEA)]

Focus our attention on the building sector and study its development in the energy field.

2.2 Energy effinciency in building sector

2.2.1 The sustainable architecture

An important aspect that made a crisis of modern architecture is the lack of control of environmental characters during the design phase, construction and use of the built environment. **What does the '***environmental characters***' means? It is the** combination of two aspects:

1. The relation between the architecture's environmental performance and the construction processes, use of materials and environmental resources. It means what is its environmental's impact at local and global levels;

2. The relation between the architecture's environmental performance and the building's requirements (connected to the indoor comfort of heat, cold, natural light ..).

All the settlements, from the oldest to the most modern are 'unsustainable' because they are open thermodynamic systems and they dissipate energy for to satisfaction the aspects (1) and (2).
The role of designers (a team of engineers and architects) is to reduce, as soon as possible, the use of energy and make the settlements (building, group of buildings, civil works etc ..) from 'unsustainable' to 'sustainable'.

So, the sustainable architecture is the set of more aspects:

- The energy consumed during its construction;
- The materials used (local produce or import, so the Import costs);
- The energy consumed during its exercise;
- The disposal of construction materials.

In other words, it is a conscious approach to energy and ecological conservation to minimize costs and CO_2 emissions during its construction and use. It also reduces the environmental impact.

Some example of the sustainable architecture selected by *The American Institute of Architects* (AIA) and its *Committee on the Environment* (COTE) are showed below. These belong to the top ten sustainable architecture and ecological design projects for 2016:

Figure 2.4 - Biosciences Research Building (BRB); Galway, Ireland / Payette and Reddy Architecture + Urbanism

'The design of the BRB embraces the moderate climate of Ireland. By locating low*-load spaces along the perimeter of the building, the project is able to take advantage of natural ventilation as the sole conditioning strategy for the majority of the year and is supplemented less than 10% of the year with radiant heating. Due to this approach, 45% of this intensive research building is able to function without mechanical ventilation. This is an extremely simple, yet radical approach and is rarely implemented to even a modest extent in similar laboratories in comparable U.S.* ***climates.'***

Figure 2.5 - Jacobs Institute for Design Innovation; Berkeley, CA / Leddy Maytum Stacy Architects

*'**Founded on the conviction that design can help address some of society's most pressing challenges,** the Jacobs Institute for Design Innovation at UC Berkeley is devoted to introducing sustainable design innovation at the core of university life. The project provides a new interdisciplinary hub for students and teachers from across the university who work at the intersection of design and technology. It is designed as both a collaborative, project-based educational space and a symbol to the region of the Un**iversity's commitment to sustainable innovation, modelling high**-density / low-carbon living and learning by reducing energy use 90% below national **baseline.'***

Figure 2.6 - Rene Cazenave Apartments; San Francisco / Leddy Maytum Stacy Architects and Saida + Sullivan Design Partners, Associated Architect

'This supportive housing for formerly chronically homeless individuals replaces a former parking lot and freeway off-ramp with a high density, transit oriented, and healthy living alternative. Filtered ventilation, low emitting materials, ample daylight and views combine to aid the residents, many with mental and physical disabilities. Energy costs for the residents and non-profit owner are minimized by a combination of high efficiency lighting and hydronic heating, a continuously insulated rain-screen building envelope and a roof top solar canopy with both hot water and photovoltaic panels. Water is carefully managed by a vegetated roof, smart irrigation, a courtyard storm water tank and reclaimed water piping.'

Figure 2.7 - The Dixon Water Foundation Josey Pavilion; Flato Architects

'The Josey Pavilion is a multi-functional education and meeting center that supports the mission of the Dixon Water Foundation to promote healthy watersheds through sustainable land management. Traditionally livestock has caused more harm than good by overgrazing and not allowing native prairies to play their important role in habitat and watershed protection, and carbon sequestration.
As a certified Living Building, the Josey Pavilion facilitates a deeper understanding of how grazing livestock as well as the built environment can work to do more good than harm. Just like the Heritage Live Oak that defines the site, the building tempers the climate and enhances visitor experience by shading the sun, blocking the wind, and providing protected views.'

2.2.2 The building sector

The energy consumed in building construction, for space heating and domestic hot water, accounts for about 40% of all energy consumption in the EU, and represents about 25% of EU total emissions of carbon dioxide, one of the main causes of the effect the greenhouse and the consequent rise in temperature of the globe.

Adopting energy saving measures you can:

- Consume less energy;
- Reduce the heating and air conditioning costs;
- Improve the level of comfort and welfare of those who stay and live there;
- Reduce greenhouse gas emissions;
- Save on utility bills.

How does it can reach it? First of all adopting construction techniques and materials that allow to reducing consumption of heating and cooling. In a nutshell, increase the thermal resistance of the building. Secondly, adopt the use of renewable energy and energy efficient technologies. So before isolating the building and after relying on renewable resources.

<u>The European experiences and the German pragmatism</u>

In the construction field, indoor comfort improves along with the evolution of the limits of acceptable consumption that are getting more stringent with the demonstration of the efficiency of the passivhaus.

The basic idea is to get a very efficient envelope to ensure suitable internal comfort conditions through the preservation of all thermal gains available.

The passive house standard is based on the performance of the necessary elements in a building, as opaque and glazed envelope and the ventilation system. it doesn't need introduce experimental or complex components and it doesn't require to changes the users' habits. The strategies to be adopted to reach the levels of expected consumption are listed:

- Opaque envelope with high insulation that can be reached through an insulator thickness 35, 40 cm;
- Constructions techniques that involve the near absence of thermal bridges;
- High-performance glazed elements. These must ensure maximum solar gain during the day and minor losses overnight. Usually, the window has a triple clear glass with double air chamber containing inert gas and effectively isolated frames;
- Air tightness of the building and mechanical ventilation system with heat recovery.

These strategies are valid in German and continental climate, therefore, cannot always be translated in other European contexts. Anyway, the rational use of natural resources is no longer an option, it is now a necessity, and it is possible thanks to new thermal walls, improved insulation, efficient HVAC systems, and consumption.

There are a lot of solutions that we can be adopted in order to save energy and make the building more efficient. The nZEB (nearly Zero Energy Building) is an example of a low-energy house.

2.2.3 The nZEB

The *nZEB*, nearly zero-energy building, means a building that has a very high energy performance, where the consuming of the primary energy is about 0 kWh/m^2 year. The amount of energy required, for these buildings, should be covered to a very significant extent by renewable sources energy produced on-site or nearby.

This topic has become very importantly after the Directive 2010/31/UE (Energy Performance of Buildings Directive, EPBD) and 2012/27/UE (Energy Efficiency Directive). They show an overview of goals about the building's performance and their energy efficiency. The Members' States have the work to choice an own solution to achieve these goals.

The energy performance of a building is determined by the annual energy consumption for the indoor comfort, like the use for heating, cooling and domestic hot water needs. By 31 December

2020, all new buildings are nearly zero-energy buildings, and after 31 December 2018, all public's buildings too.

The building rehabilitation represents the most demanding challenge. They must adapt to new levels of performance and their change is definitely more complex than the new buildings, efficiently designed from the first step.

According to the European directives mentioned above, a building can be considered nZEB if his energy annual generation/consumption is low enough to result in zero balance through the use of renewable energy sources. It can be possible if there are a reduced demand for energy and a simultaneous production of renewable energy in site.

Although the concept of nZEB may seem simple and immediate, it isn't. A differents professionals with different knowledge have to collaborate for develop the project. They are involved in the design and construction of the building, as architects, engineers, plant engineers, geologists, physicists of the building etc.

There is a distinction between the study of buildings in a small-scale and large-scale.

In the first case, it is talking about the nZEB, in the second, of BedZEd, 'Zero Energy District', as the popular district in Sutton, London.

Figure 2.8 – BedZED, the eco-village in Sutton, south of London

Health and happiness
BedZED residents say they know on average 20 of their neighbours by name; the local average is eight.

Equity and local economy
Half of the homes are for low cost rent or shared home ownership.

Sustainable Water
Water consumption per BedZED resident is about 50% of the London average.

Sustainable materials
Just over half of the construction materials by weight came from within 35 miles.

Sustainable Transport
BedZED was the first residential location in London to have an onsite car club from the outset.

Zero Carbon
We estimate BedZED produces 37% less carbon dioxide emissions from gas and electricity use than an average development of the same size and mix of uses.

'BedZED continues to attract visitors from around the world. This award winning development was designed to achieve big reductions in climate-changing greenhouse gas emissions and water use. It sought to make it easy for people living there to have a greener, lower impact lifestyle, relying less on private cars and producing less waste. Most importantly, BedZED has turned out to be a great place to live.
The project was initiated by Bioregional, developed by The Peabody Trust in partnership with Bioregional and designed with architects, ZEDFactory (also based in BedZED) and Arup engineers. Peabody is one of the largest and longest established providers of social housing in London.'
- Bioregional.com -

A BedZED is like an nZEB but in works on a large scale. The Zero Energy District creates a sustainable community in wich many people live in harmony with each other and in the district too. It doesn't consider the buildings individual's consumption but the consumption of the whole district.

The annual consuption considaret in the Zero Enery Building are:

- Heating and cooling;
- Domestic hot water (DHW);
- Electric consuptions;
- Artificial light, etc...

To get a general view of the building energy consumption could be also considered the '"Embodied Energy". this is an energy uses during the building construction, it means the energy that was required to produce, transport and dispose of the element itself. This approach is more extensive and accurate. It gives us information about the costs of construction, maintenance and disposal of the same. It provides us with a more broad view.

The first step to reach an nZEB is decreased the energy demands, reached trough energy efficiency measures. Figure 2.9

Figure 2.9 – Energy efficiency measures and lower energy bills

The second step is the use of Energy Supply. It is the delivery of fuels or transformed fuels to point of consumption. It potentially encompasses the extraction, transmission, generation, distribution and storage of fuels. It is also sometimes called energy flow.

Figure 2.10 – fotovoltaic panel like Energy supply

The building' mode of use by the users is a factor that affects its consumption, in fact, the design, calculations, simulations, and tests performed, are referred to a 'standard users'. These results can get away from reality and its actual use, because everyone has the different perception of comfort (temperature, air speed, humidity, lighting) and habits that are related to the building's proper use which aims to minimize waste.

Unfortunately, today there is a widespread awareness of the improper use of buildings by users. They considerate the technological innovations not like something that can help them to improve the building's energy use, but like something introduced only to obtain any temperature within the building. They open windows, leave doors open, regulate with excessive temperature thermostats. To obtain the real results consumption, the building should be monitored and it is based on actual consumption.

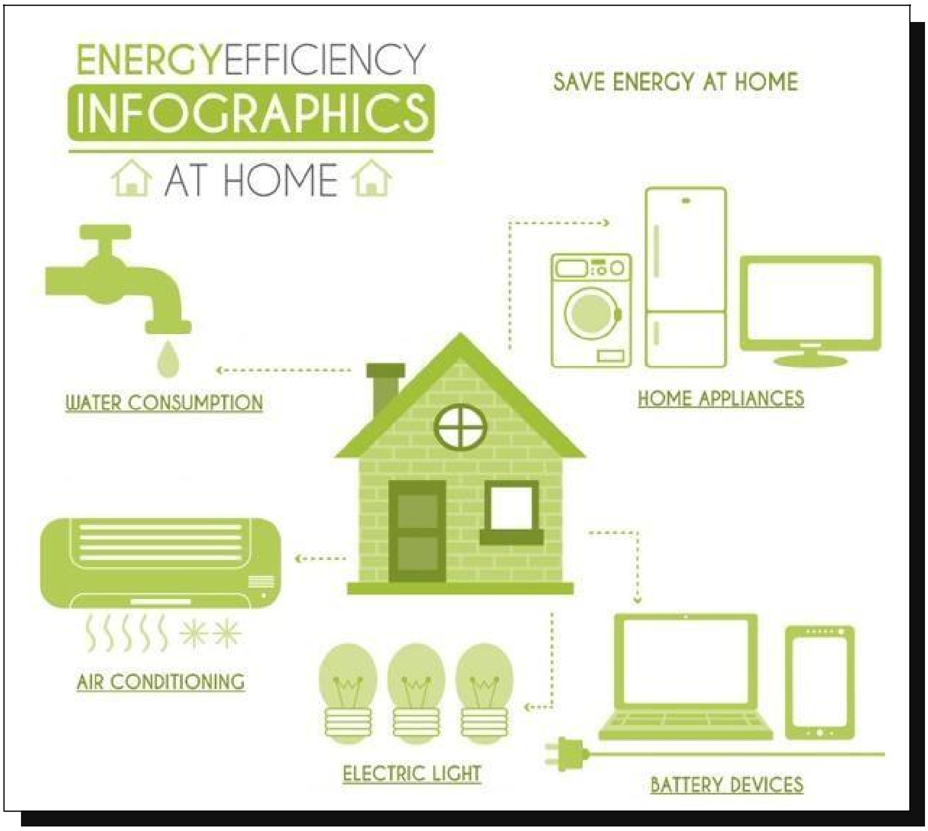


Figure 2.11 – Save Energy at home linked to the users' habits

To achieve ZEB certification it must verify the energy performance of the building through its testing, and verify the status of the materials (acceptance of this by the DTE project manager) who arrive on site.

What is the approach to get a nZEB? We can fallow three roads:

Passive strategies. A building built to passive techniques exploit its geographical position and orientation. It will be able to heat and cooling individually. Indoor air audibility will be guaranteed by a natural ventilation. The aim is to maximize comfort and minimize costs.

Active strategies. A building that exploits the active strategies using energy from renewable sources such as solar or photovoltaic panels, micro wind turbines, heat pumps etc ..

Hibrid systems. To ensure the highest level of comfort, often, only the active strategies are not enough. The building needs energy from other sources. In this case the building use both of them.

Same example of passive strategies are:

1. *Traditional passives strategies*: passive strategies, used across the globe for centuries, are a logical and economic response to the environmental conditions of the building, such as the temperature, orientation and the wind in the area. You can also take advantage of the geographical location to thermally regulate the interior spaces or use materials with high thermal mass and insulating capacity;

2. *Green house effect and solar orientation*: depending on the latitude, buildings should be oriented to the south or north to make the most of daylight hours. This implies a direct or indirect solar gain inside the building that greatly affect its energy expenditure. To enhance the solar gain, there are buildings that try to make use of the greenhouse windows, glass galleries, glass panels or enclosures.

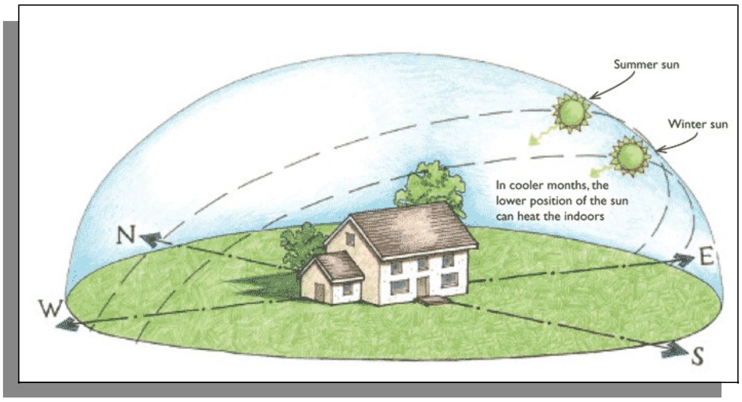


Figure 2.12 - Solar path

Opening the walls of the house to harness solar radiation all day long, and the effect of the sun's position in winter and summer.

3. *Natural ventilation*: this is a mechanism to create cool air, with is only useful in moderate climates. In order to create cross ventilation, one part of the house must be designed that is cooler and the other warmer, so as to generate a flow of fresh air between both parts that cools down the rooms in its path. It is only useful in spring and fall, because if the outside air is warmer than the interior of the building, this system is counterproductive.

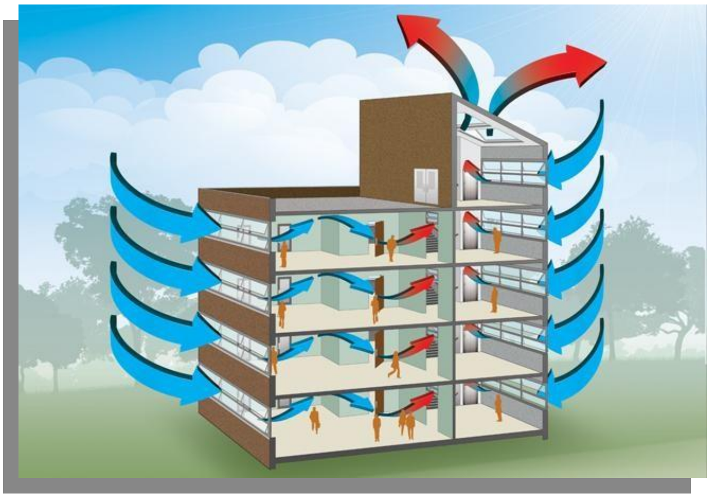


Figure 2.13 - natural vetilation

System to generate fresh aire valid from moderate climates.

4. *Insulation and enclosures:* good insulation prevents energy loss in a building. Thermal insulation should be fitted to the external part of the walls, floors and roofs, but it should also be used for woodwork and partitions. The widespread use of double-sheet glass will be replaced in coming years to triple-glazed glass and even vacuum insulated glass, preventing heat conduction caused by the gas present in the chamber between two strips.

Figure 2.14 - insulation and enclosures

Insulation of fachade and roof withe the insulation paneles.

5. *Thermal mass*: the greater the mass of the building, the more heat it can accumulate. The building remains warm at night, because heat has been stored in the floors, walls and ceilings during the day and dissipate at night. There are high thermal mass materials such as

concrete, adobe or thermal clay blocks, which have the ability to slowly release the heat they retain.

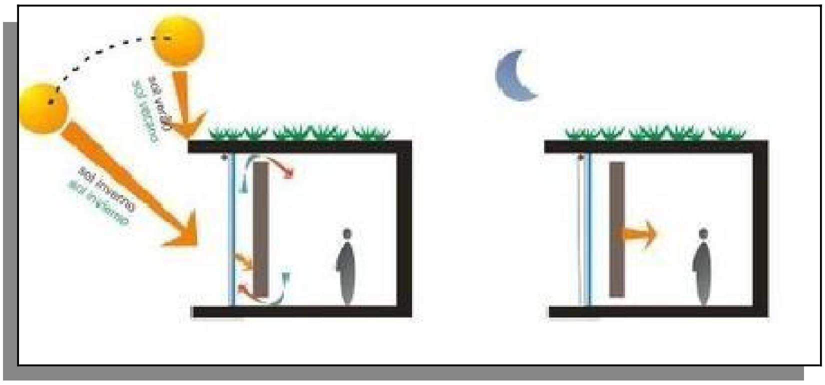


Figure 2.15 – thermal mass

Example of thermal mas

- Trombe Wall -

6. *Sun protection in the facade:* buildings historically have used traditional methods to protect against solar radiation, such as awnings, shutters, blinds, curtains, brise-soleil or other types of sunscreens. Technological improvement explain that mainly lattice systems or automated adjustable openings have been used in corporate or office buildings. Other options are solutions of facade integrating sun protection.

Figure 2.16 – sun protection in the facade

Example of bris-soleil.

7. *Green roofs and green walls:* vegetation on the roof or the facades represents a passive thermal control system that purifies the air, cool the interior during the day and regulates temperature changes at night. The species must be native and low maintenance. The options include a green roof, a roof with a rainwater tank and a green facade or indoor wall.

Figure 2.17 – green walls and roofs

Exemple of green wall in Madrid.

8. *Ventilated and automated facades:* The facade as building envelop can be an important factor to reduce energy consumption. The current market present different options, such as the ventilated facade or motorized and automated systems that react in real time to climate changes. A ventilated facade accentuate this condition through a separation structure, which ensures continuous ventilation along the entire surface of the facade.

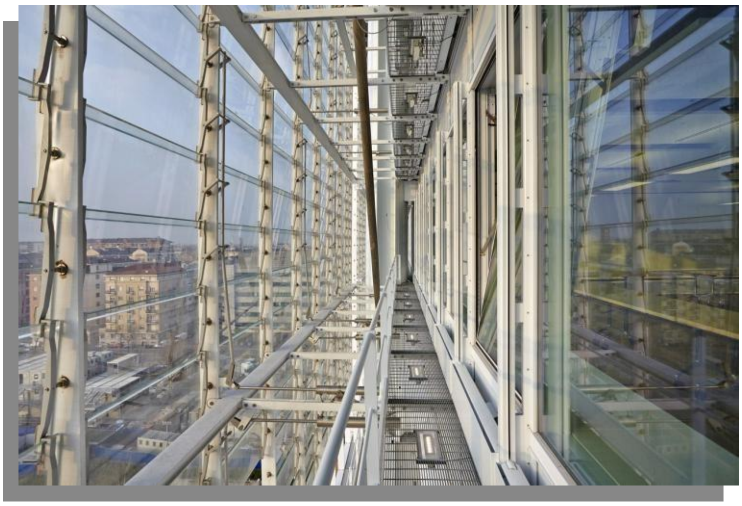


Figure 2.18 – ventilated and automated facades

Example of doble skin of San Paolo's Tower en Turin. It allowes the natural ventilation.

9. *Integrate installations:* over the years, the bioclimatic design of home has resulted in the increase of improved technological solutions for domestic energy supply with renewable energy. This is the case of solar photovoltaic, solar thermal, wind, hydro and geothermal energy and the use of biomass boilers. Some of them need to be installed in the design phase of the house, and obviously lead to a higher embodied energy than bioclimatic solutions.

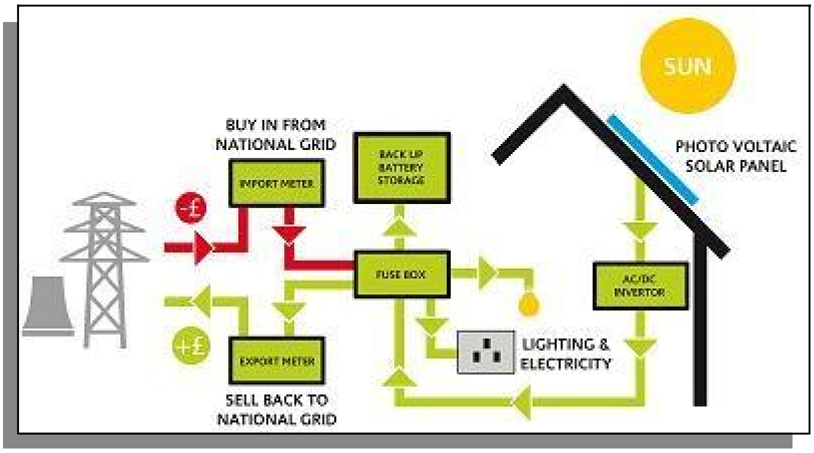


Figure 2.19 – integrete installation

The photovoltaic paneles like an help to reduce the bill's cost.

10. *Domotic:* automated heating control systems adjust the temperature of the house according to changes in outside temperature, time of day or room. The intelligent automatic control of awnings, blind and curtains, as well as hazards and internal security parameters (smoke, flood, burglary), can also be controlled. Thus the overall functioning of the house is much more optimized.

Figure 2.20 – domotic house

It can control and regulate an remote the installation of the house.

Let's focus on what most will relate to the thesis work:

- The passive strategies:
  - building's orientation, insulating and closures (materials and their features);
- The active strategies:
  - Heating, cooling and ventilation's installations.

3 Passive strategies: building's envelope, orientation and insulation

To get the most from your home: think the sun. The sun can heat and cool your home and reduce its energy use. More importantly, the energy from the sun can make your home comfortable year round.

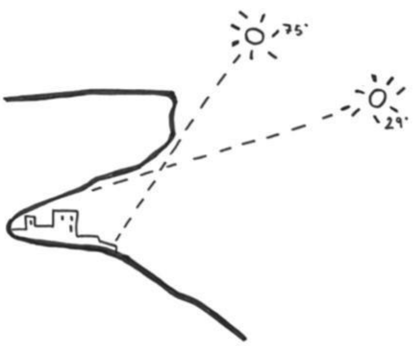
There are two types of solar design systems: *passive* and *active*.

Homes constructed with passive solar design use the natural movement of heat and air to maintain comfortable temperatures, operating with little or no mechanical assistance. It's called passive solar because the home receives the maximize benefits from the sun. It still has standard construction features but its design allows to take advantage of the sun's benefits., as local breezes and landscape features such as shade trees and windbreaks, and uses a simple system to collect and store solar energy.

> *Passive solar design, an idea within the growing trend of green building, is a creative way to use the sun to our advantage, both for heating and cooling, based on the design of buildings. As green building has continued to become more popular, many changes have been made to make the design and construction of our buildings more environmentally and economically sustainable. This review focuses on the development in passive solar applications, from its earliest appearances in ancient Greek buildings to current designs that take advantage of radiation convection or acrylic panels. There have been many passive solar developments that can be explored, and the innovative technology today has brought about great advancements in the past few decades alone. As the popularity of green building continues to grow, it is essential to develop an understanding of passive solar design, and other green building techniques, in order to be equipped for the years to come.* [History of Passive Solar Energy, Scott Barber, East Carolina University].

Passive solar systems are used to "collect, store and distribute thermal energy by natural radiation, conduction and convection through sophisticated design and wise selection of building materials"(definition, provided by J.K. Paul). Passive solar energy also involves blocking the sun's rays in order to provide cooling during the summer. Incorporating solar energy into our buildings will decrease the amount of money we spend on energy as well as extend the time other sources of energy will last.

Solar power has benefited civilizations for centuries, and the knowledge from our past provides foundational understanding of the sun's energy to bring about our current understanding of solar power. The earliest known application of solar energy arose during the 15th century B.C. The figure 3.1 shows us an old passive solar:



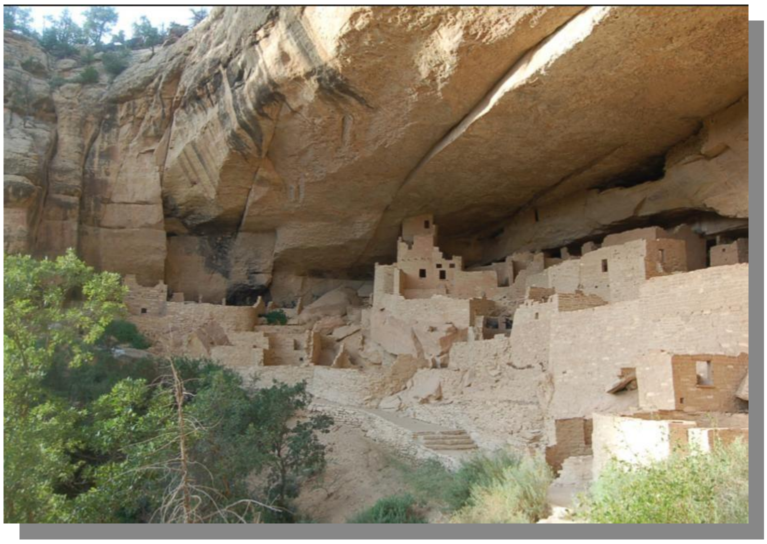


Figure 3.1 – An old passive solar at Mesa Verde's Cliff Palace

To have a better understanding of passive solar energy, it is helpful to know how to categorize passive systems used for this type of solar energy. It dipends about the radiation effect on the building:

- *Direct gain*: is the simplest application of passive solar energy, where the space of the building is directly heated by the sunlight, which most often enters through windows within the south-facing wall for buildings in the northern hemisphere. Ideally, in this approach, the materials within that space ought to be capable of storing heat and the air flow throughout the room should distribute the heat. A representation of direct

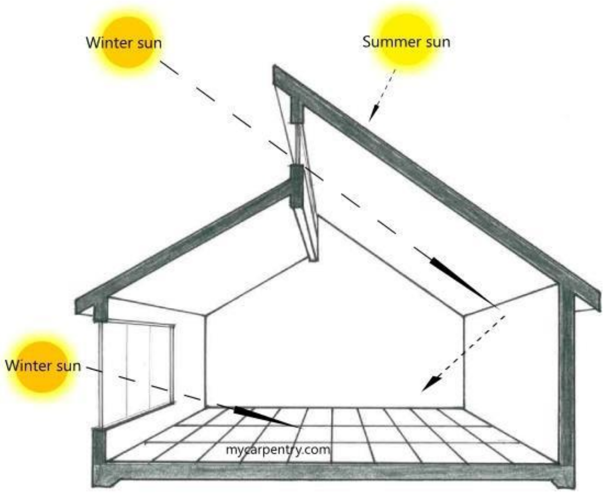


Figure 3.2 – Direct gain passive solar Energy.

gain is shown in figure 3.2, which also depicts the difference of the angle of the sun during the summer and winter, and how an overhang can be incorporated into the building design for further temperature control.

- *Indirect gain*: the south-facing wall recive the sunlight, and as air moves throughout the internal space, the heat will then be transferred from the wall to the living space. For increased control of indoor temperature, ventilation at the top and bottom of the wall or other thermal mass is included, assisting in regulating the temperature. Figure 3.3 clearly displays indirect gain, the use of a thermal mass for solar heat gain, as well as vents integrated into the thermal mass for air circulation and heat distribution.

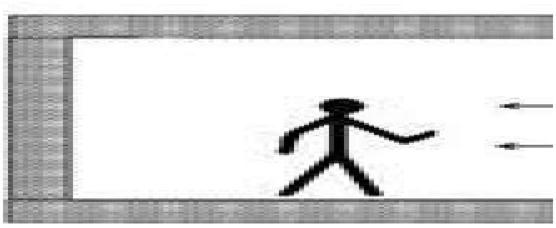


Figure 3.3 – Indirect gain passive solar Energy.

- *Isolated gain*: it uses solar collection and thermal storage that are separate from the actual living space, moving heat to the living space through natural or forced convection. Ventilation is also essential in this method of passive solar heat gain. An advantage to isolated gain systems is that they can be added to new and existing buildings

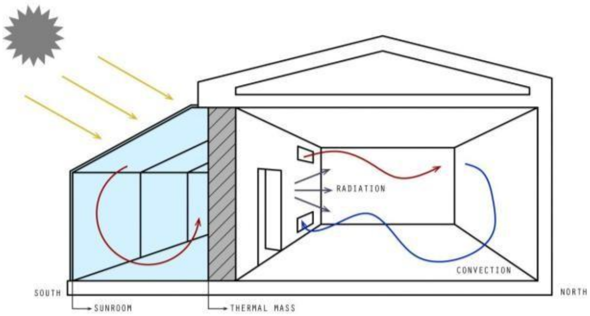


Figure 3.4 – Isolated gain passive solar Energy.

On the other hand, active solar use the solar energy to heat a fluid, liquid or air, and then transfer the solar heat directly to the interior space or to a storage system for later use. If the solar system cannot provide adequate space heating, an auxiliary system provides the additional heat. Liquid systems are more often used when storage is included, and are well suited for radiant heating systems, boilers with hot water radiators, and even absorption heat pumps and coolers. Both liquid and air systems can supplement forced air systems.

This North Carolina home gets most of its space heating from the passive solar design, but the solar thermal system supplies both domestic hot water and a secondary radiant floor heating system.

|Energy.gov|

Figure 3.4 – house in North Carolina with active solar system

One of the most important goals of a building project is the people's comfort. The concept of comfort is very broad and not always easy to ensure, however, a good design house project will guarantee the comfort and also an energy saving.

Build a house with passive strategies require careful planning and the focus on the following points:

- The envelope;
- The orientation;
- The insulating.

3.1 The building envelope

The building envelope is the element that works like an interface between inside and outside, its function is to close and protect the interior areas. The envelope is not only we can see, like a facade, but every element that works to separate the inside from outside like the roof and the wall in contact with the ground (garages, cellar..).

The aim of the building envelope is to create enclosed spaces for the human's needes. It has to protect them from the outer temperature, but on the other hand they also need a space in which they can feel safe, relax themselves, entertain social relations, create, work, etc.. The result is that every place requires a space with different characteristics that can satisfy any type of necessity and human activity that takes place inside it.

Since the olds times, man has tried to create spaces that can reach the above objectives. The ancients buildings had thick walls and an almost absence of openings. With the passage of time, the science and technologic development have improved the envelope construction, for example, they realized that it had to be made depending on the geographic location in which the building was built. Every city has a different temperature and climatic condition that affect the building's construction, from here come the studies about the building's orientation (it will be detailed in the subchapter 3.2) and insulation.

The concept of the building's orientation was introduced from the traditional architectures through the presence of many windows in the walls facing to the south, to maximize solar gains, while the north walls were very thick and there were few windows or nothing of these. The presence of a thick masonry, for years, played a role of thermal insulation, which despite its obsolescence, it ensured adequate internal comfort conditions, in relation to those who obviously the standards were. The thick walls, as well as taking up much space, encouraged the large use of building materials, for this reason, the technological evolution has focused on the improving of construction techniques and the optimization of materials.

With this new architecture approach, more 'lightweight buildings' were increased with less thick walls, a greater presence of windows and the use of new and different materials (like steel, concrete, glass etc,) with significantly better performance characteristics.

Technological advances have allowed the development of modern façades that move away from the idea of 'separation' and more closely resemble that of integration between inside and outside.
In this way, the building envelope goes from being a passive to an active element that intervenes in the indoor comfort but especially in what it has become widely discussed topic: energy conservation, linked to the energy required by the occupants. The energy demand includes different fields:

- heating in the winter season;
- cooling in summer;
- indoor air quality (IAQ);
- artificial lighting;
- production of domestic hot water (DHW).

The external environmental parameters can be managing to meet the internal needs, here the envelope plays a fundamental role: it can be used to filter, accumulating and / or modify the mass and energy flows.

What is the energy performance that the building envelope should have? The following subchapter will be focused on this aspect

3.1.1 Thermal performance of building

The thermal performance of a building refers to the process of modeling the energy transfer between a building and its surroundings. For a conditioned building, it estimates the heating and cooling load and hence, the sizing and selection of HVAC equipment can be correctly made. These quantifications enable one to determine the effectiveness of the design of a building and help in evolving improved designs for realizing energy efficient buildings with comfortable indoor conditions.

In this chapter, we will discuss a method for estimating the thermal performance of a building.

Between a building and the external environment there are various heat exchange processes, as shown in Figure 3.5:

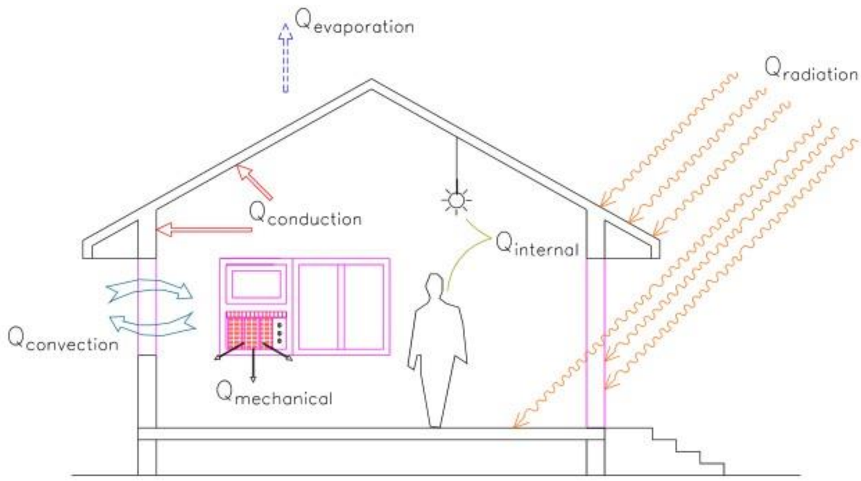


Figure 3.5 – Heat exchange processes between a building and the external enviorment

- *Conduction*: a process by which heat flows from a region with higher temperature to the lower temperature region through a single middle (solid, liquid or gaseous), or by middle in direct physical contact. In the conduction, the energy is transmitted by direct contact between its molecules.

$$Q = A\ U\ \Delta T \tag{3.1}$$

where,

A = surface area (m_2);

U= thermal transmittance (W/ m_2K);

ΔT = temperature difference between inside and outside air (K).

- *Convection*: it is the transfer of heat from one place to another by the movement of fluids. The transmission of energy by convection occurs in several stages: first heat passes by conduction from the surface to the fluid particles adjacent, so that energy thus transmitted face increase energy and the internal temperature of the particles, and after these particles then go to move toward a region of the fluid at a lower temperature and mingle with it yielding part of their energy to other particles. In this case, the heat transfer is due to the movement of some parts of the mass of fluid, with the transport of substance.

- *Radiation*: it is the transfer of heat in form of electromagnetic radiation in the form of waves or particles through space or through a material medium. Besides, solar radiation is transmitted through transparent windows and is absorbed by the internal surfaces of the building.

Heat is also added to space due to the presence of human occupants and the use of lights and equipment. The interaction between a human body and the indoor environment is shown in Figure 3.6:

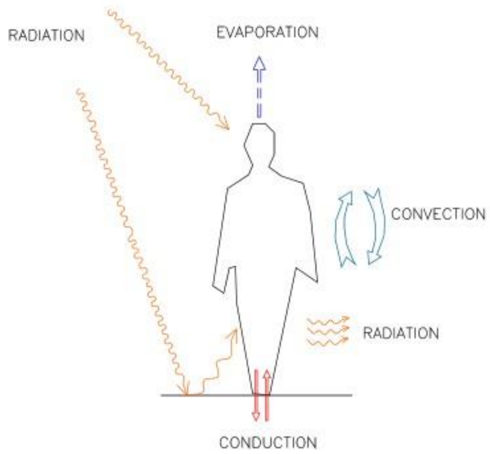


Figure 3.6 – Heat exchange processes between a human body and the interior enviorment

Due to metabolic activities, the body continuously produces heat, part of which is used as work, while the rest is dissipated into the environment for maintaining body temperature.

The body exchanges heat with its surroundings by convection, radiation, evaporation and conduction. If heat is lost, one feels cool. In the case of heat gain from surroundings, one feels hot and begins to perspire. Movement of air affects the rate of perspiration, which in turn affects body comfort.

To guarantee the wellness and comfort of human activities within the building is necessary that the facade possesses the requirements and performances. They must be able to safeguard appropriate conditions of safety, wellness, management, appearance, and usability.

- the opaque elements;
- the glazed elements.

In these two subchapters, we will analyze in detail their technological development of the opaque and glazed element and how they are closely linked to energy efficiency.

3.1.2 The opaque elements

The opaque element, since the oldest time, has always had a protect function against the water and climate variability. Its different features depend by the building's geographical location, so by the climate. The buildings of Northern Europe, for example, must be capable of storing heat produced inside the building itself, so the walls are supposed to have low thermal transmittance values and the air infiltration must be reduced through doors and windows. In the hot location, the solutions adopted are different.

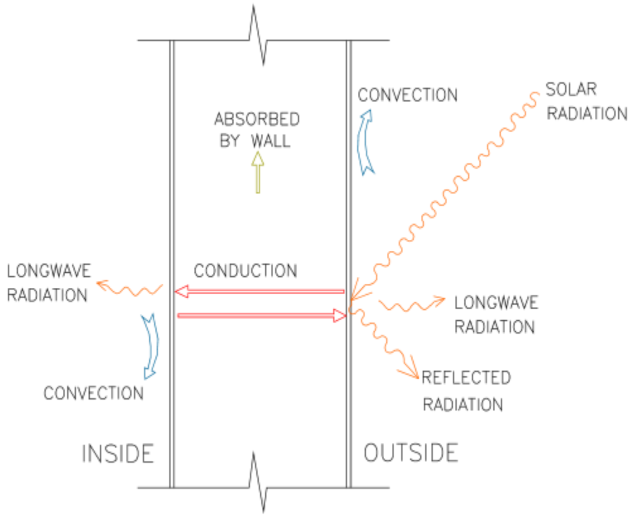


Figure 3.7 – Heat transfer processes occurring in a wall.

The walls are thick in order to increase thermal inertia and the phase shift, then these are coated with clear elements to reduce the phenomenon of heat absorption and ensure the reflectance.

The opaque elements functions

- *Thermal insulation*: they must be able to protect ourselves from outside temperatures, so the walls, as the doors, have to be well designed and well chosen;
- *Humidity control*: **the opaque's design and its material's choice affect the humidity control. Its** coefficient measures the amount of vapor (in Kg) that crosses the thickness of 1 meter of a certain material on a surface of 1 m^2 and for a uniform difference in vapor pressure.
- *Air resistance*: is a force acting opposite to the relative motion of any object moving with respect to a surrounding fluid. This can exist between two fluid layers (or surfaces) or a fluid

and a solid surface. Unlike other resistive forces, such as dry friction, which are nearly independent of velocity, drag forces depend on velocity.

The opaque elements properties

- *Thermal resistance [$m^2 \cdot k/W$]*: the thermal resistance R is the materials propriety to resist at the heat flow when there is a temperature difference:

$$R = \frac{d}{\lambda} \tag{3.2}$$

where

d is the thickness of the material layer in the component [m];

λ is the design thermal conductivity of the material **[W/m·k].**

The thermal conductivity is the property of a material to conduct heat. It can be calculated in accordance with ISO 10456 or obtained from tabulated values.

So a good opaque element must be with high resistance, so with low conductivity.

- ***Thermal transmittance [$W/k \cdot m^2$]***: the transmittance U (EN ISO 6946) is defined as the heat flow crossing a uniform surface subjected to temperature difference of 1° C and it is linked to heat transfer conditions and material's features that makes up the structure. It is assumed equal to the inverse of the sum of the thermal resistances of each layer:

$$U = \frac{1}{R_T} \tag{3.3}$$

R_T is the total thermal resistance of a plane building component consisting of thermally homogeneous layers perpendicular to the heat flow:

$$R_T = R_{si} + R_1 + R_2 + R_3 + \cdots + R_n + R_{se} \tag{3.4}$$

where

R_T total thermal resistance [$m^2 \cdot k/W$];

R_{si} internal surface resistance [m^2·k/W];

R_n thermal resistances of each layer [m^2·k/W];

R_{se} external surface resistance [m^2·k/W].

R_{si} and R_{se} are marked values, as we can see from the *Table 1* of the EN ISO 6946

Surface resistance m^2·K/W	Direction of heat flow		
	Upwards	Horizontal	Downwards
R_{si}	0,10	0,13	0,17
R_{se}	0,04	0,04	0,04

NOTE 1 The values given are design values. For the purposes of declaration of the thermal transmittance of components and other cases where values independent of heat flow direction are required, or when the heat flow direction is liable to vary, it is advisable that the values for horizontal heat flow be used.

NOTE 2 The surface resistances apply to surfaces in contact with air. No surface resistance applies to surfaces in contact with another material.

Figure 3.8 - Table 1 from the EN ISO 6946_conventional surface resistances

For non-planar surfaces or for specific boundary conditions, use the procedures in Annex A of the same European Standard Norm.

The surface resistance is given by Equation (3.5)

$$R_s = \frac{1}{h_c + h_r} \quad (3.5)$$

where

h_c is the convective coefficient;

h_r is the radiative coefficient.

So the opaque element has to have a lower thermal conductivity, high thermal resistance y low thermal transmittance.

- <u>*Thermal inertia*</u>: it is a material property related to thermal conductivity and volumetric heat capacity, in other word, it is the materials ability to retain heat and return it after a time. The time of heat return, is what identify the inertia magnitude of material. The temperature of a material with low thermal inertia changes significantly during the day, while the material temperature with high thermal inertia does not change as drastically.

Have a high thermal inertia of walls will be a good idea in the hot climate, in this way the indoor comfort will be improved (in cold climate it does not improve the inner comfort). We can reach it with a careful choice of materials and not necessarily with thick walls.

- *The phase shift*: it is the time when the internal temperature reaches the external (during the winter, if we are in spring or in summer it happens the opposite). The phase shift is depending on the thermal inertia, larger is the inertia, more large will be a phase shift.

3.1.3 The glazed elements

Nowadays the construction of glazed facade is more and more used, in according to the modern architecture. We haven't underestimated the material's intrinsics features that affect the building's sustainability and its energy efficiency.

Today the market of construction provides component and system able to satisfy the different customer's needs. The thermal insulation, solar radiation control and the optimization of the utilization of natural light, are the focus point of the glazed element that, thanks to research, are improved year by year.

Thermophysical properties of windows, improve the levels of the indoor comfort and they reduce energy consumption related to the use of artificial lighting and air conditioning systems.

The glazed elements functions

- *Thermal insulation:* the glass, as the walls, must be able to protect ourselves from outside temperatures;
- *Solar gain:* it is the ability to capture and store heat which then will be return as solar energy to the inside space (this offsets winter heat losses);
- *Sunscreen:* reduction of solar radiation that affects the windows. It will protect us from them (it operates in summer, so as to reduce internal heat gain);

- *Natural light:* it allows us to use the minimum of artificial light, we must not forget the glare phenomenon which occurs when there is too much light;

- *Natural ventilation:* through the windows' opening and closing they are able to give a great IAQ (Indoor Air Quality).

The glazed elements properties

- ***Thermal transmittance [W/k·m²]***: the transmittance U_w is defined as the heat flow crossing a uniform surface subjected to temperature difference of 1° C and it is linked to heat transfer conditions and the type of window and glaze. With the *International Standard ISO 10077* we can calculate the transmittance of windows and pedestrian doors.

The ISO 10077 includes the calculation of :

- Single, double and coupled windows;
- Different type of glazing (glass or plastic; single or multiple glazing, with or without low emissing coatings, etc...);
- Opaque panels within the window or door;
- Various type of frames (wood, plastic, metallic, etc...).

For a single window the transmittance is calculated with the equation (3.6):

$$U_w = \frac{\sum A_g U_g + \sum A_f U_f + \sum l_g \psi_g}{\sum A_g + \sum A_f} \tag{3.6}$$

Where

U_g is the thermal transmittance of the glazing;

U_f is the thermal transmittance of the frame;

ψ_g is the linear thermal transmittance due to the combined thermal effects of glazing space end frame;

A_g is the glazed area;

A_f is the area of the frame;

l_g is the total perimeter of the glazing, and it is the sum of the visible perimeter of the glass.

The figure 3.9 shows us the glazed area and the perimeter:

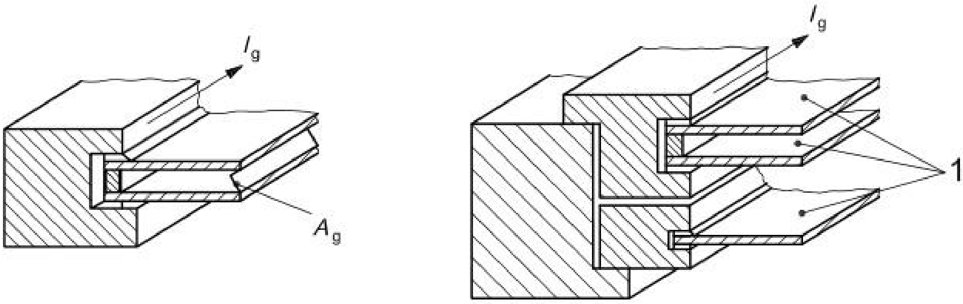


Figure 3.9 - illustration of glazed area and perimeter

The figure 3.10 shows us a single window:

1- frame (fixed)

2- sash (muveble)

3- glazing

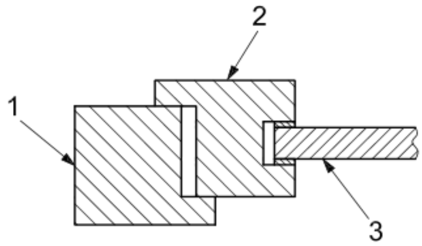


Figure 3.10 - illustration of single window

For a <u>doble windows</u> the transmittance is calculated with the equation (3.7):

$$U_w = \frac{1}{{}^{1}/_{U_{w1}} - R_{si} + R_s - R_{se} + {}^{1}/_{U_{w2}}} \tag{3.7}$$

Where

U_{w1}, U_{w2} are the thermal transmittances of the two windows, calculated with the (3.6);

[redacted], [redacted] are the internal and external surface resistance respectively of the internal and external windows when used alone;

R_s is the thermal resistance of the space between the glazing in the two windows.

The figure 3.11 shows us a doble window:

1- frame (fixed)
2- sash (movable)
3- glazing
a- internal
b- external

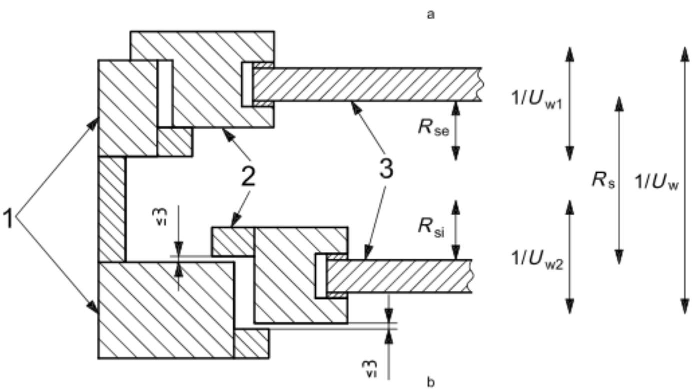


Figure 3.11 – illustratinon of doble windows

For a coupled windows the transmittance is calculated with the equation (3.6) and U_g is calculated with the (3.8):

$$U_g = \frac{1}{{}^{1}/_{U_{g1}} - R_{si} + R_s - R_{se} + {}^{1}/_{U_{g2}}} \tag{3.8}$$

where

U_{g1}, U_{g2} are the thermal transmittance of the external and internal glazing. They are calculated with the equation (3.7) and (3.8) respectively.

The fugure 3.12 illustred us a coupled windows:

1- glazing

a- internal

b- external

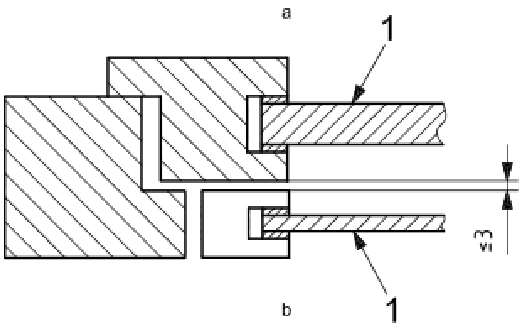


Figure 3.12 – illustratinon of coupled windows

A coupled window consists of one frame and two separate sashes.

Until now we have listed the types of windows that can be found in commerce and we showed what equation be applied for calculating the transmittance of the window. You can clearly see how the transmittance decrease with increasing resistance. More obstacles interpose to the passing of heat, more resistance increases.

The same mechanism works for glass technology: more it resists to the passage of the heat, lower will be the final transmittance of the window.

How can the glass resists to the passing of the heat? It works in two ways:

- With laminated glazing (single or multiple glazing);
- With coating glazing.

For a single glazing the transmittance is calculated with the equation (3.9):

$$U_g = \frac{1}{R_{se} + \sum_j \frac{d_j}{\lambda_j} + R_{si}} \qquad (3.9)$$

with

R_{se} internal surface resistance;

is the thickness of the glass pane or material layers j;

λ_j is the thermal conductivity of glass or material layer j;

R_{si} is the internal surface resistance.

Figure 3.13 – Image of single glass

For a multiple glazing the transmittance is calculated with the equation (3.10):

$$U_g = \frac{1}{R_{se} + \sum_j \frac{d_j}{\lambda_j} + \sum_j R_{sj} + R_{si}} \qquad (3.10)$$

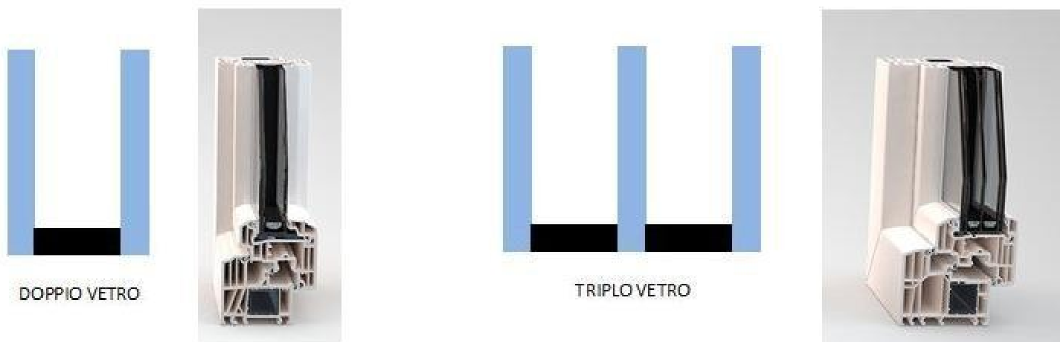


Figure 3.14 – Image of double and triple glass

The difference from the single glazing is the thermal resistance of air space j. Contrary to what you think, increase the air chamber between glass elements doesn't reduce the transmittance. Put more glass layers can help it because they add resistance and Ug decrease and consequently Uw too, as showed in the Figure 3.15:

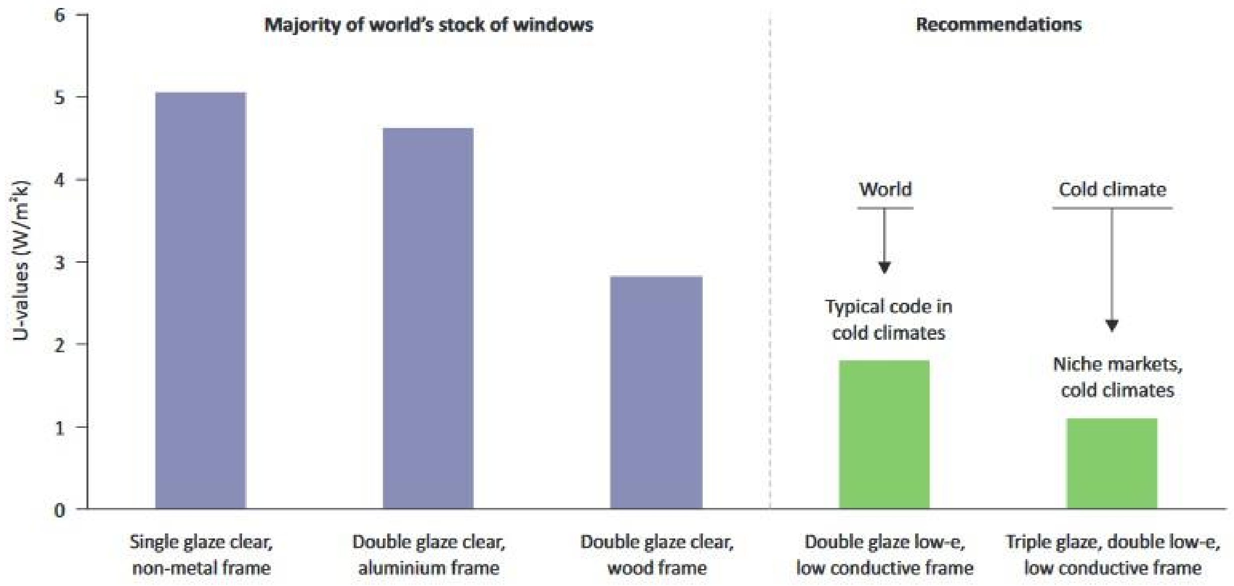


Figure 3.15 – Glazing insulation performance [from Internacional Energy Agency (IEA)]

- *The reflectance (reflection coefficient):* It is the percentage of light striking the glazing that is reflected back. Most manufacturers provide both outside reflectance (exterior daytime view) and inside reflectance (interior mirror effect at night). All smooth glass is somewhat reflective; various treatments such as metallic coatings increase the reflectance. High reflectance brings with it low visible transmittance.

- *The absorbance (absorbent coefficient):* represent the relationships between absorbed energy flows and its energy incident.

When solar radiation affects on a glass it is decomposed into three components. Those parameters are related to the radiation characteristics and nature of the material itself.
A simplified schematization of the phenomenon is presented in Figure 3.16, from which shows that the radiation incident 'I' is divided into three components.

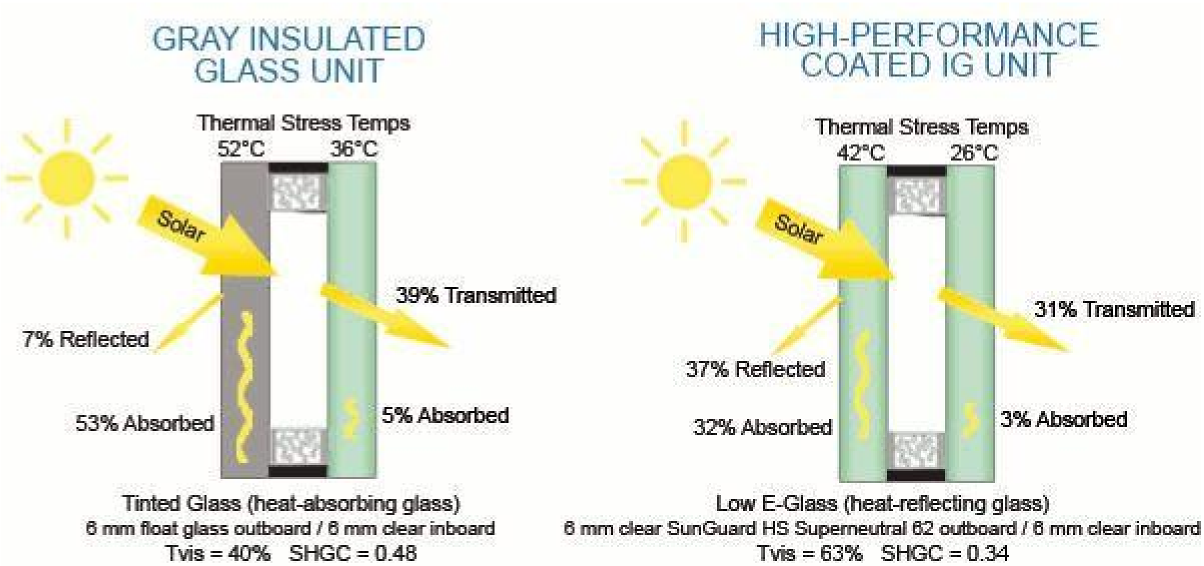


Figure 3.16 – Glazing insulation performance

3.2 The orientation

When we talk about building orientation, we are introducing the sunshine concept. This is the visible part of the sky above the obstacles and the solar path during the day and season. We can use it to illuminate and heating the spaces during the winter but we have to defend from it during the summer.

Now we'll focus on three different points that we can't forget during the project phase or rehabilitation:

- *Latitude and solar path*. Every place receives a different solar radiation depending on its geographical location and season. With the term latitude, we define the angular distance between the geographical location and the equator. This influence the annual temperatures. The solar path represents the sun's position during the Earth's rotation (Figure 3.17).

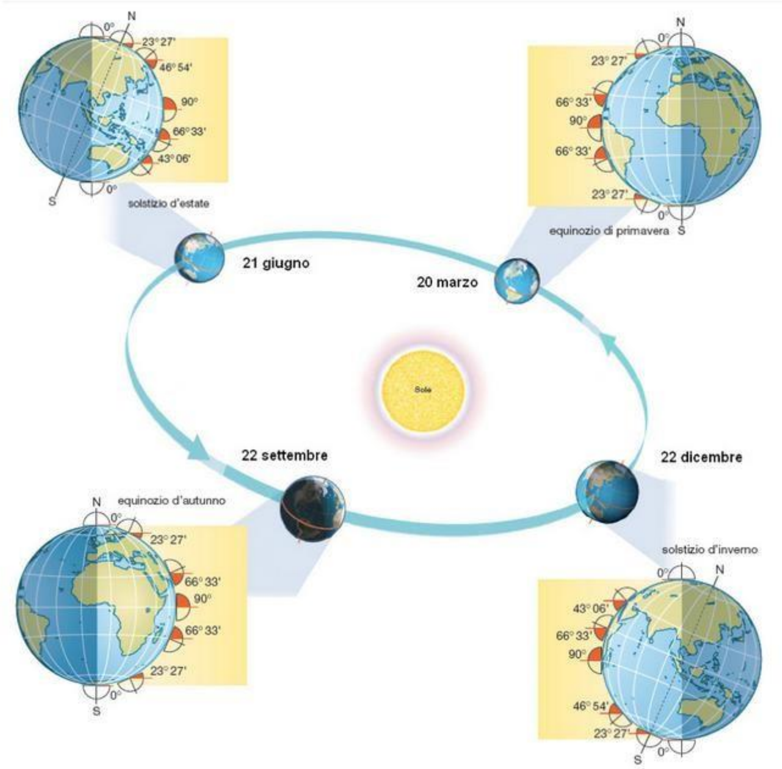


Figure 3.17 - Earth's Revolution

As we can see from the Figure 3.17, the sun's rays have a different inclination depending on the earth's position caused by its Revolution movement. Each place will receive a different solar energy from zone to zone, thanks to the latitude, and the same place will never receive the same solar energy throughout the year (except for the equatorial zone that always receives the maximum radiation).

- *The solar chart.* The solar chart represents the sky's projection on a plane. On it it's possible track the sun's path in different seasons and latitude, so locate sun's position in every time. The projection can take place onto a horizontal plane (polar diagram) or on a vertical plane (cylindrical diagram) as the Figure 3.18 shows:

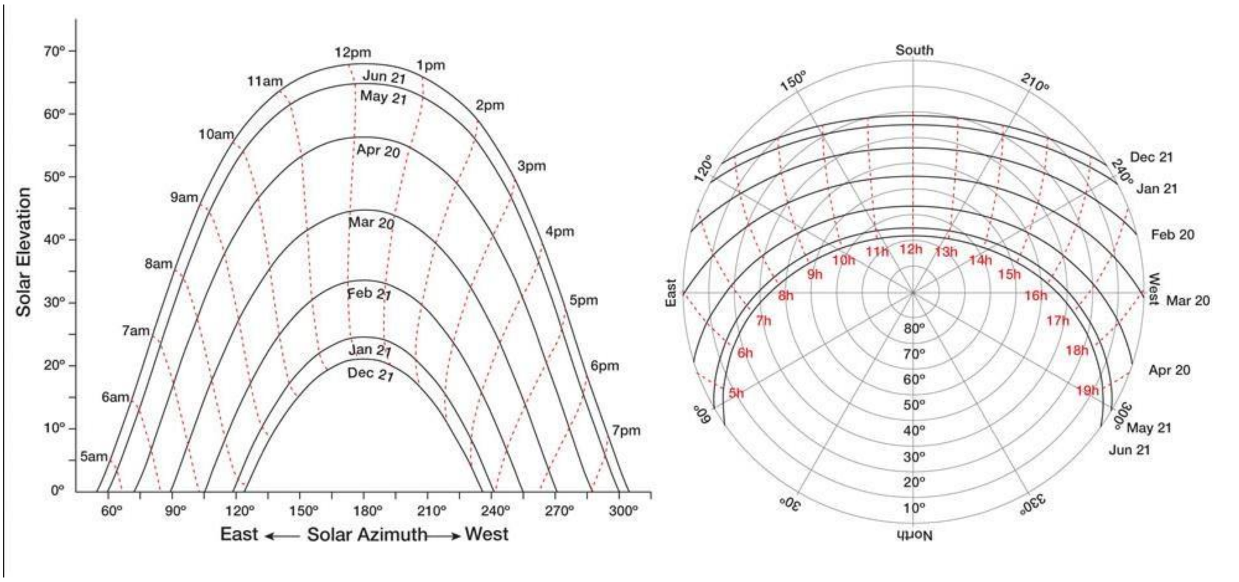


Figure 3.18 - Solar Chart (cylindrical diagram on left and polar diagram on right)

The chart is a useful tool to know the amount of sunshine that impact on the envelope of the building. It is especially used to know the shadows projected by other buildings around it or the shadows of the building itself such as the balconies or vertical bosses.

There are a lot of software that use solar chart and it simplifies us the calculations. The software easily identifies the tilt angle of the sun's rays on the building at any time of year and it shows you images to the gray areas and the sunny ones. It is crucial when we want to create opening in the building and then protect them from sunlight.

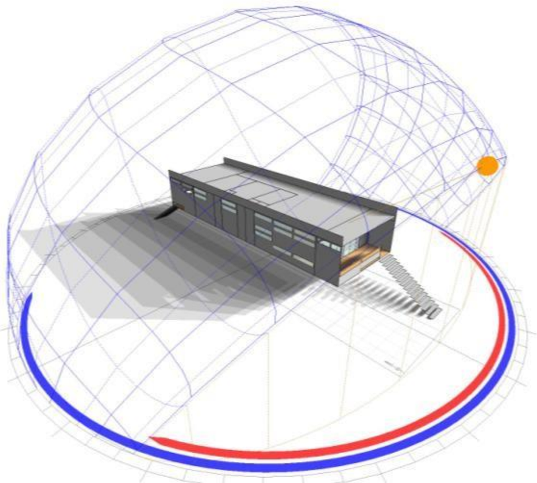


Figure 3.19 – En example of solar tool (software)

- *Cloudiness (hours of sunshine and its index) and intensity of solar radiation.* The urban plot's microclimate and the building's climate behavior depend on solar radiation. There are three types of solar radiation:

- *direct radiation,* it is used to describe solar radiation traveling on a straight line from the sun down to the surface of the earth;

- *diffuse radiation,* sunlight that has been scattered by molecules and particles in the atmosphere but that has still made it down to the surface of the earth.
- *reflected radiation,* describes sunlight that has been reflected off of non-atmospheric things such as the ground, for example the asphalt reflects about 4% of the light that strikes it.

  The global insulation is the total insulation: direct + diffuse + reflected light. It is used to refer to the total insulation on a horizontal, vertical or sloping surface.

  The cloudiness that changed the global insulation and the solar rays' intensity on the building. It is not simple to estimate, for this reason, there are a lot of software that can help us.

- Landscape improvement. The building project must be oriented not only to energy goal (sunlight to exploit natural light and heat) but also to take advantage of the held landscaping to improve the mental and psychological comfort of the people who live in it. The openings in the building have to be well designed and oriented to allow a good landscape view. A lot of protection systems can be included, such as internal and external curtains, bris soleil etc...

Figure 3.20 – En example of solar protection

When a new building will be designed it will be a good use not forget the items mentioned above, in order to create a building with a right orientation to maximize solar energy. Through studies and simulation software, it was concluded that the best exposure is the South (S) for the perfect sunshine during the cooler months of the year, while to avoid exposures are East and North-East (E-NE) and West and North-West (W-NW) to the excessive effects of sunlight in the fall months of the year. So a perfectly oriented building will be located along the East-West axis so as to facilitate the entry of the sun to the south facade and reducing the surface that has the worst orientation (east and west).

3.3 The insulation

From the web site of Green building alliance:

> *Insulation is not the most attention grabbing building component, but it is essential to both the performance of the building and health of the occupants. Without sufficient insulation, large portions of the energy used to heat or cool a building will be lost to the outdoors. Insufficient insulation can also lead to mold problems as heated air rapidly cools and causes water vapor to condense. Historically, mud, asbestos, and cork were used as insulation materials for buildings and pipes. The insulation products available today are much more effective, especially in conjunction with air sealing and ventilation*.

Every building needs a different type and amount insulation according to building type and use. Many service-sector buildings have higher internal thermal loads, for example, because of a higher density of people, more electrical equipment and more artificial light, so they may need less insulation than a residential building.

The insulation contains many tiny air cavities that slow heat transmission when installed on a building's interior or exterior surface. Each material has an R-value rating that indicates a measure of its thermal resistance. The R-value of materials changes with their density and a higher R-value indicates a better insulator.

The regional climate, and the type of building, affects the R-values and the material's density. There are many types of insulating material, and certain types are better suited to different applications. Most new buildings in cold climates are being constructed with insulation. In most parts of the world, however – except for a few regions, such as Northern Europe – the level of insulation is not as high as economically justified. Furthermore, many existing buildings have little or no insulation. In hot regions, especially in less developed countries, many new buildings are being constructed without any insulation, thus substantially increasing cooling loads. Policy makers need to make significant efforts to ensure the building industry uses more insulation.

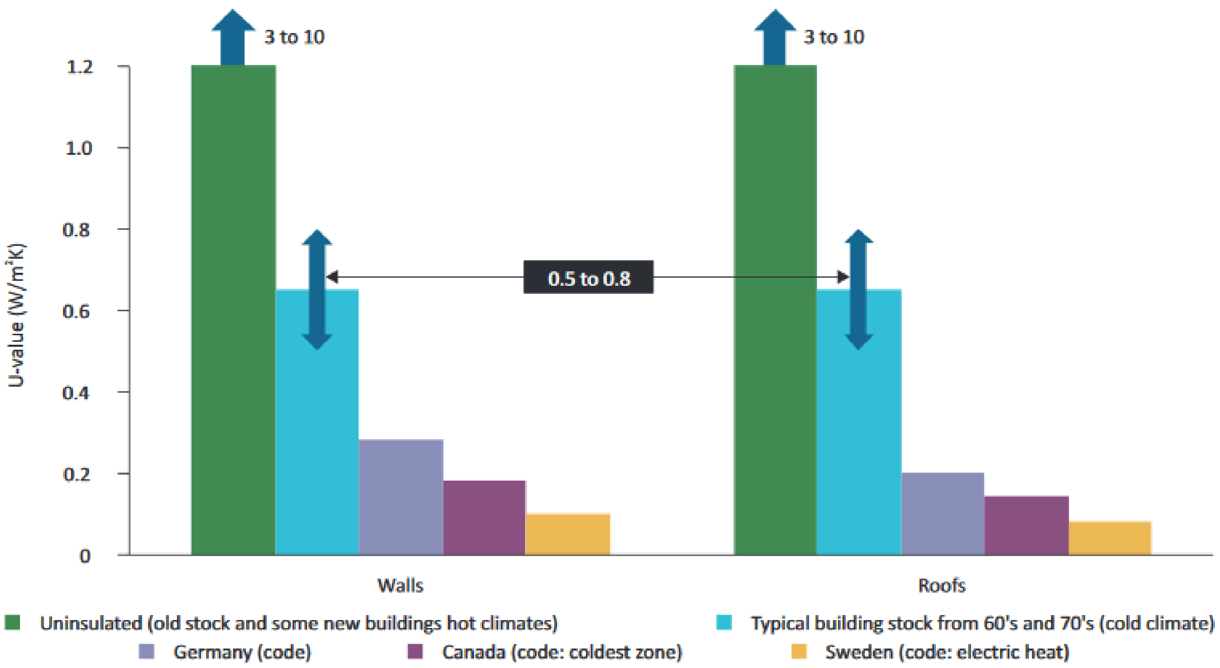


Figure 3.21 – Insulation levels from old buildings to buildings meeting stringent current codes [from Internacional Energy Agency (IEA)]

The best way to insulate a building is to have a well-defined thermal boundary. The thermal boundary of a building separates the conditioned (heated or cooled) spaces from outdoor or unconditioned areas. A building should be insulated continuously around the thermal boundary, including corners and edges. The characteristics of building materials and the position of insulation can cause a common problem that is the thermal bridge. The thermal bridge is a phenomenon that occurs when there is a not homogeneous heat flow. This happens when a different conductive materials overlap, or when there is a change of the shape that changes the heat flow direction.

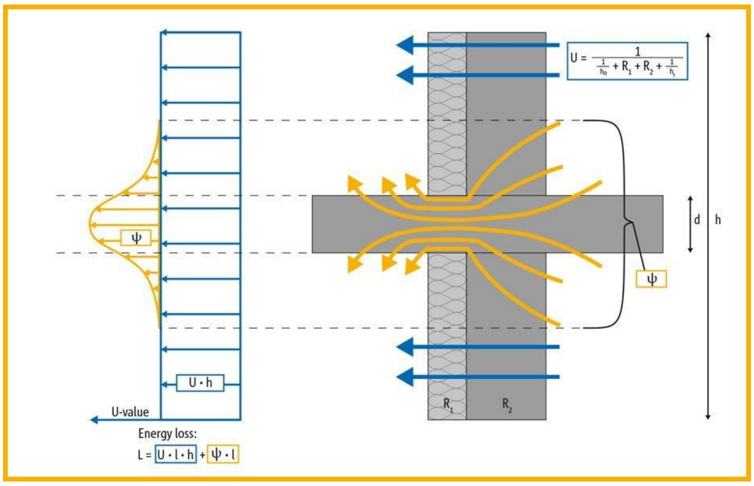


Figure 3.22 – En example of Thermal bridge

It is good practice try to minimize the thermal bridge, in this way the heat flow will not increase. A building should be insulated continuously around the thermal boundary, including corners and edges.

3.3.1 Insulation materials

There are a lot of insulating materials that can be used in construction, their choice will depend on the type of building (size and use), indoor air quality impacts, life cycle costs, recycled content etc.. Below some types of materials and their features will be listed.

- Fiberglass: it consists of extremely fine glass fibers and it is one of the most use insulation materials. It's commonly used in two different types of insulation: blanket (batts and rolls) and loose-fill and is also available as rigid boards and duct insulation. Most manufacturers use 20% to 30% recycled glass content.
- Mineral Wool: it contains an average of 75% post-industrial recycled content. It doesn't require additional chemicals to make it fire resistant, and it is commonly available as blanket (batts and rolls) and loose-fill insulation.
- Cellulose: Cellulose insulation is made from recycled paper products, its content is generally 82% to 85%. The paper is first reduced to small pieces and then fiberized, creating a product that packs tightly into building cavities, inhibits airflow. To ensure fire and insect resistance, manufacturers add the mineral borate, sometimes blended with the less costly ammonium sulfate. Cellulose insulation typically requires no moisture barrier and, when installed at proper densities, cannot settle in a building cavity.
- Plastic Fiber: it is made from recycled plastic milk bottles (polyethylene terephthalate or PET). The fibers are formed into batt insulation similar to high-density fiberglass. The insulation is treated with a fire retardant so it doesn't burn readily, but it does melt when exposed to flame.
- Natural fiber
  - Cotton: it is made of 85% recycled cotton and 15% plastic fibers that have been treated with flame retardant and insect repellent, as in cellulose insulation. It is also nontoxic and its price is about 15% to 20% more than fiberglass batt insulation.

- <u>Sheep's wool</u>: For use as insulation, sheep's wool is also treated with borate to resist pests, fire, and mold. It can hold large quantities of water, which is an advantage for use in some walls, but repeated wetting and drying can leach out the borate. Its thermal resi stance is similar to other fibrous insulation types.

- <u>Polystyrene</u>: it's a colorless and transparent thermoplastic. It is commonly used to make foam board or beadboard insulation, concrete block insulation, and a type of loose-fill insulation consisting of small beads of polystyrene. There is a large type of polyetyrene material as:

  - <u>MEPS</u>: molded expanded polystyrene;
  - <u>EPS</u>: expanded polyestyrene;
  - <u>XPS</u>: estrude polyestyrene.

- <u>Vermiculite and perlite</u>: Vermiculite and perlite insulation materials are commonly found as attic insulation in homes built before 1950. Today they aren't widley used for its contain of amounts tiny trace. Vermiculite and perlite consist of very small, lightweight pellets, which are made by heating rock pellets until they pop. These pellets can be poured into place or mixed with cement to create a lightweight, less heat-conductive concrete.

- <u>Wood fiber</u>: It is made of transforming timber waste. The wood fibre insulation has an attractive environmental profile combined with a whole bag of functions as rigid insulation, sheathing and of course, for its renovable characteristics

Figure 3.23 – Fiberglass insulation (left) and XPS insulation (right).

3.3.2 The progression of insulation technology

In many parts of the world, buildings have long been constructed using local materials to maximise comfort given the local climate. Structures with high thermal mass have been common for a very long time and are still typical in many regions, but their use has diminished in some regions to reduce cost. Modernisation has resulted in higher densities in urban areas, the need for faster construction techniques, and more affordable approaches that in many cases result in less efficient structures than old techniques.

The evolution of traditional envelope solutions, to reach hight thermal and acoustic performance, is lead by new types of multi-layer thermally insulated.
The facade walls, can be classified into three typologies, depending on the position of the thermal insulation.

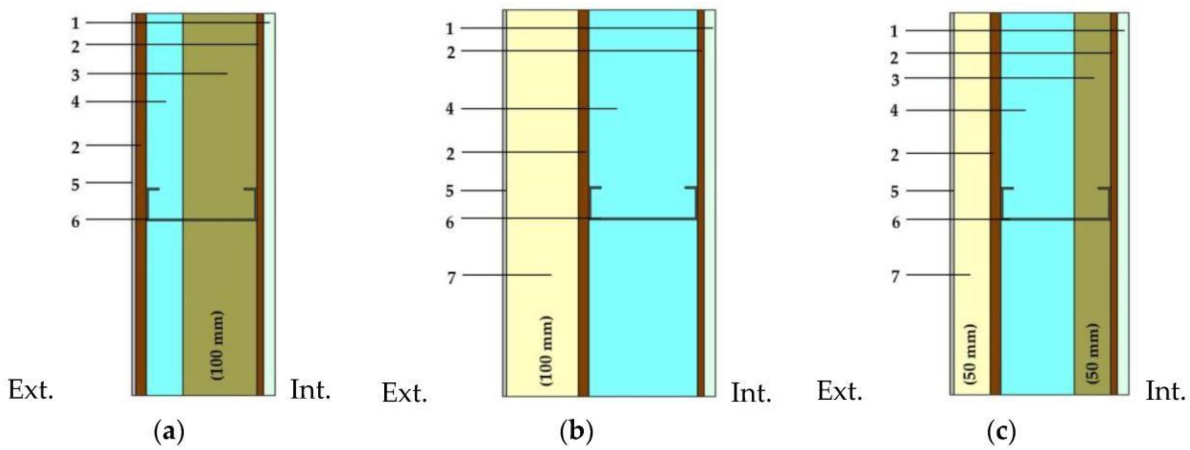


Figure 3.24 – (a) cold frame construction; (b) warm frame construction; (c) hybrid frame construction.

A good insulation must have a low thermal transmittance, to avoid heat dispersion. However, a high thermal inertia guarantees hot spaces in winter and cool in summer.

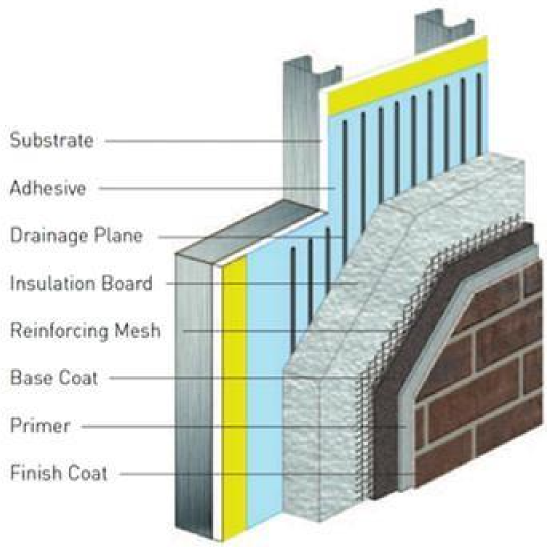


Figure 3.25 – Façade with Exterior Insulation

The façade with external insulation is called Exterior Insulation and Finishing System (EIFS). It has the good winter thermal behavior and it allows to achieve good values of thermal insulation and thermal inertia.

In this case, the building is in thermal stillness toward thermal changes both in summer. So, in winter it guarantees a cost saving of house. This is the best solution to solve thermal bridge, caused by beams and column, and remove the development of mildew and condensation. The cold construction presents a higher risk of interstitial condensation, due to the low temperatures that can be registered inside the walls, especially in the steel studs and their vicinity.

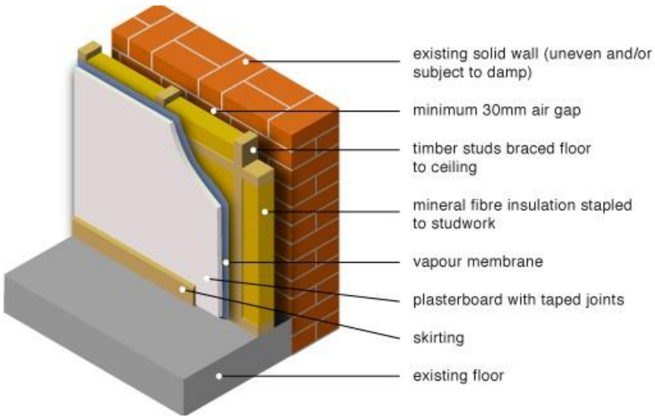


Figure 3.26 – Façade with Internal Insulation

Instead the facades with internal insulation are used for temporary buildings, because the mass is outside of the insulating layer. The internal insulation is the perfect solution to reduce energy consumption and costs for heating and cooling installation. Especially when the buildings are historic and the integration of isolation from the outside is not possible.

In spite of the evident advantages of the warm construction, placing the thermal insulation in direct contact with the exterior environment conditions and climatic cycling can accelerate the degradation of its integrity and thermal performance if not considered or well designed. This solution, differently from others, causes a risk of condensation and not resolve the thermal bridges. It is important use the vapour barrier, to avoid these problems.

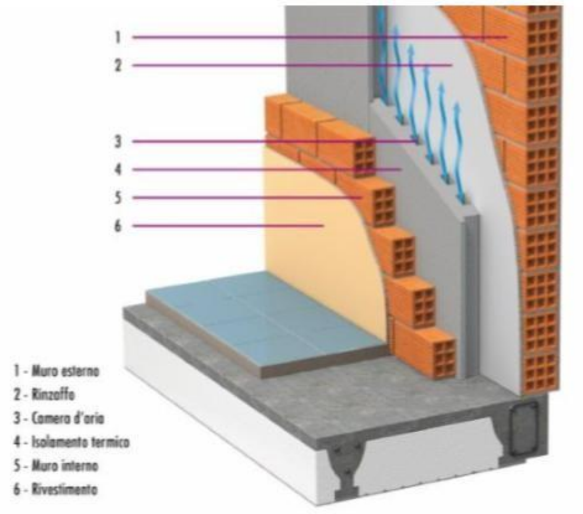


Figure 3.27 – Façade with Middle Insulation

The façades with insulation in the middle are characterized by a low sensitivity to the combined action of rain and wind. Particularly these allow a good balance of thermal insulation and thermal inertia both in the winter and summer season. The insulation in the middle layer has a significant increase in the thermal and acoustic comfort, with consequent of energy savings and protection against noise. In general, these are used exclusively in new buildings.

The technology that support more advantages is the ventilated facade.

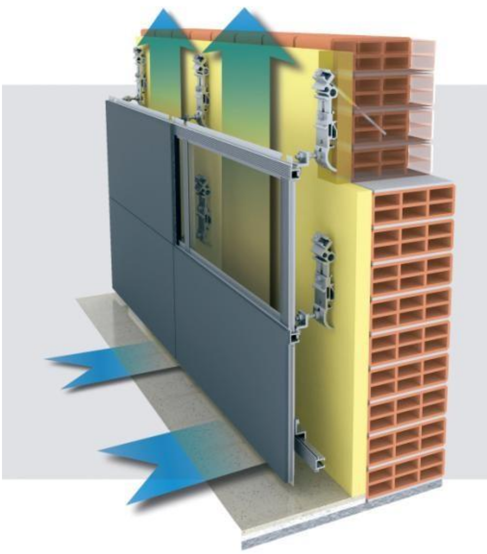


Figure 3.28 –Ventilated Façade

With this system a continuous insulation can be achieved for the exterior of the building, protecting the interior sheet as well as the slab edges. In the ventilated chamber, due to the heating of the air layer of the intermediate space compared to the environment air, the so called "chimney effect" is produced which generates a continuous ventilation in the chamber.

Appropriately dimensioned the air entry and exit, a constant evacuation of water vapour coming both from the interior as well as the exterior of the building is achieved, keeping the insulation dry and obtaining a better performance of the insulation and big savings in energy consumption.

The Ventilated Facade, additionally to impact in the energy consumption savings of the building, eliminates the direct radiations or the bad weather on walls or slabs protecting them from the pathologies which affect buildings constructed with traditional systems.

It is characterized by the presence of a gap between the external coating and the layer of the façade. Usually, the first is a panel, generally of metal or brick material. It fixed to the wall with clamp and anchoring. Inside there is an insulating material, in cohesion to the façade, and an air chamber to ensure a natural ventilation.

The passage to efficient building envelopes can be understood in terms of three distinct time of technological evolution (see Figure 3.31). The first would be a very basic building with a poorly performing building envelope, single-glazed clear windows, no insulation and high air lost. The second has double-glazed, low-e windows and high levels of insulation, and is sealed fairly well. The third stage is represented by buildings of the future, designed with passive method, highly insulated windows, and passive heating contributions. Such buildings will probably incorporate solar thermal systems.

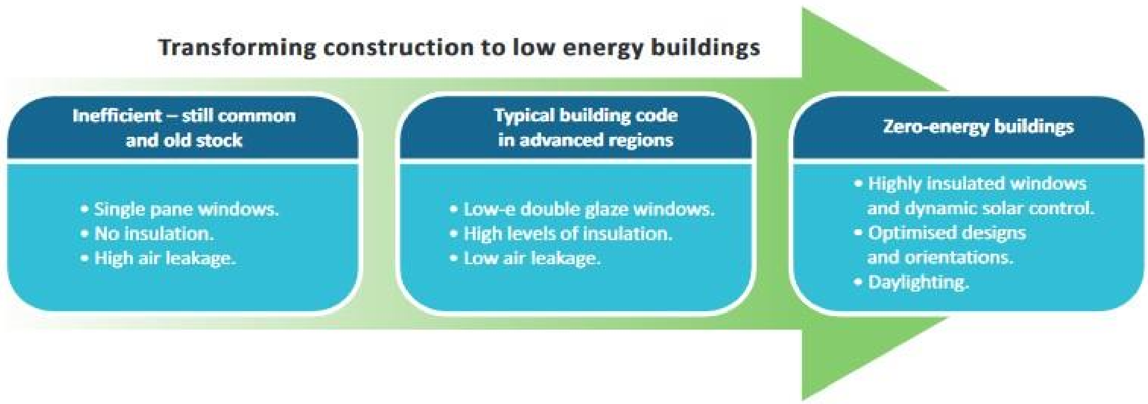


Figure 3.29 – Progression of building from old stock to future technology.[from Internacional Energy Agency]

4 Active strategies: heating, cooling and ventilation's installations

It will be a good practice use the right combination of passive and active design strategies with the aim to reach the people comfort. High-performance buildings use the right blend of passive and active design strategies to minimize energy, materials, water, and land use.

Active performance strategies should always be designed after the passive characteristics of a building have been defined and optimized. Active strategies bring a passively designed building into the high performance and comfort realm. Active performance strategies include the following systems and principles:

Heating, Cooling, Ventilation, and Air Conditioning (HVAC) Systems: guarantee an indoor space in a good climate condition and the mechanical ventilation guarantees pre-filtered fresh air greatly that improves air quality.

Artificial Lighting Systems: proper placement, output strength, and light fixture and source type are critical to economizing a lighting system.

Low-Flow Plumbing Fixtures: they use a fraction of the water that traditional fixtures demand. Combined with a rainwater harvesting system, low-flow fixtures conserve large amounts of water that would otherwise be wasted.

Solar Power (Photovoltaic or Photoelectrochemical) Systems: they convert the sunlight that falls onto their surfaces into electricity.

Air and Ground Source Heat Pumps: they use electricity to move heat from a cool space to a warm space. During the heating season heat pumps move heat from outside to inside building, and during the cooling season they move heat from a building to the outside. This natural transfer of heat from one location to another helps to reduce demands on HVAC systems.

Wind Turbine Generators: they work by converting wind energy that propels turbine blades into electricity, as a big wind generator in the field.

Building Controls and Automation: it allows owners to have a high degree and control of the building. The owners establish an appropriate level of efficiency and output for all building systems and can be adjusted as patterns are defined.

Through a comprehensive system approach, almost any building can be transformed into a comfortable, energy-saving and cost-saving place.

This thesis work will focus on heating, cooling and ventilation's installations.

4.1 Heating systems

*Heating is the largest energy expense in most homes, accounting for 35% to 50% of annual energy bills. Reducing your energy use for heating provides the single most effective way to **reduce your home's contribution to global environmental problems. […]***

A combination of conservation efforts and a new high-efficiency heating system can often cut your pollution output and fuel bills by one-third, and in some homes by half. Just upgrading your furnace or boiler to a high-efficiency model can save 1–2 tons of CO2 emissions each year in colder climates [from smarthouse.org].

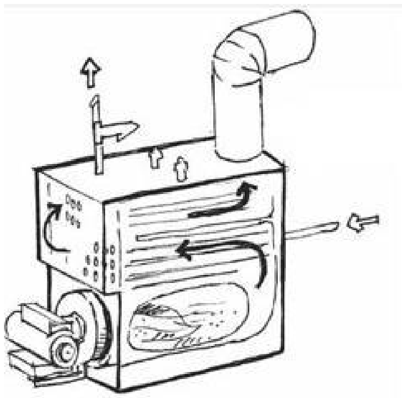


Figure 4.1 – Heating system

Normally the building lost a part of the interior heat and the heating system works to replaces that heat. How much heat the building lost depend on these factors: the building location (in colder places, the house will lose more heat), the energy efficiency of the house, how big the house is and how energy efficient the heating system is.

To save a great deal, the heating system has to be upgrading, either by installing a new high-efficiency system or boosting the efficiency of your present system.

A heating system may be a central or direct heating.

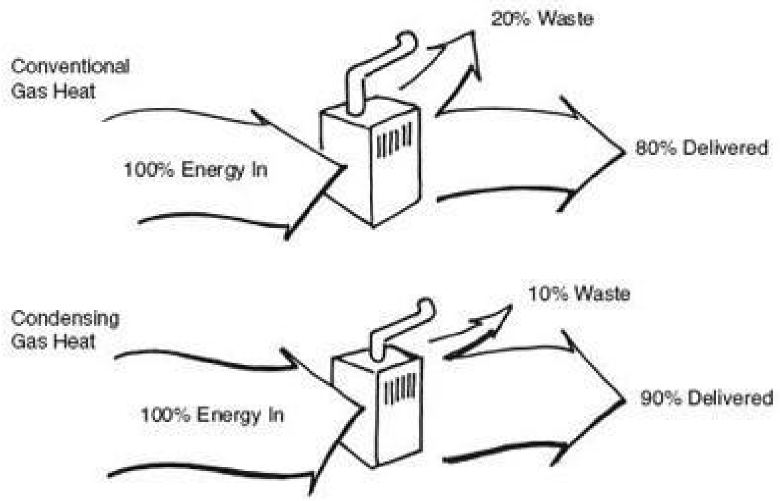
4.1.1 Central heating system

A central heating system provides warmth to the whole interior of a building (or portion of a building) from one point to multiple rooms. Its heat generation occurs in one place, such as a furnace room or basement in a building. The heat is distributed throughout the building through ductwork if the system uses forced-air, or pipes if the system uses the hot water or steam. The most common method of heat generation involves the combustion of fossil fuel in a furnace or boiler.

- Furnace: It can be powered by electricity, natural gas, fuel oil or wood. It is necessary to have a gas- or oil-fired furnace in which the fuel is mixed with air and burned. Inside the furnace, there is a metal heat exchanger heating by the flames. Its work is to transfer its heat to the air that is pushed through the heat exchanger by the “air handler’s” furnace fan and then forced through the ductwork downstream. This process causes combustion products that are vented out of the building through a flue pipe. Older “atmospheric” furnaces vented directly to the atmosphere and about 30% of the fuel energy was lost. Current minimum-efficiency furnaces reduce this waste substantially by using two type of furnace:

  “inducer” that pull the exhaust gases through the heat exchanger and induce draft in the chimney;

  “condensing” furnaces are designed to reclaim much of this escaping heat by cooling exhaust where water vapor in the exhaust condenses into water. These typically vent through a sidewall with a plastic pipe.

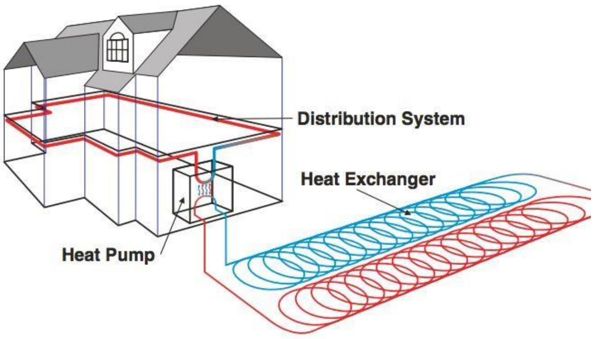


The efficiency of a fossil-fuel furnace or boiler is a measure of the amount of useful heat produced per unit of input energy (fuel). Figure 4.3

Figure 4.2 – Efficiency of furnace or boiler

- Boiler*:* it distributes the heat in hot water, which gives up the heat as it passes through radiators or other devices of the building. The cooler water then returns to the boiler to be reheated. Residential boilers generally use natural gas or heating oil for fuel.
  Less common in homes today are the steam boilers. Here the water is boiled and steam carries heat through the building, condensing to water in the radiators as it cools. Oil and natural gas are commonly used. The boiler system uses a pump to circulate hot water through pipes to radiators. A radiant floor heating is a system that allows the water to circulate through plastic tubing in the floor.
  As with furnaces, condensing gas-fired boilers are relatively common, and significantly more efficient than non-condensing boilers.
- Heat pumps: during the summer, an air conditioner works by moving heat from indoors to outdoor. In winter, the heat pump reverses this trick, scavenging heat from the cold outdoors with the help of an electrical system, and discharging that heat inside the house. There are two relatively common types of heat pumps. Air-source heat pumps use the outside air as the heat source in winter and heat sink in summer. Ground-source (also called geothermal, GeoExchange, or GX) heat pumps get their heat from underground, where temperatures are more constant year-round. Air-source heat pumps are far more common than ground-source

heat pumps because they are cheaper and easier to install. Ground-source heat pumps, however, are much more efficient, and are frequently chosen by consumers who plan to remain in the same house for a long time, or have a strong desire to live more sustainably. How to determine whether a heat pump makes sense in your climate is discussed further under "Fuel Options."



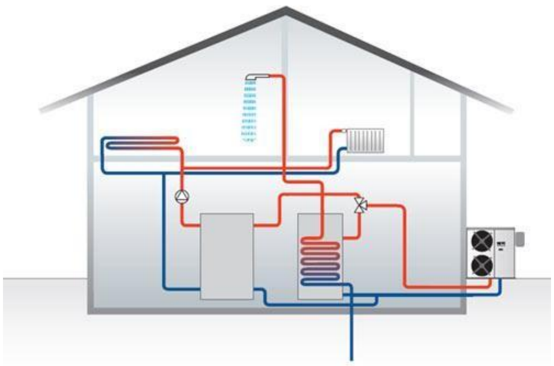


Figure 4.3 – Ground-source heat pump (left); Air-source heat pump (right).

4.1.2 Direct heating system

- Gas-Fired Space Heaters: It allows heating a single room or area of the building. It doesn't need pipelines in which the hot fluid circulates. Its structure can be of different dimensions, depending on the power required by the room.
  To provide combustion air and carry off the combustion products, the better models that are more used is "sealed combustion air" systems, with pipes installed through the wall.

Figure 4.4 – Gas-fired space heater

- Electric Space Heaters: are inexpensive to buy, but costly to use. They convert electric current from the wall socket directly into heat. It takes a lot of electricity to deliver the same amount of useful heat that natural gas or oil can provide onsite. On the other hand, for intermittent use, it is the best solution.

Figure 4.5 – Electric space heater

- Wood-Burning and Pellet stove: its heat can from the burning of the wood or pellet.
  Wood prices are generally lower and constant than gas, oil, or electricity. If you cut your own wood, the savings can be large. Pollutants from wood burning have been a problem to implement regulations that govern pollution emissions from wood stoves. As a result, new models are quite clean-burning. Pellet stoves offer a number of advantages over wood stoves. They are less polluting than wood stoves and offer users greater convenience, temperature control, and indoor air quality.

Figure 4.6 – Pellet stove

4.2 Cooling systems

The air conditioners are large usually in the every type of building. Its energy consumption is very high like its release of CO2. As air conditioning becomes the norm in all regions of the countries, it is important to realize that often the easiest and most affordable way to stay comfortable during the summer is to reduce your need for air conditioning.
There are many ways to get rid of unwanted heat, in this way will be reduced the cooling loads and a lot of money will be saved right away by letting buy a smaller, less expensive system.

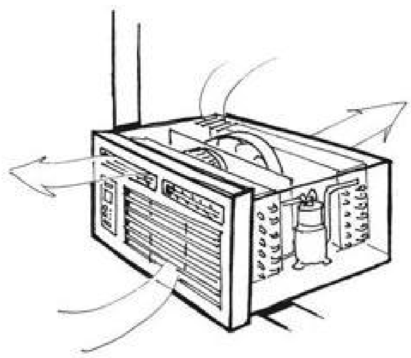


Figure 4.7 – Air conditioning.

Air conditioning, or cooling, is more complicated than heating. Instead of using energy to create heat, air conditioners use energy to take heat away. The most common air conditioning system uses a compressor cycle (similar to the one used by your refrigerator) to transfer heat from your house to the outdoors. It takes heat from a cooler place and dumps it in a warmer place, seemingly working against the laws of physics. What drives the process, of course, is electricity.
There are different types of cooling systems. They will be explained in the subchapter 4.2.1.

4.2.1 Central Air Conditioners and Heat Pump

Central air conditioners and heat pumps are designed to cool the entire house. In each system, a large compressor unit located outside drives the process; an indoor an indoor cool battery refresh the air and then it is distributed throughout the house via ducts. Heat pumps are like central air conditioners, except that the cycle can be reversed and used for heating during the winter months. With a central air conditioner, the same duct system is used with a furnace for forced warm-air heating. In fact, the central air conditioner typically uses the furnace fan to distribute air to the ducts.

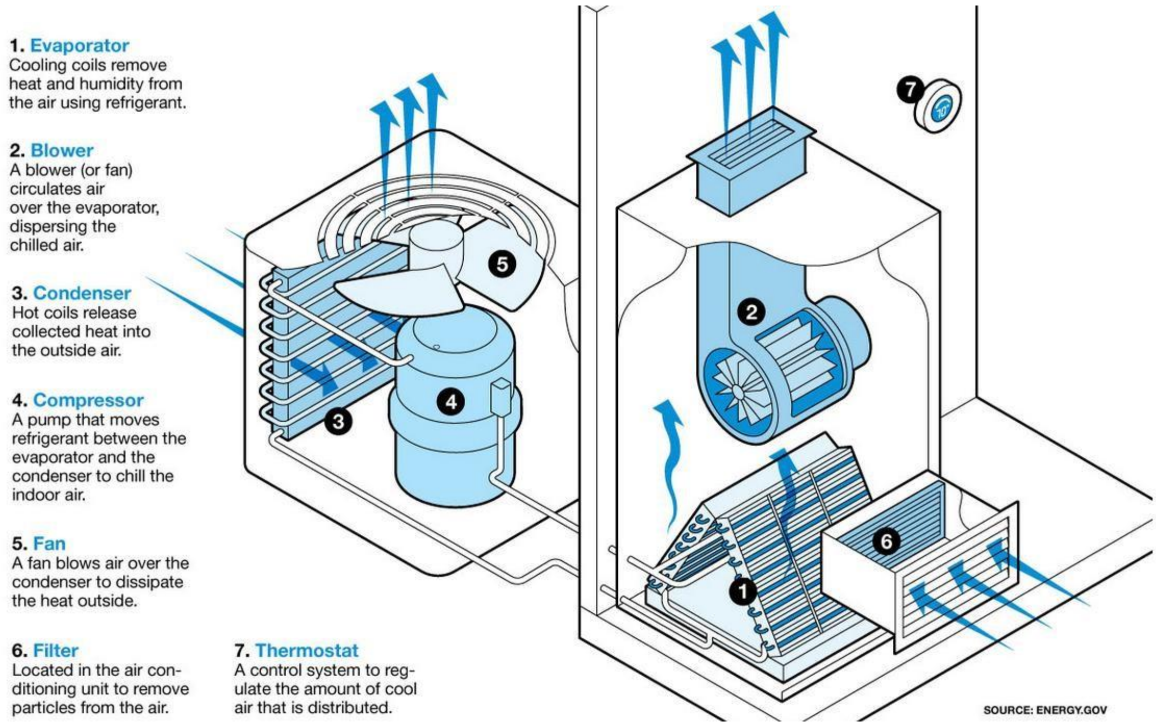


Figure 4.8 – Illustration of how an air conditioner work.

4.2.2 Ductless Mini-Split Air Conditioners

Mini-split systems is a good option for room additions and for houses without ductwork. Like conventional central air conditioners, mini-splits use an outside compressor/condenser and indoor air handling units. The difference is that each room or zone to be cooled has its own air handler. Each indoor unit is connected to the outdoor unit with. Indoor units are typically mounted on the wall or ceiling.

The major advantage of a ductless mini-split is its flexibility in cooling individual rooms or zones. By providing dedicated units to each space, it is easier to meet the varying comfort needs of different rooms.

The primary disadvantage of mini-splits is cost. They cost much more than a typical central air conditioner of the same size, where ductwork is already in place. But, when considering the cost and energy losses associated with installing new ductwork for a central air conditioner, buying a ductless mini-split may not be such a bad deal, especially considering the long-term energy savings.

4.3 Ventilation and air distribution

When you think about it, energy efficiency is not just about saving money on energy bills, it is really about using less energy to protect human health, assure comfort, and protect your house from damage. As air moves through your house, it removes pollutants that include odors, gases, particles, and (most surprisingly) moisture. But, it can also contribute to drafty walls and uncomfortable indoor temperature and humidity levels. Proper ventilation and air distribution play an important role in providing a safe, comfortable, and durable home as efficiently as possible.

Virtually all houses exchange indoor air with the outdoors. There are two reasons for this: air passages, however small, include larger gaps around pipes, vents, and chimneys, and smaller cracks at places such as the join between the window frame and the wall (thermal bridge). The second reason for air exchange is the temperature and pressure differences between inside and outside, the air moves from the higher to lower pressure, the stack effect.

There are two type of air exchange: ventilation and infiltration.

The ventilation is the replacement of stale inside air with fresh outside air. It can occur naturally, helped by the stack effect and open windows, or mechanically, with the use of a fan, or series of fans, that pull air in or out of the house.

The infiltration is an accidental air movement between inside and outside.

Before discussing ventilation systems that can be installed in buildings, it is good practice to follow simple steps to avoid or reduce their installation and their energy consumption.

1. Combustion products from space or water heating appliances should never mix with the indoor environment;

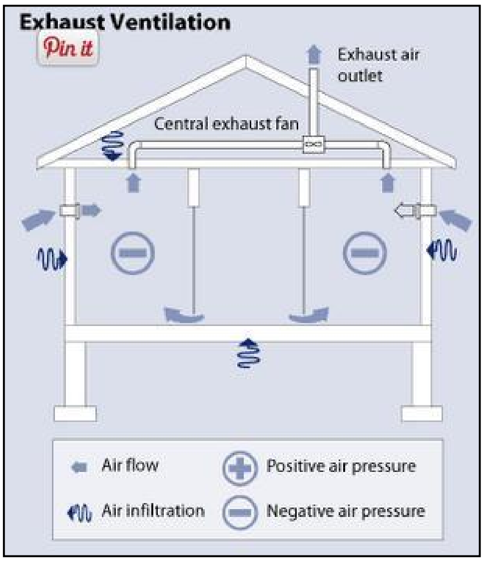
2. Make sure that the connection between the garage and the living space is airtight to prevent car exhaust and other chemicals substance;

3. Moisture control. The most common and easily corrected errors come from improperly disposing of water shed from the roof. Make sure that rain gutters drain away from the building, not toward the basement or foundation (slab) walls.
   In southern climates in particular, dehumidifiers may be necessary to control moisture levels in the house, if the air outside is hot and humid.
   Ventilate the interior spaces especially in the kitchens and bathrooms, where more humidity is created. In these spaces, the air condensation probability is greater.

Spot ventilation can be used to improve the effectiveness of natural ventilation. However, if both spot and natural ventilation together don't reach the ventilation needs, a ventilation system should be put.
Ventilation systems can be categorized as: exhaust, supply, balanced, and heat-recovery.

4.3.1 The exhaust ventilation systems

Exhaust ventilation systems work by depressurizing the building. They work extracting indoor air from a house while make-up air infiltrates through leaks in the building.



Exhaust ventilation systems are most applicable in cold climates. In climates with warm, humid summers, depressurization can draw moist air into building wall cavities, where it may condense and cause moisture damage.

Figure 4.9 – Illustration of exhaust ventilation system.

4.3.2 The supply ventilation systems

Supply ventilation systems work by pressurizing the building. They use a fan to force outside air into the building while air leaks out of the building through holes in the shell, bath- and range-fan ducts, and intentional vents.

It has a fan and duct system that introduces fresh air into rooms that residents occupy most (for example, bedrooms, living room, kitchen).

By pressurizing the house, this system allow better control of the air that enters the house than do exhaust ventilation systems. They also allow air introduced into the house to be filtered to remove pollen and dust or to be dehumidified.

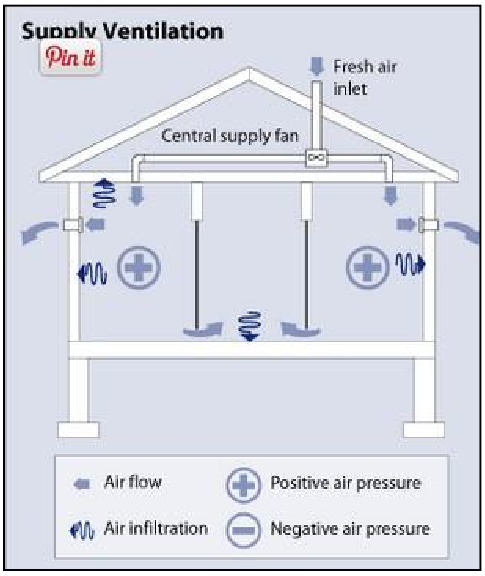


Figure 4.10 – Illustration of supply ventilation system.

4.3.3 The balanced ventilation systems

Balanced ventilation systems introduce and exhaust approximately equal quantities of fresh outside air and polluted inside air, respectively. A balanced ventilation system usually has two fans and two duct systems.

A typical balanced ventilation system is designed to supply fresh air to bedrooms and common rooms where people spend the most time. It also exhausts air from rooms where moisture and pollutants are most often generated, such as the kitchen, bathrooms, and the laundry room.

Like both supply and exhaust systems, balanced ventilation systems do not temper or remove moisture from the air before it enters the house.

They do, however, use filters to remove dust and pollen from outside air before introducing it into the house.

Balanced ventilation systems are appropriate for all climates; however, because they require two duct and fan systems, they are usually more expensive to install and operate than supply or exhaust systems.

4.3.4 The enrgy recovery systems

Figure 4.11 – Illustration of heat recover

Energy recovery ventilation systems usually cost more to install than other ventilation systems. To save on installation costs, many systems share existing ductwork. Complex systems are not only more expensive to install, but often they are also more maintenance intensive and consume more electric power. These types of ventilation systems are still not very common.

The heat recuperator works to reduce the internal heating costs. When the outside air enters in the building, during the winter, it has a lower temperature than the interior ones.

The heat recuperator, as the same words say, recovers internal heat before throwing it out. The outside air, before to be forced to inside the building by the fans, it is mixed and heated up with the recovery air.

5 Energy certificates

From European Commission data, the buildings are responsible for 30% of energy consumption and 25% of CO_2 emissions in the EU. While new buildings generally need fewer than three to five litres of heating oil per square meter per year, older buildings consume about 25 litres on average. Some buildings even require up to 60 litres.

Figure 5.1 – Energy classification class

Currently, about 35% of the EU's buildings are over 50 years old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5-6% and lower CO_2 emissions by about 5%.

The Directive 2010/31/EU that regulates the energy performance of building is divided in different articles:

- Article 3: adoption of a methodology for calculating the energy performance of buildings;
- Article 4: Setting of minimum energy performance requirements;
- Article 5: calculation of cost-optimal levels of minimum energy performance requirements;
- Article 6: new buildings;
- Article 7: existing buildings;
- Article 8: technical buildings systems;
- Article 9: nearly zero-energy buildings;
- Article 10: financial incentives and market barriers;
- Article 11, 12, 13: energy performance certificate;
- Article 14, 15, 16: periodical inspection of heating systems;
- Article 17: independent expert;
- Article 18: independent control system.

The Energy Performance of Building Directory – EPBD, defines energy efficiency of a building as the amount of necessary energy calculated or measured to reach the energy needs associated with normal use of the building.

The Energy Performance Certificates provide information for consumers on buildings they plan to purchase or rent. They include an energy performance rating and recommendations for cost-effective improvements.

Certificates must be included in all advertisements in commercial media when a building is put up for sale or rent. They must also be shown to prospective tenants or buyers when a building is being constructed, sold, or rented. After a deal has been concluded, they are handed over to the buyer or new tenant.

5.1 The energy certificate methodology

The Directive defines the calculation methodology of the performance certificate. The methodology shall include the following aspects:

- **The building's thermal characteristics, its envelope, interior partitions,** etc..;
- **Building's installations as heating, cooling, DHW, ventilation, lighting** systems;
- **Climate dates (depending on the building's location): maximum and minimum temperature,** relative humidity, etc..;
- Position and orientation of building;
- Passive solar systems and solar protection;
- Active solar systems based on the renewable energy sources;
- Natural ventilation;
- **Indoor climate conditions (depending on the building's use and its climates** zones).

The certification is to be carried out in an independent manner by qualified and/or accredits expert. The energy performance certificate is expected to classify buildings on a banded scale from A (High efficiency building) to G (Low efficiency building), based on annual CO_2 emissions per unit floor area. CO_2 emission figure expressed in kg/m² and represent emissions for winter heating and summer cooling.

In addition to CO_2 consumption, the certificate provides information on demand for heating, cooling and domestic hot water consumption, expressed in kWh/m^2.

5.1.1 Italian Certification

The Italian energetic legislation in the 2016, Figure 5.6.

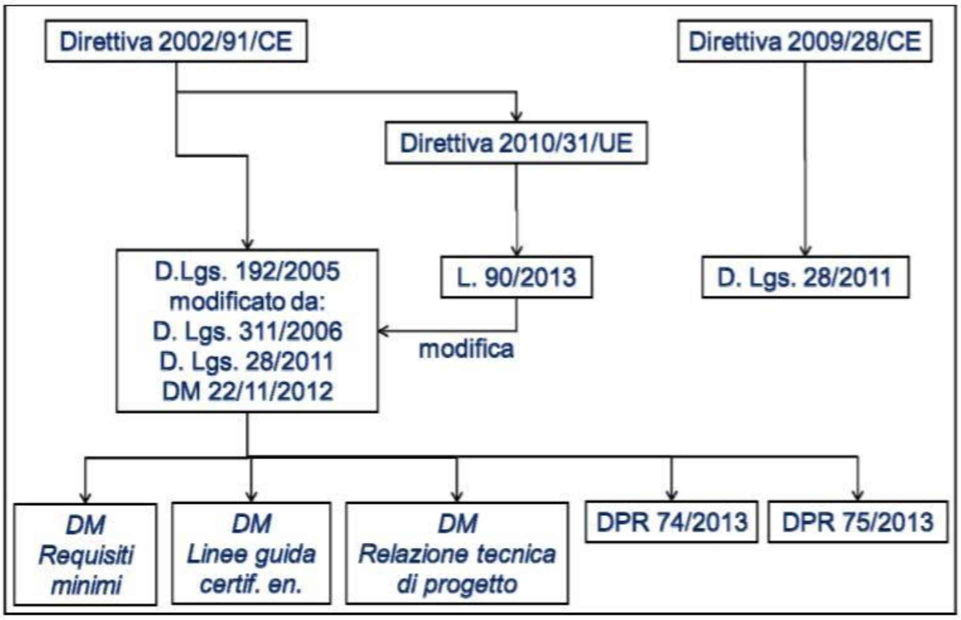


Figure 5.2 - Italian energetic legislation in the 2016 [From Corrado VIncenzo presentetion].

The Directive that regulates the energetic legislation in Italy is the 2010/31/UE, already described in chapter 5. From it derived the Ley 90/2013 that promotes the improvement of the buildings energetic performance taking into account the outdoor local and climatic conditions, as well as the requirements for indoor climate and cost-effectiveness. It specifies buildings subject to energy interventions as well as a calculation method.

The reference standard is the Legislations UNI/TS 11300, that it is divided in 4 parts:

- UNI/TS 11300-1 : Energy performance of buildings - Part 1: Determination the building's thermal energy demand for summer, winter and air conditioning;
- UNI/TS 11300-2: Energy performance of buildings - Part 2: Determination of primary energy demand and efficiency for air conditioning winter and for the production of sanitary hot water;
- UNI/TS 11300-3: Energy performance of buildings - Part 3: Determination of primary energy demand and performances for summer climate;
- UNI/TS 11300-4: Energy performance of buildings - Part 4: Use renewable energy and other generation methods for heating environments and production of sanitary hot water.

The figure below shows the European and National standard used for calculate the energetic performance of the building:

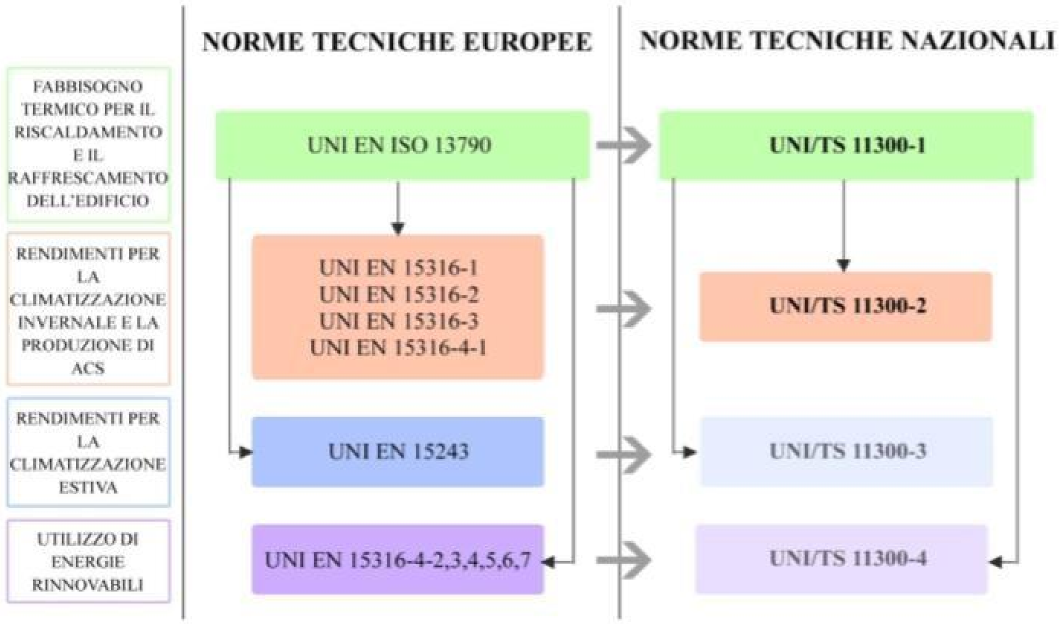


Figure 5.3 - European and National Standards [From Corrado VIncenzo presentetion].

The thermal building energy demand is estimated from the heat balance between indoor and outdoor building envelope than it is possible to get its primary energy demand by the heating/cooling system efficiency.

The primary energy per single energy service represents the global annual energy needs, and it is calculated as with monthly intervals. In the same way, it is possible to determine the energy from renewable sources.

The building has to have the minimum requirements. The calculation to be carried out involves the application of the conversion factors in total primary energy $f_{p,tot}$ and no renewable total primary energy $f_{p,nren}$, given in table 5.1 These are necessary for calculating total and non-renewable primary energy.

Vettore energetico	$f_{P,nren}$	$f_{P,ren}$	$f_{P,tot}$
Gas naturale [1]	1,05	0	1,05
GPL	1,05	0	1,05
Gasolio e Olio combustibile	1,07	0	1,07
Carbone	1,10	0	1,10
Biomasse solide [2]	0,20	0,80	1,00
Biomasse liquide e gassose [2]	0,40	0,60	1,00
Energia elettrica da rete [3]	1,95	0,47	2,42
Teleriscaldamento[4]	1,5	0	1,5
Rifiuti solidi urbani	0,2	0,2	0,4
Teleraffrescamento[4]	0,5	0	0,5
Energia termica da collettori solari [5]	0	1,00	1,00
Energia elettrica prodotta da fotovoltaico, mini-eolico e mini-idraulico [5]	0	1,00	1,00
Energia termica dall'ambiente esterno – free cooling [5]	0	1,00	1,00
Energia termica dall'ambiente esterno – pompa di calore [5]	0	1,00	1,00

[1] I valori saranno aggiornati ogni due anni sulla base dei dati forniti da GSE.
[2] Come definite dall'allegato X del decreto legislativo 3 aprile 2006, n. 152.
[3] I valori saranno aggiornati ogni due anni sulla base dei dati forniti da GSE.
[4] Fattore assunto in assenza di valori dichiarati dal fornitore e asseverati da parte terza, conformemente al quanto previsto al paragrafo 3.2.
[5] Valori convenzionali funzionali al sistema di calcolo.

Table 5.4 - Conversor factor in primary energy

The formula below, shows the conversion factors in total primary energy:

$$f_{p,tot} = f_{p,nren} + f_{p,ren}$$

where:

$f_{p,nren}$ = conversion factors in no-renewable primary energy;

$f_{p,ren}$ = conversion factors in renewable primary energy.

For the energy classification, the building performance is expressed by the non-renewable global energy performance index $EP_{gl,\ nren}$, the index is expressed in kWh/m2 per year, in relation to its useful area. The table 5.2 shows the buildings classification:

	Classe A4	$\leq 0{,}40\ EP_{gl,nren,rif,standard\ (2019/21)}$
$0{,}40\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe A3**	$\leq 0{,}60\ EP_{gl,nren,rif,standard\ (2019/21)}$
$0{,}60\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe A2**	$\leq 0{,}80\ EP_{gl,nren,rif,standard\ (2019/21)}$
$0{,}80\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe A1**	$\leq 1{,}00\ EP_{gl,nren,rif,standard\ (2019/21)}$
$1{,}00\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe B**	$\leq 1{,}20\ EP_{gl,nren,rif,standard\ (2019/21)}$
$1{,}20\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe C**	$\leq 1{,}50\ EP_{gl,nren,rif,standard\ (2019/21)}$
$1{,}50\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe D**	$\leq 2{,}00\ EP_{gl,nren,rif,standard\ (2019/21)}$
$2{,}00\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe E**	$\leq 2{,}60\ EP_{gl,nren,rif,standard\ (2019/21)}$
$2{,}60\ EP_{gl,nren,rif,standard\ (2019/21)} <$	**Classe F**	$\leq 3{,}50\ EP_{gl,nren,rif,standard\ (2019/21)}$
	Classe G	$> 3{,}50\ EP_{gl,nren,rif,standard\ (2019/21)}$

Table 5.5 - Classification of the index global non-renewable energy performance

The classification is given in the APE (Attestato di Prestazione Energetica) document which contains two performance indicators of the envelope for the winter and summer season, as the tables below shown:

Prestazione invernale dell'involucro	Qualità	Indicatore
$EP_{H,nd} \leq 1^*\ EP_{H,nd,limite\ (2019/21)}$	alta	
$1^*\ EP_{H,nd,limite\ (2019/21)} < EP_{H,nd} \leq 1{,}7^*\ EP_{H,nd,limite\ (2019/21)}$	media	
$EP_{H,nd} > 1{,}7^*\ EP_{H,nd,limite\ (2019/21)}$	bassa	

Table 5.6 - Classification of the winter quality of the envelope

Prestazione estiva dell'involucro		Qualità	Indicatore
$A_{sol,est}/A_{sup\ utile} \leq 0{,}03$	$Y_{IE} \leq 0{,}14$	alta	
$A_{sol,est}/A_{sup\ utile} \leq 0{,}03$	$Y_{IE} > 0{,}14$	media	
$A_{sol,est}/A_{sup\ utile} > 0{,}03$	$Y_{IE} \leq 0{,}14$		
$A_{sol,est}/A_{sup\ utile} > 0{,}03$	$Y_{IE} > 0{,}14$	bassa	

Table 5.7 - Classification of the summer quality of the envelope

where:

$EP_{H,nd}$: index of useful thermal efficiency for heating;

$A_{sol,est}/A_{sup,utile}$: summer area equivalent to surface area useful;

Y_{IE}: periodic thermal transmittance.

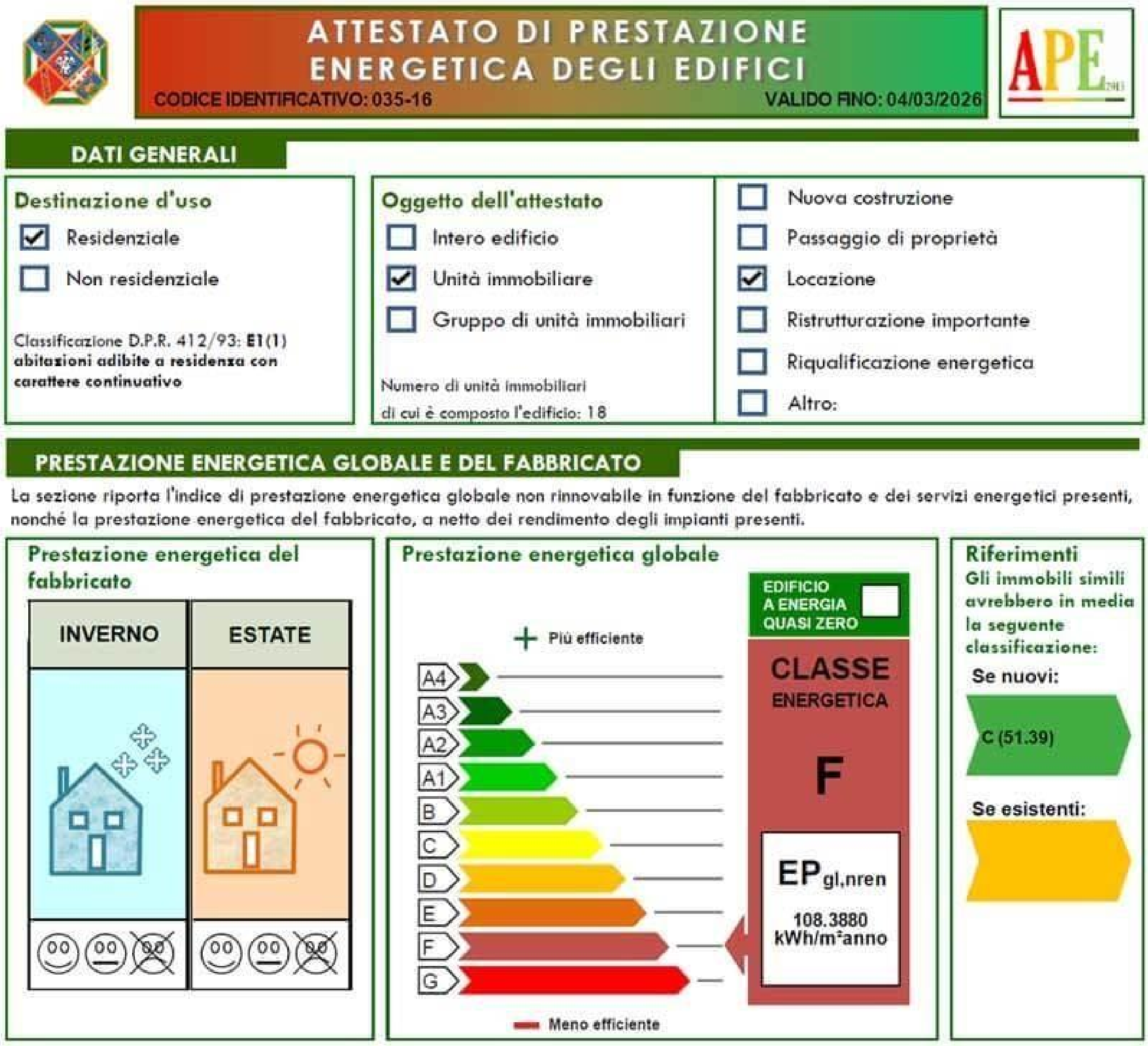


Figure 5.8 – Example of APE (Attestato di Prestazione Energetica).

5.1.2 Spanish Certification

The Directive that regulates the energetic legislation in Spanish is the 2010/31/UE, already described in chapter 5. From it derives the Real Decree 235/2013 that approved the building energy certification process. In the 17/01/2006, the Real Decree of 314/2006 approved the new *Código Técnico de la Edificación* (CTE). This chapter is focused on DBHE, *Documento Básico de Ahorro de*

Energía that specifies the energy efficiency requirements for residential buildings. It is composed of different parts:

- HE 0: *Limitation of energy consumption*: achieve a rational use of the energy necessary for the buildings use, reducing their consumption to sustainable limits and make sure that part of the consumption comes from renewable sources;
- HE 1: *Limitation of energy demand*: It define the characteristics of the building envelope with the aim of reducing the energy demand for indoor thermal comfort in according to the geographic location (external temperature and humidity, solar radiation), orientation and the building use (internal temperature and humidity as well as number of occupants);
- HE 2: *Performance of thermal installations*: defines the thermal installation are appropriate to supply of heat and to the comfort of the building;
- HE 3: *Energy efficiency of lighting installations*: defines that the lighting installation has the correct performance, in order to providing a control system, that optimizes the use of natural light;
- HE 4: *Minimum solar contribution of domestic hot water*: defines the limit of the demand of hot water, that contributes to the sustainability, in according to the geographical characteristics of area;
- HE 5: *Minimum photovoltaic contribution of electrical energy*: calculates the solar energy in electricity through photovoltaic panels. Also there values are minimum.

The buildings involved are defined in the Decree 226/2014 of building energy certification (BOVP, *Boletín Oficial del País Vasco*). They are new buildings and existing buildings modified or restructured, if they have a floor area greater than 1000 m2. It valids for up to 10 years and the Autonomous Community sets specific conditions for renewal or upgrade.

The energy qualification is based on standard procedure and it is expressed through indicators that explain the reasons for a good or bad energy performance of the building. They are:

- CO_2 annual emissions [kg CO_2/m^2];

- no-renewable annual consumption of the energy [kWh/m^2].

These indicators comes from the calculation for winter heating and summer cooling demand, their final and primary energy consumption and the same for sanitary hot water and artificial lightning. The energy class is determined by the total primary energy consumption and by the total annual emissions.

The energy class is identified by an alphabet indicator, in which the letter G represents the class characterized by the index of higher performance (greater energy consumption), while the letter A represents the class with the best performance index (lower energy consumption).

The tables below show the index of energy efficiency for residential and other sectors.

Calificación	Índice				
A			$C1$	$<$	0,15
B	0,15	$\leq$	$C1$	$<$	0,50
C	0,50	$\leq$	$C1$	$<$	1,00
D	1,00	$\leq$	$C1$	$<$	1,75
E	1,75	$\leq$	$C1$		
			$C2$	$<$	1,00
F	1,75	$\leq$	$C1$		
	1,00	$\leq$	$C2$	$<$	1,50
G	1,75	$\leq$	$C1$		
	1,50	$\leq$	$C2$		

Calificación	Índice				
A			C	$<$	0,40
B	0,40	$\leq$	C	$<$	0,65
C	0,65	$\leq$	C	$<$	1,00
D	1,00	$\leq$	C	$<$	1,30
E	1,30	$\leq$	C	$<$	1,60
F	1,60	$\leq$	C	$<$	2,00
G	2,00	$\leq$	C		

Table 5.9 - Index energy class of residential sector (left). Index energy class of other (right).

5.1.3 Passive House Certification

Passive house (German: *Passivhaus*) is a rigorous, voluntary standard for energy efficiency in a building that is truly energy efficient, comfortable and affordable at the same time.

Passive House is a true construction concept that can be applied by anyone and anywhere.

Figure 5.10 - Passivehouse logo

The Passive Houses:

- Allow for space heating and cooling;
- Make efficient use of the sun;
- Have high level of indoor comfort;

- Have ventilation system for superior air quality and a highly efficient heat recovery unit.

  No matter the climate or geographical region, Passive Houses stay at a comfortable ***temperature year round with minimal energy inputs. Such buildings are heated "passively",*** *making efficient use of the sun, internal heat sources and heat recovery so that conventional heating systems are rendered unnecessary throughout even the coldest of winters. During warmer months, Passive Houses make use of passive cooling techniques such as strategic shading to keep comfortably cool. Either way, a Passive House****'s high quality insulation keeps the*** *temperature comfortable, just where it is needed*.[Source: passivehouse-international.org]

The Passivhaus standard requires to the buildings the following requirements:

- Annual heating and cooling demand not more than 15 kWh/m^2 per year;
- Total primary energy consumption must not be more than 60 kWh/m^2 per year;
- The building must not leak more air than 0.6 times the house volume per hour at 50 Pa as tested by a blower door, or alternatively when looked at the surface area of the enclosure, the leakage rate must be less than 0.05 cubic feet per minute.

The Passive House concept itself remains the same for all of **the world's climates but the details** have to be adapted to the specific climate in which the building will be constructed. The building characteristics that meets the Passive House requirements will be different for one located in a cool climate than for a located in a warm climate.

Figure 5.5 – Buildings with Passive house certification in the world

5.1.4 LEED Certification

'LEED - Leadership in Energy and Environmental Design - is the most widely used green building rating system in the world. Available for virtually all building project types, from new construction to interior fit-outs and operation & maintenance, LEED provides a framework that project teams can apply to create healthy, highly efficient, and cost-saving green buildings. LEED certification is a ***globally recognized symbol of sustainability achievement.'*** [Source: usgbc.org]

It is devised by the United States Green Building Council (USGBC) and it is credit-based, allowing projects to earn points for environmentally friendly actions taken during construction and use of a building. Different levels can be reached, based on the building scores, as shown in the figures below:

Figure 5.11 - Logo LEED

- Certified 40 - 49 Points;
- Silver 50 - 59 Points;
- Gold 60 - 79 Points;
- Platinum 80-110 Points.

The LEED rating system is structured in 7 sections organized into prerequisites and credits. The prerequisites of each section are obligatory for the entire building to be certified; Credits can be selected according to project characteristics. The sum of credit scores derives from the certification level obtained.

Below are the prerequisites that make up LEED:

- Sustainability Site;
- Water Management;
- Energy and Environment;
- Materials and Resources;
- Indoor Environmental Quality.

Now the credits:

- Innovation in Design;

- Regional Priority.

LEED is a voluntary program, obtaining a LEED certification give a good and positive environmental image to the community. Additionally, it allows better indoor air quality and plenty of daylight. Studies have shown that workers in these environments have increased labor productivity, job retention, and days worked and students in these environments have higher test scores and lower absenteeism.

5.1.5 BREEAM Certification

From the England, BREEAM - Building Research Establishment Environmental Assessment Method for buildings, as leed certification, it is required by the building's customer. It can be applied not only to newly built buildings but also to existed and rehabilitated ones:

Figure 5.12 - BREEAM logo

- BREEAM New Construction;
- BREEAM International New Construction;
- BREEAM In-Use;
- BREEAM Refurbishment;
- BREEAM Communities.

It establishes a method of assessing, rating, and certifying the sustainability of buildings, as:

- Management;
- Energy;
- Health & wellbeing;
- Transport;
- Water;
- Materials;
- Waste;
- Land use and ecology;
- Pollution.

BREEAM Rating	% score
OUTSTANDING	≥ 85
EXCELLENT	≥ 70
VERY GOOD	≥55
GOOD	≥ 45
PASS	≥ 30
UNCLASSIFIED	< 30

Figure 5.13 - BREEAM reating

6 Building refurbishment

The residential sector has increased considerably in recent years, causing a huge energy demand growth. It was caused by technological installations that provide the indoor comfort such as super-technological appliances, computers, air conditioning and so on.

For this reason, the residential and tertiary sector, are put in the forefront of energy policies with the aim of controlling, or even better, minimizing energy demand.

When we are talking about a new construction, we can easily control and reduce the energy demand. It is planned during the firsts steps of building's design, as its orientation, magnitude, envelope (opaque and glass material and it's featured), types of installations, feeding with renewable sources...

When we are talking about of constructed buildings, we have to change our point of view. The year of construction plays an important role: the normative was different and no energy performance was required, so these buildings need to be rehabilitated to improve their energy efficiency levels and reduce wastes and energy costs.

How can the energy efficiency of extinguishing buildings be improved? There are different options:

- Rehabilitation of the enclosure (facade and cover);
- Replacement of existing installations with others with better efficiency;
- Change the fuel that feeds the installation adopting renewable energy sources.

It's not always possible to make these changes, or rather, not always can be done at the same time. The rehabilitation of existing buildings must be focused on different aspects.

First of all its cost. Often the rehabilitation promoter does not have the money available, so he is forced to choose cheaper technologies that, however, can ensure adequate levels of efficiency and comply with current energy-saving regulations.

The second aspect to be taken into account is the current urban planning legislation. This often limits the choice of materials, their position, color or the presence of workers, noise, scaffolding and so on.

The third aspect, but no less important, is the size of the building, both inside and outside. Rehabilitation of a building requires time and space, often there is no space available and you are forced to formulate a different rehabilitation plan.

6.1 Case study: Azkorri Ikastetxea

The building to be rehabilitated is a primary school located in Getxo, a municipality on the coast of the historic territory and province of Vizcaya in the Basque Country, Spain. It is located on the right side of the Bilbao river the Nervión and it is part of the metropolitan area of Bilbao.

Below the imagines show the location.

Figure 6.1 - Localization of Basque Country and geographical division

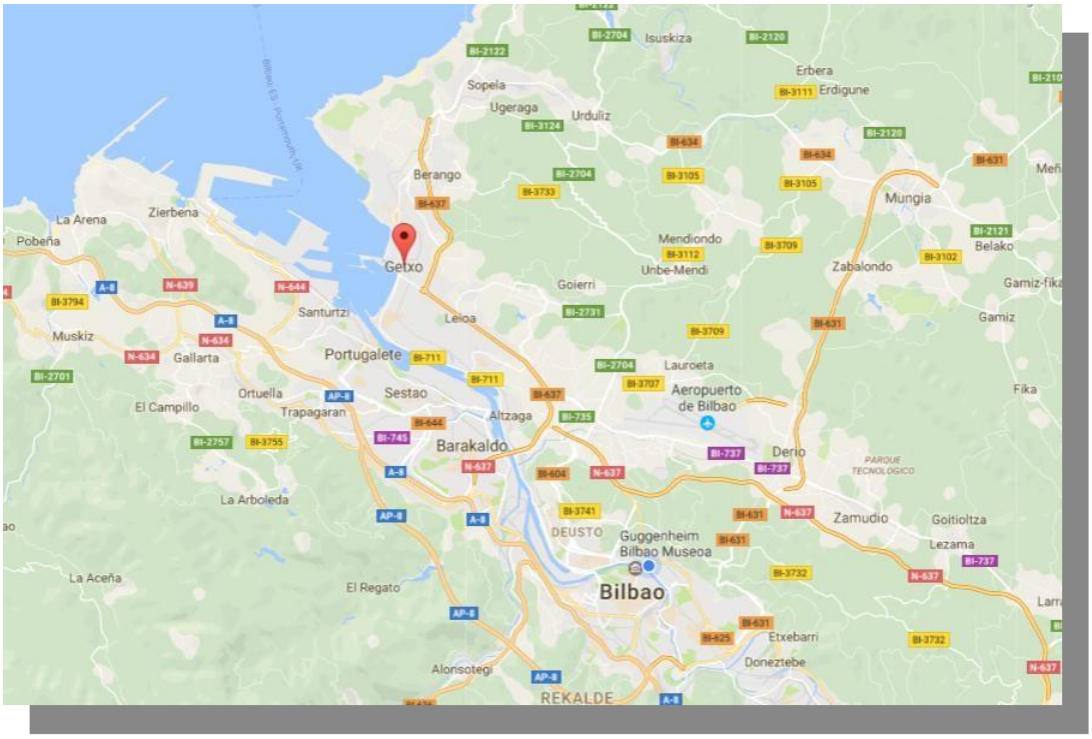


Figure 6.2 - Localization of Getxo from Google Maps

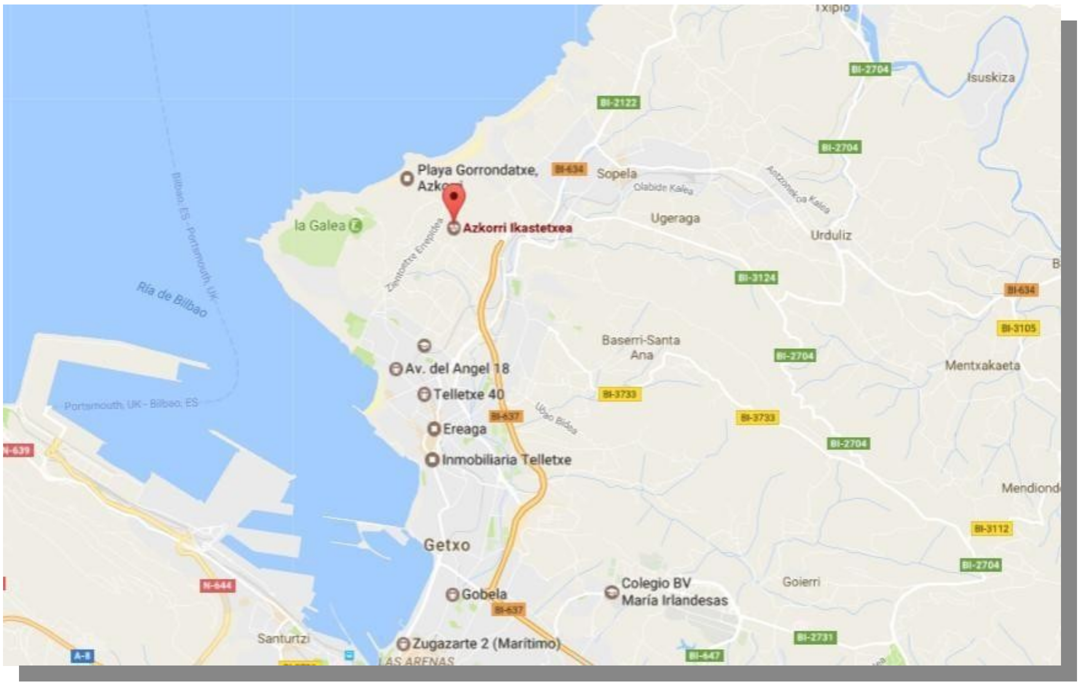


Figure 6.3 - Localization of Azkorri school from Google Maps

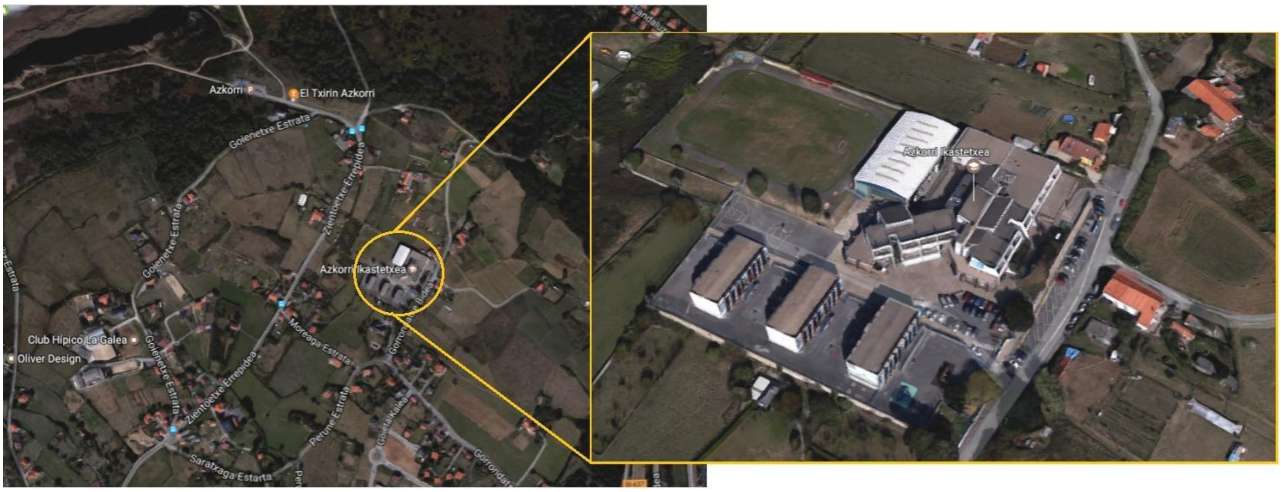


Figure 6.4 - Detail of geografical location

The school building is made up of different parts, as shown by the figure 5.4, built in different years. The first was built around the 70s, they are identify with the letter B. Then, in the 80s, was built the A and it was completed with another part Cin the 2006. In the same year the gym's roof was built, identified with the letter D (figure 6.5):

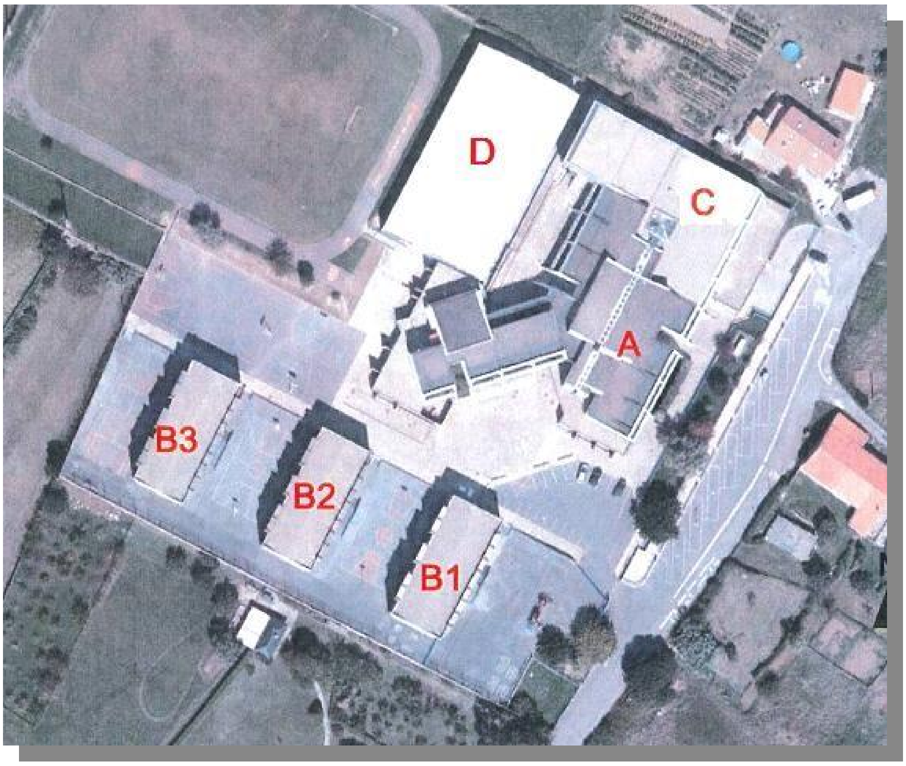


Figure 6.5 - Identification of buildings

More detail about the buildings:

- **B1, B2, B3: classrooms and teacher's offices, built in the** 70s;

  A: administration, offices, warehouse 80s;

  C: the dining room on the ground floor, built in the 80s;

  C: classrooms and library at the first floor, built in the '06 ;

  D: the gym roof, built in the '06.

Object of the study is the buildings B1. It is made of a basement, a low level and a first floor, as showed in the pictures below:

Figure 6.6 – Building façade. On the left: SE façade;
On the right: NO façade;
Down: a windows detail

BASEMENT

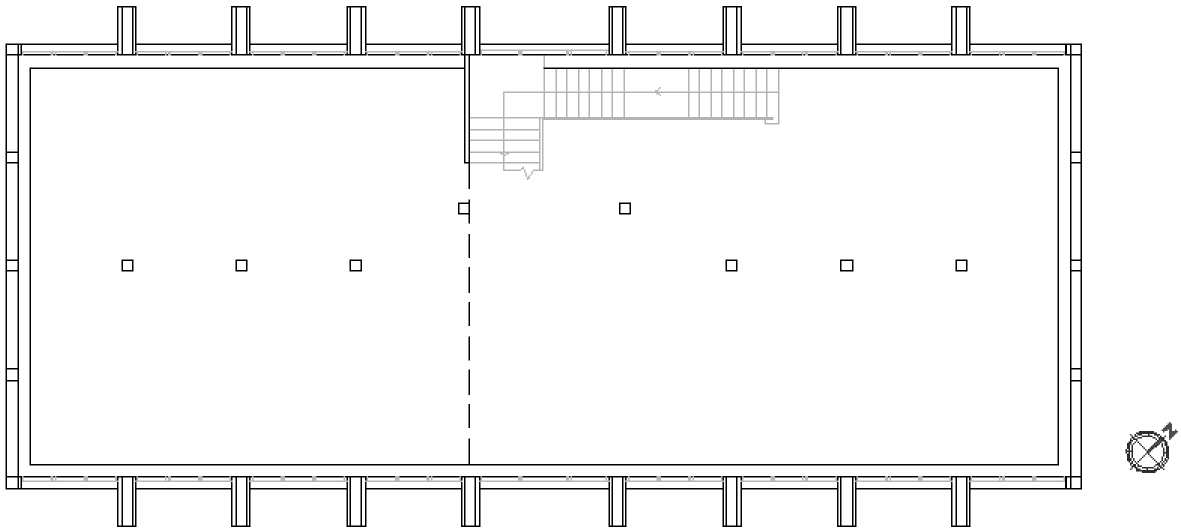


Figure 7.7 - Plane of basement

LOW LEVEL

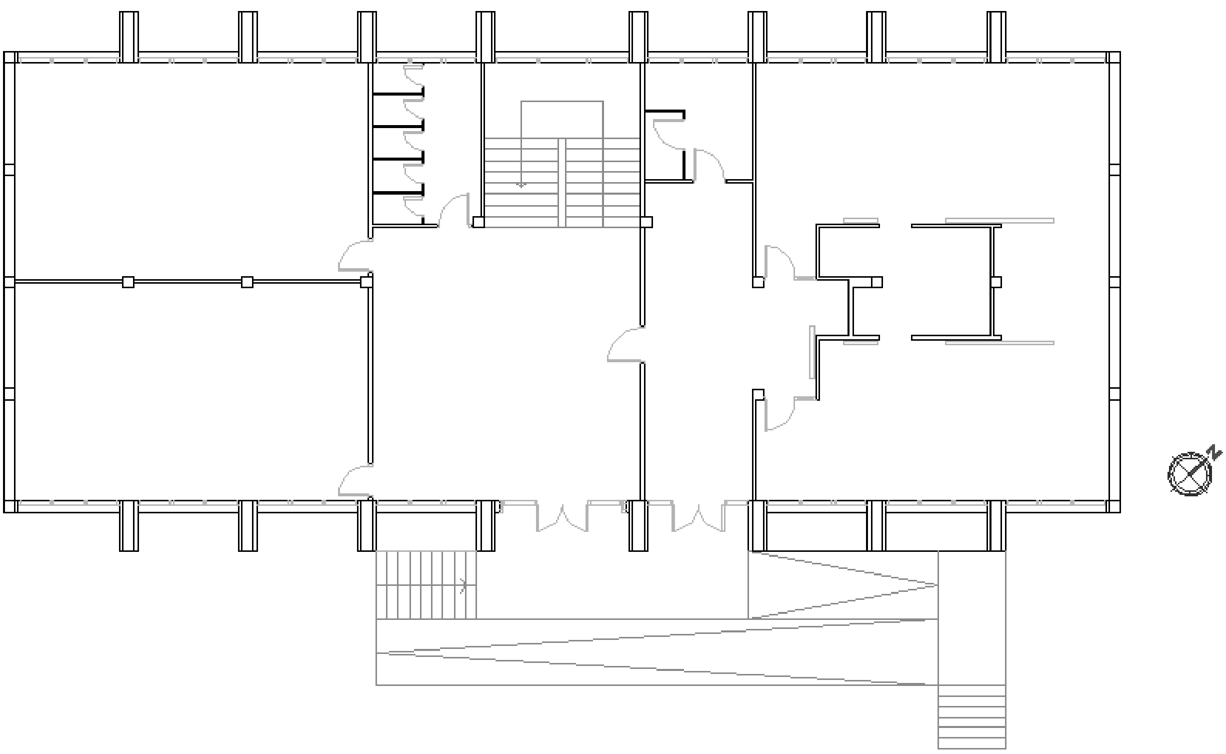


Figure 6.8 - Plane of low level

FLOOR 1

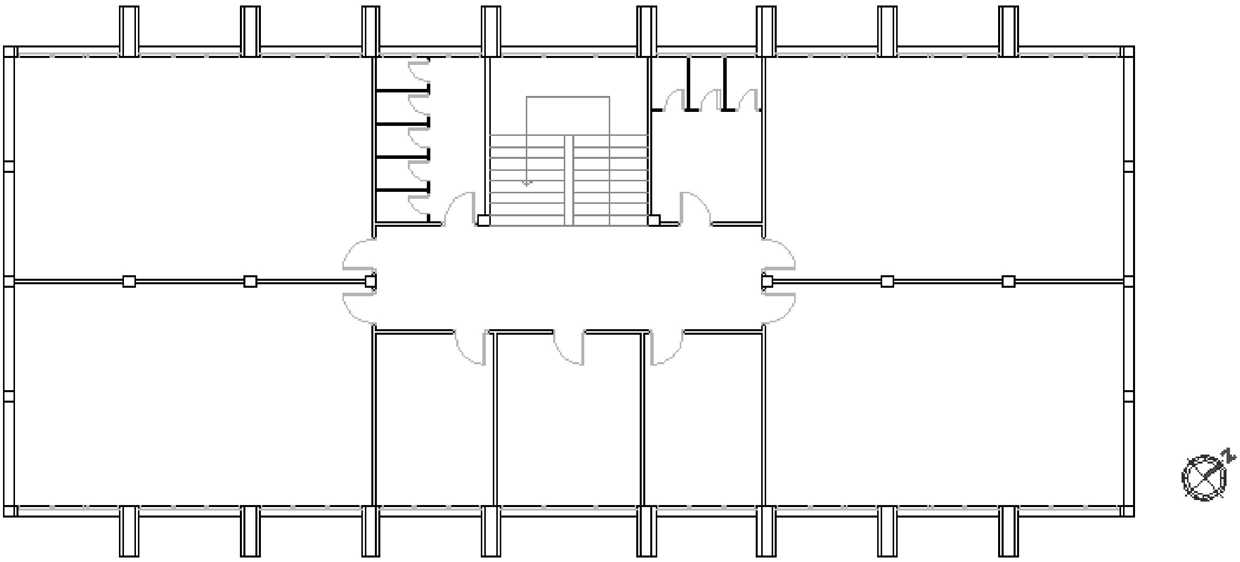


Figure 6.9 - Plane of floor 1

The building is made of the spaces that are shown in the table 6.1:

	Name	Area [m²]	Height [m]
BASEMENT	diaphanous space	260,78	4
	warehouse	75,6	4
	stairs	22,32	-
LOW LEVEL	entry	57,33	4
	infant school zone	149,94	4
	toilets	13,19	4
	classroom 1A	56,28	4
	classroom 2A	56,28	4
	stairs	22,32	-
1^ FLOOR	aisle	29,16	4
	toilets	26,38	4
	classroom 1B	56,28	4
	classroom 2B	56,28	4
	classroom 3B	56,28	4
	classroom 4B	56,28	4
	chief office	14,1	4
	teacher room	20,02	4
	meeting room	14,1	4
	stairs	22,32	-

Table 6.1 – School spaces and areas.

Below the façade are showed:

SOUTH-EAST

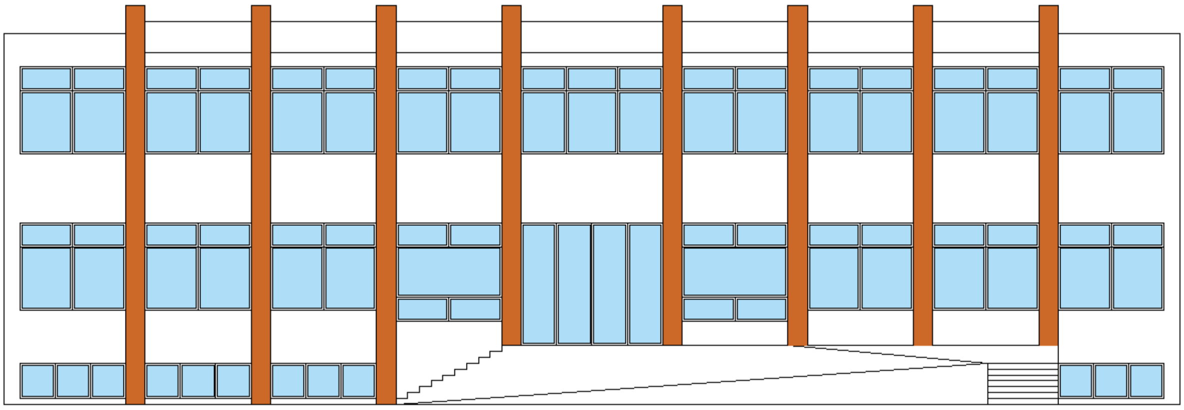


Figure 6.10 –South-East Façade

NORTH-WEST

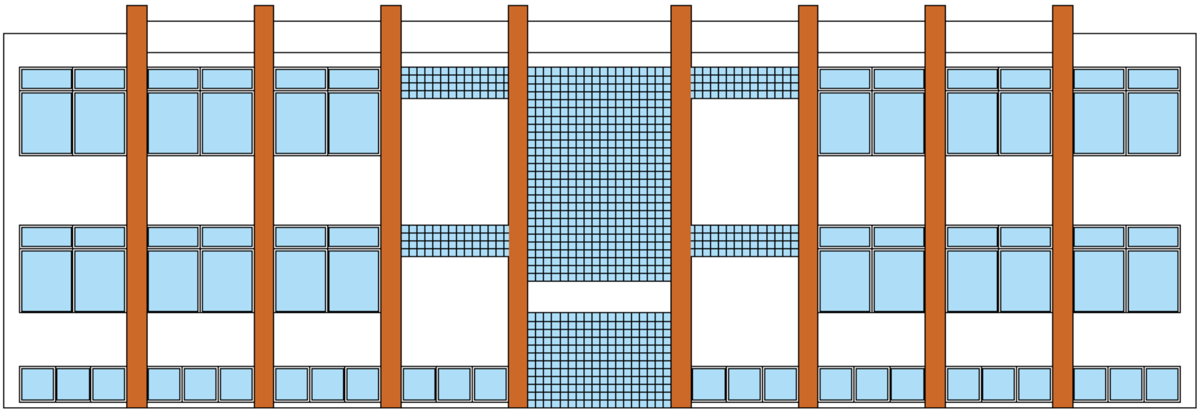


Figure 6.11 –North-West Façade

NORTH-EAST and SOUTH-WEST

Figure 6.12 – North-east and South-West Façade

6.1.1 Analysis of the envelope

In this subchapter, an analysis of the envelope will be carried out, with the aim of studying its features and thermal characteristics.

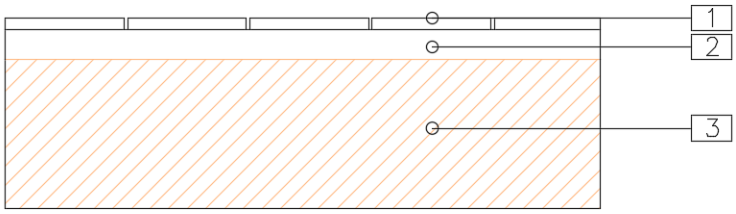
The opaque element

The envelope is made of double brick with the air chamber and painting with light and dark blue color finished.
The South East and North west façades are characterized by vertical projections with thermal protection function, their dimensions are 10,20 x 0,50 x 1,27 m.
The North East and South West façades have no the vertical protrusions but the water proofing.

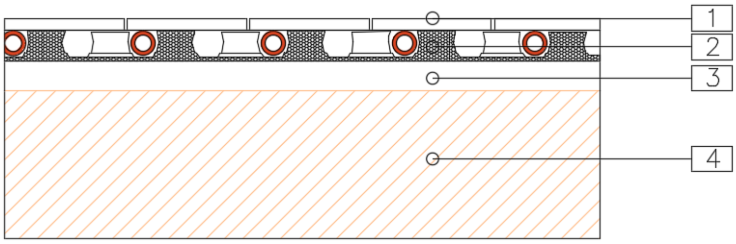
The floor is characterized by the same structure for all the plants with the only difference of having a radiant floor system in the basement.

The roof is made of the structural part on which the waterproofing is protected by the rock gravel.

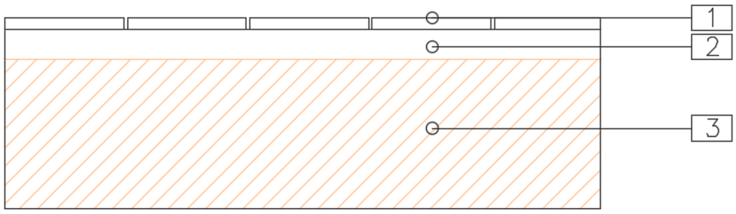
Same structural details are showing below:



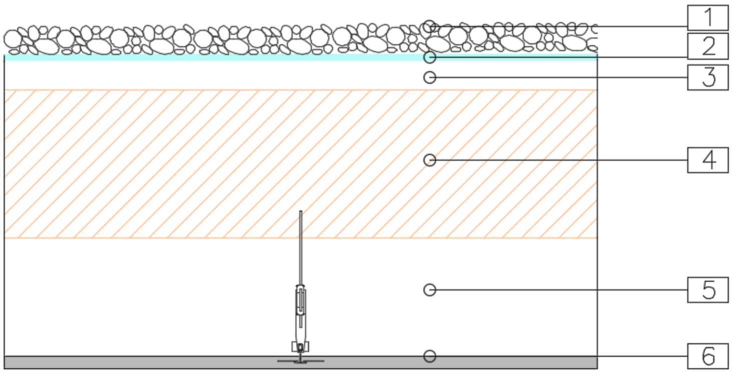
GROUND FLOOR		
N.	Description	s [m]
1	ceramic tiles	0,02
2	concrete	0,05
3	slab	0,25



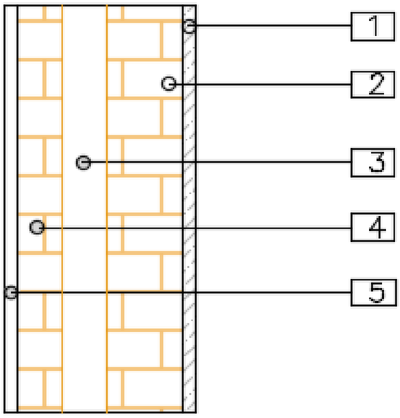
FLOOR - LOW LEVEL		
N.	Description	s [m]
1	linoleum	0,01
2	radiating floor	0,05
3	concrete	0,05
4	slab	0,25



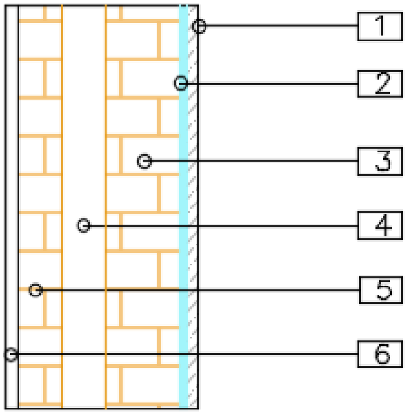
FLOOR - 1^		
N.	Description	s [m]
1	linoleum	0,01
2	concrete	0,05
3	slab	0,25



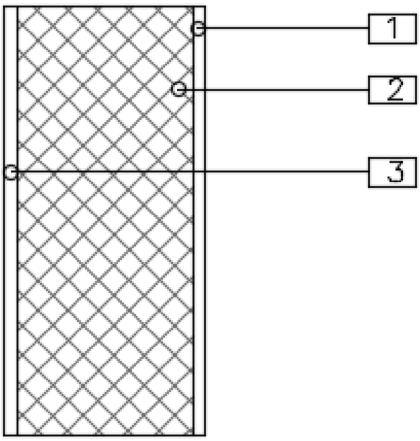
ROOF		
N.	Description	s [m]
1	rock gravel	0,05
2	water proofing	0,01
3	concrete	0,05
4	slab	0,25
5	air chamber	0,2
6	false ceiling	0,02



FACADES SOUTH-EAST AND NORTH-WEST		
N.	Description	s [m]
1	plaster	0,02
2	brick	0,12
3	air chamber	0,07
4	brick	0,07
5	plaster	0,02



FACADES SOUTH-WEST AND NORTH-EAST		
N.	Description	s [m]
1	plaster	0,02
2	water proofing	0,01
3	brick	0,12
4	air chamber	0,07
5	brick	0,07
6	plaster	0,02



BASEMENT WALL		
N.	Description	s [m]
1	water proofing	0,02
2	concrete	0,2
3	plaster	0,02

- The glazed element

The glazed part of the building is extended from the southeast to the northwest facades, while the north-east and southwest facades have no openings outside.

There are the different type of windows characterized by a different shape and thermal features, as showed in the table 6.2 and 6.3:

DESCRIPTION	Ug [W/m²K]	Uf [W/m²K]	% galss	% frame
Doble glass with aluminium frame and no thermal bridge	1,8	3,2	75	25
Glass brick with cement mortar. Thickness 8 cm	3,2		100	

Table 6.2 – Thermal characteristics of glass

CODE	x [m]	y [m]	area [m²]
TYPE 01	2,73	0,95	2,59
TYPE 02	2,73	2,05	5,60
TYPE 03	2,44	2,68	6,54
TYPE 04	4,08	2,57	10,49
TYPE 05	2,44	2,05	5,00
TYPE 06	4,08	2,05	8,36
TYPE 07	3,60	2,40	8,64
TYPE 08	2,70	0,80	2,16
TYPE 09	3,60	5,44	19,58

Table 6.3 – Type of windows and their shape

All windows, except the glass brick with cement mortar, have recently been replaced by keeping the hole size but changing the thermal characteristics, as shown in Table 6.2. These windows have the sail CLIMALIT of composition 4+ 16 + 4 + PLANITHERM 'ULTRA N' of 4mm, transparent. It is a low emissive glass with high performance intended to be assembled in double glazing. It offers up to three times more insulation than a simple traditional glass.

In the figure 6.13 a scheme of type of glass is showed:

SOUTH-EAST

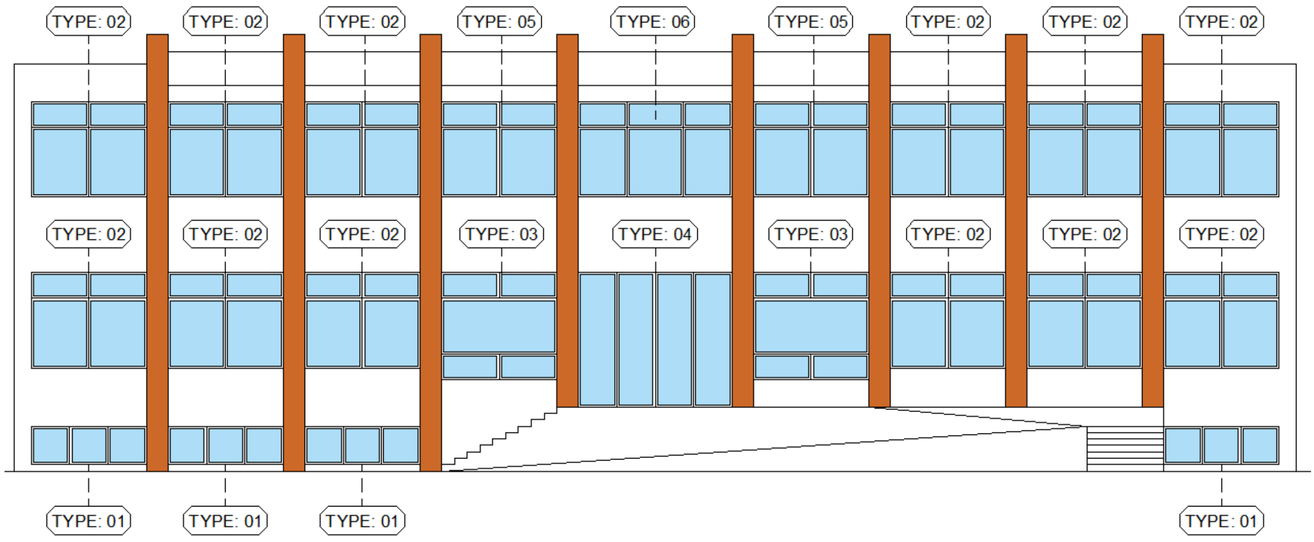


Figure 6.13 – Scheme of type of windows. South-East façade

NORTH-WEST

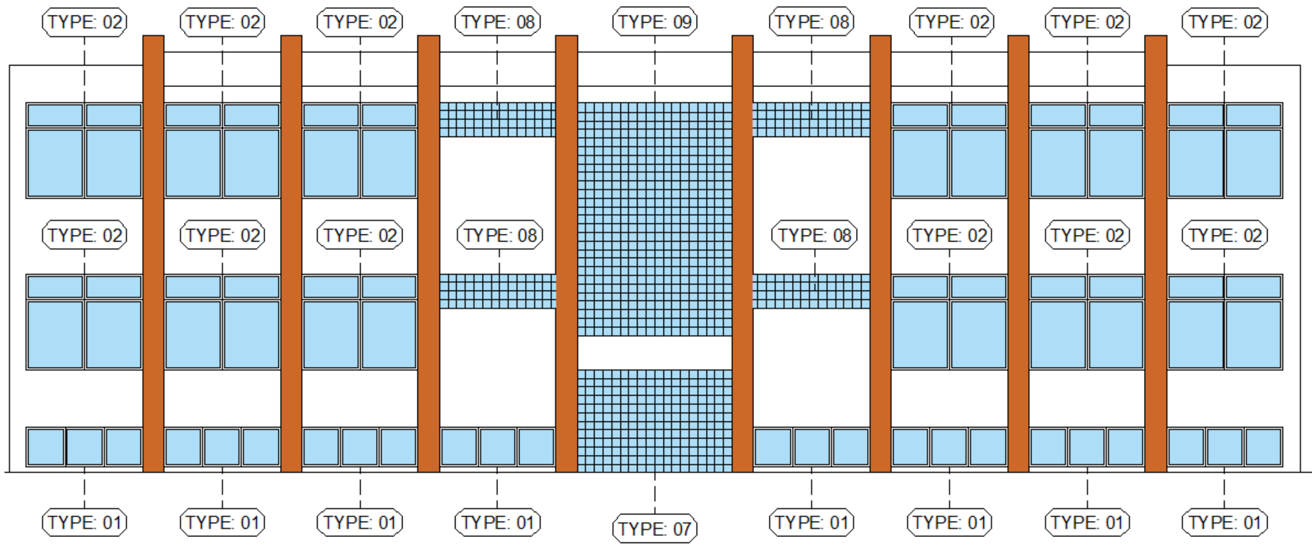


Figure 6.14 – Scheme of type of windows. North-West Façade

6.1.2 Analysis of the installations

To obtain building consumption information, it is important to study the installation's features

- Heating system

The heating system is thus distributed:

Basement: no heating system;

Low level: radiant panel;

First floor: radiators.

The system is powered by a diesel fuel boiler with the characteristics showed in the table 6.4:

BOILER	
Model	Indelcasa
Year of manufacture	700-P
Nominal power [kW]	958
Nominal yield [%]	85,8
Load rating [%]	80
Combustible	Diesel Fuel
Combustion yield [%]	93,1
Indoor temperature [ ]	25
Gas temperature [ ]	192,4
O2 concentration [%]	1,5
CO concentration [ppm]	16

Table 6.4 – Boiler characteristics. Figure 6.15 – ***Imagine of Azkorri's boilers***

- Hot water installation

In the buildings B there are no hot water installation.

- Light system

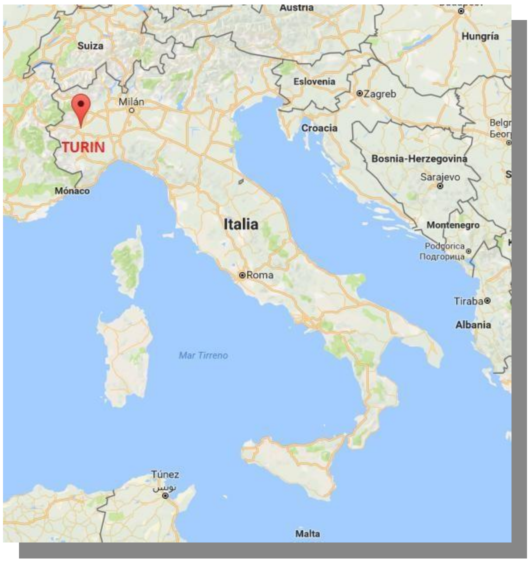
The lighting system has recently been replaced with T8 LED Tubes.

6.2 Energy simulation

In this chapter, the Azkorri building will be submitted to two energies simulation. The first energy simulation will be placed in Getxo, Basque Country, Azkorri building country. It will be done with a Spanish software: CE3X in according with the simplified energy certification procedures for existing building, and in respect to DB-HE (documento básico de ahorro de energía) of the CTE (código técnico de la edificación). The second energy simulation will be placed in Turin with the software Edilclima, in respect of Ministerial Decree of 26/06/2015 and the Technical Specification UN/TS11300.

City	Getxo
Province	Bizkaia
Region	Basque Country
Country	Spain
Latitude	43°21'24.8"N
Longitude	3°0'41.26"W.
Altitude	10 m
Average Temperature minimum	-1,4
Average Temperature maximum	29,9
Relative humidity	70%
Climate zone	C1

Figure 6.16 – Location of Bilbao and its climate date



City	Turin
Province	Turin
Region	Piedmont
Country	Italy
Latitude	45°04' N
Longitude	7°42' E.
Altitude	240 m
Average Temperature minimum	-8
Average Temperature maximum	31
Relative humidity	73%
Climate zone	E

Figure 6.17 – Location of Turin and its climate date

6.2.1 Energy performance of building with CE3X

The software CE3X is a computer tool promoted by the Ministry Industry, Energy and Tourism, through the IDAE, and by the Ministry of Obtain the energy efficiency certification of an existing building.

Figure 6.18 – CE3X Software

The program is based on the comparison of the building object of the certification and a database that has been prepared for each city of climate zones. The database is sufficiently wide to cover any case of the Spanish zone in which the building is located. The software parametrizes the data of the object building and compares them with the characteristics of the cases collected in the database. In this way, the software searches a building with more similar characteristics and obtains the demand for heating and cooling of the object building.

The simplified CE³X Energy Certification procedure begins with the collection of data that define the thermal behavior of the existing building and the efficiency of its thermal installations.

The first data to introduce are the Administrative data, as shown in the figure 6.19:

- Building location and identification;
- Client data;
- Technical data of the certificatory.

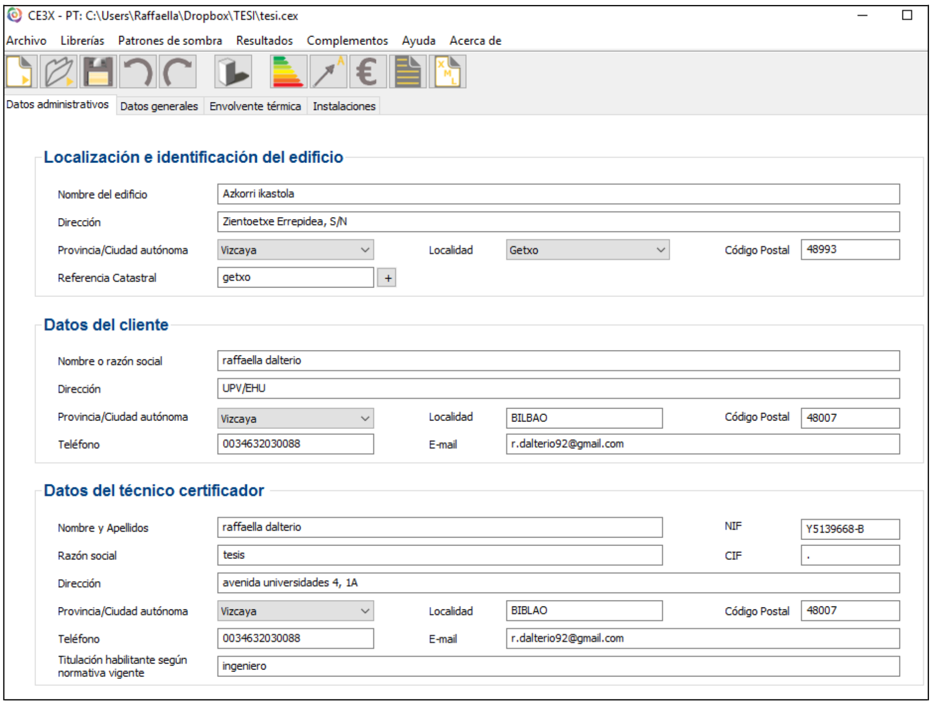


Figure 6.19 – Administrative information. CE3X Screenshot

The second data to introduce are the General data, as shown in the figure 6.20.

- Year of construction and the respective reference regulations;
- Type of building and its intensity of use;
- Geographic location and the respective thermal zone;
- Geometric data of the building: useful area, height, number of floors;
- Demand for DHW and ventilation;
- Mass of interior walls.

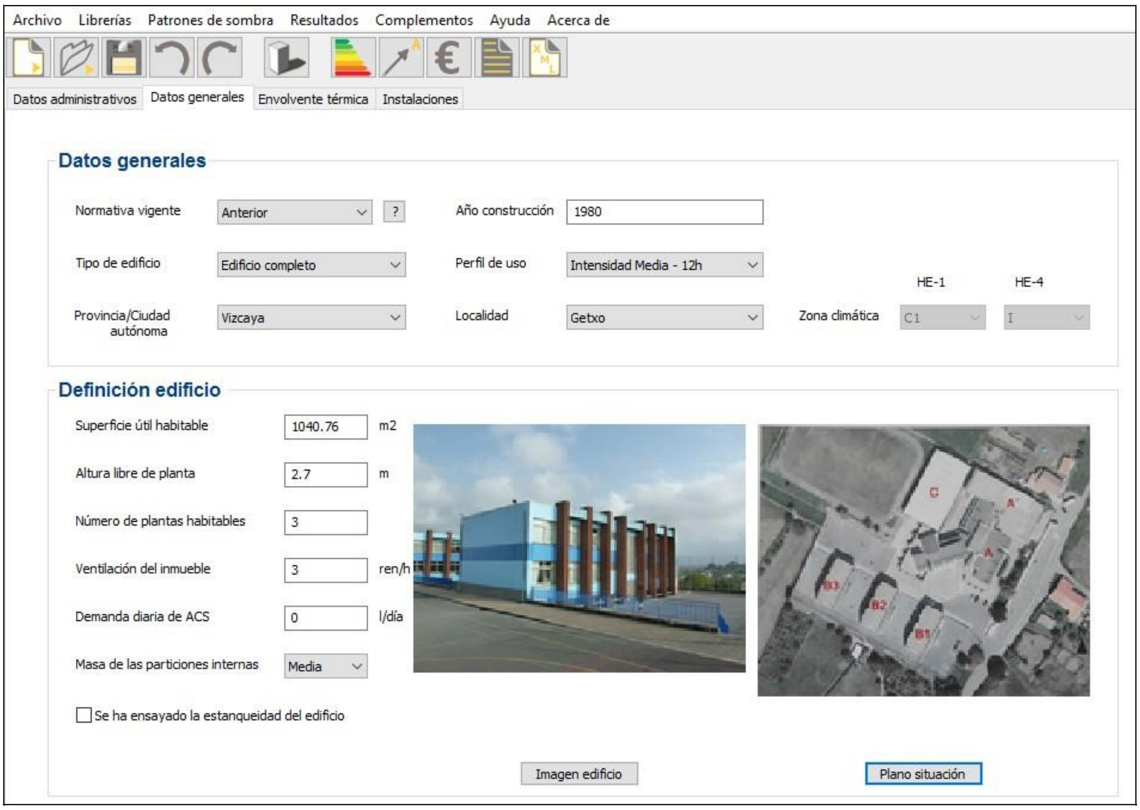


Figure 6.20 – General data. CE3X Screenshot

With the introduction of the general data of the building the software automatically associates a climatic zone to it. With this information it prepares a database to calculate heat and cool demand. To complete this calculation, CE3X needs the building envelope data.

The subchapter 6.1.1 presents the list of all types of opaque and glazed components that the program needs. All of this data can be introduced in the software, as shown in the Figures below:

- GROUND FLOOR

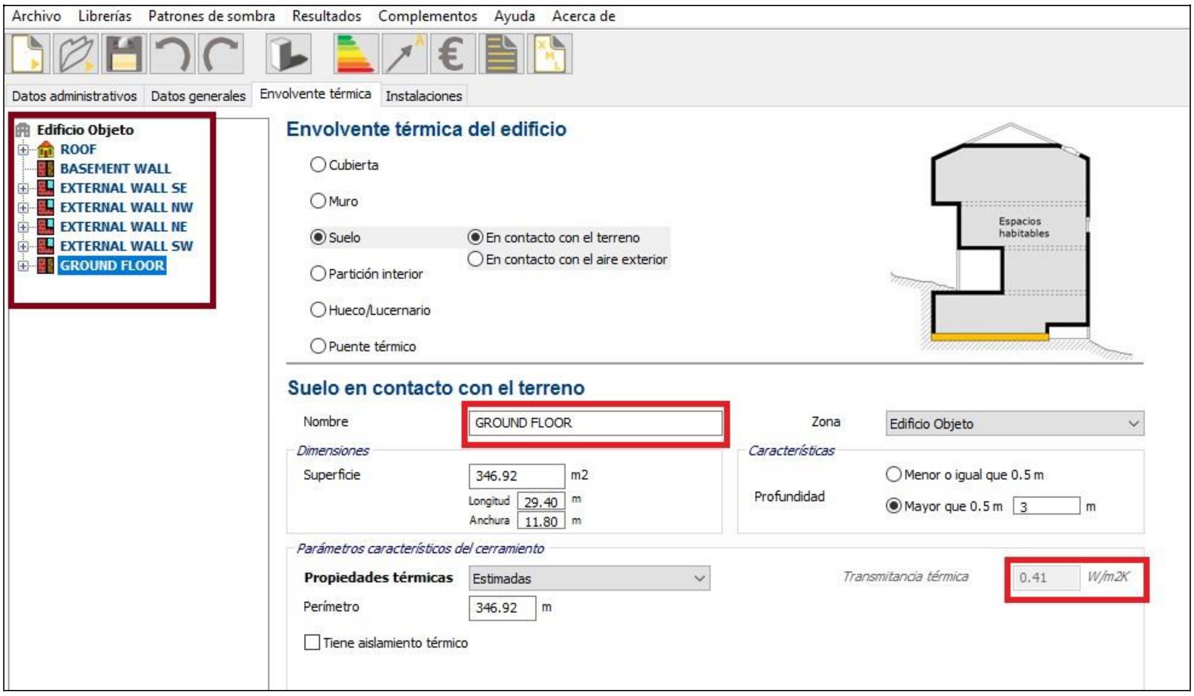


Figure 6.21 – Insertion of ground floor. CE3X Screenshot

- BASAMENT WALL

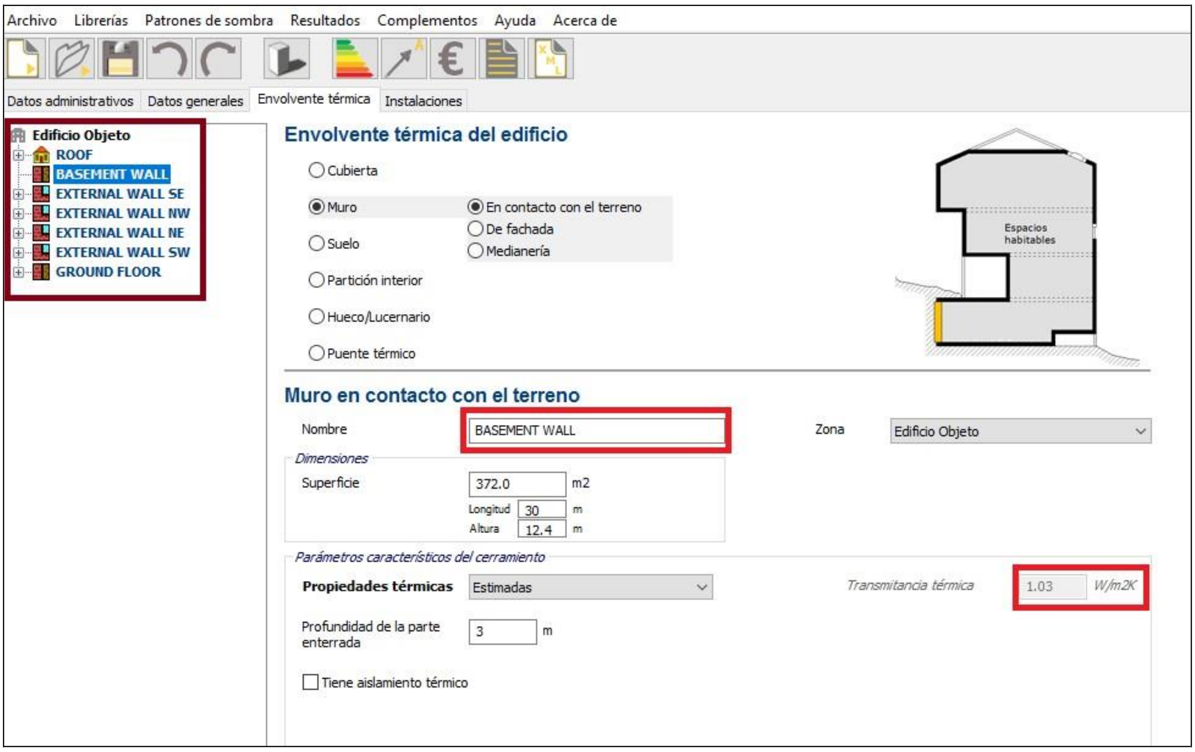


Figure 6.22 – Insertion of basement wall. CE3X Screenshot

- ROOF

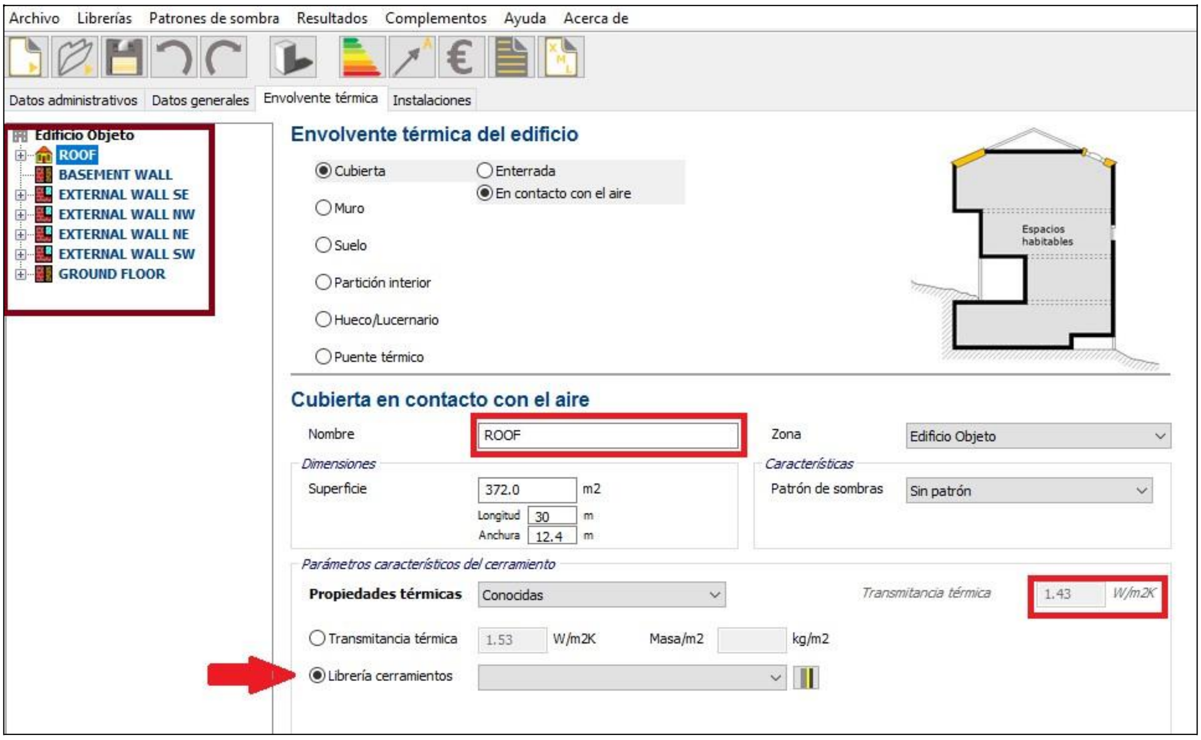


Figure 6.23 – Insertion of roof. CE3X Screenshot

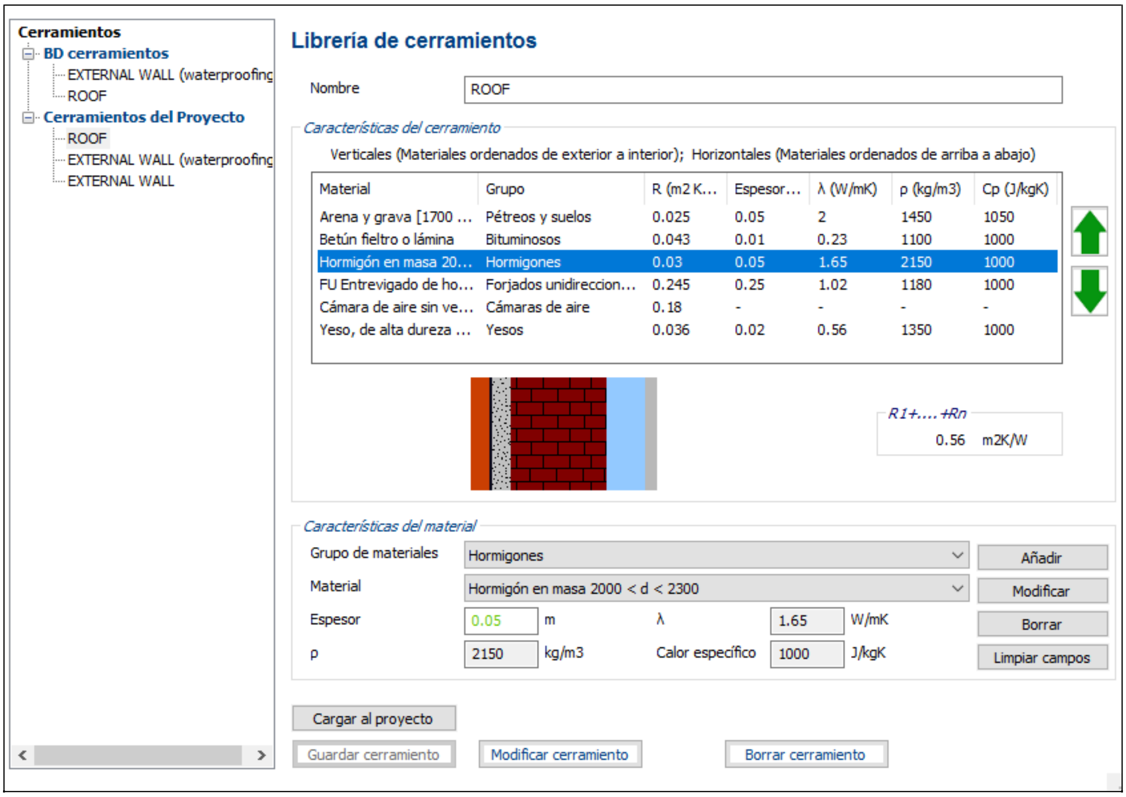


Figure 6.24 – Insertion of roof details. CE3X Screenshot

- EXTERNAL WALL

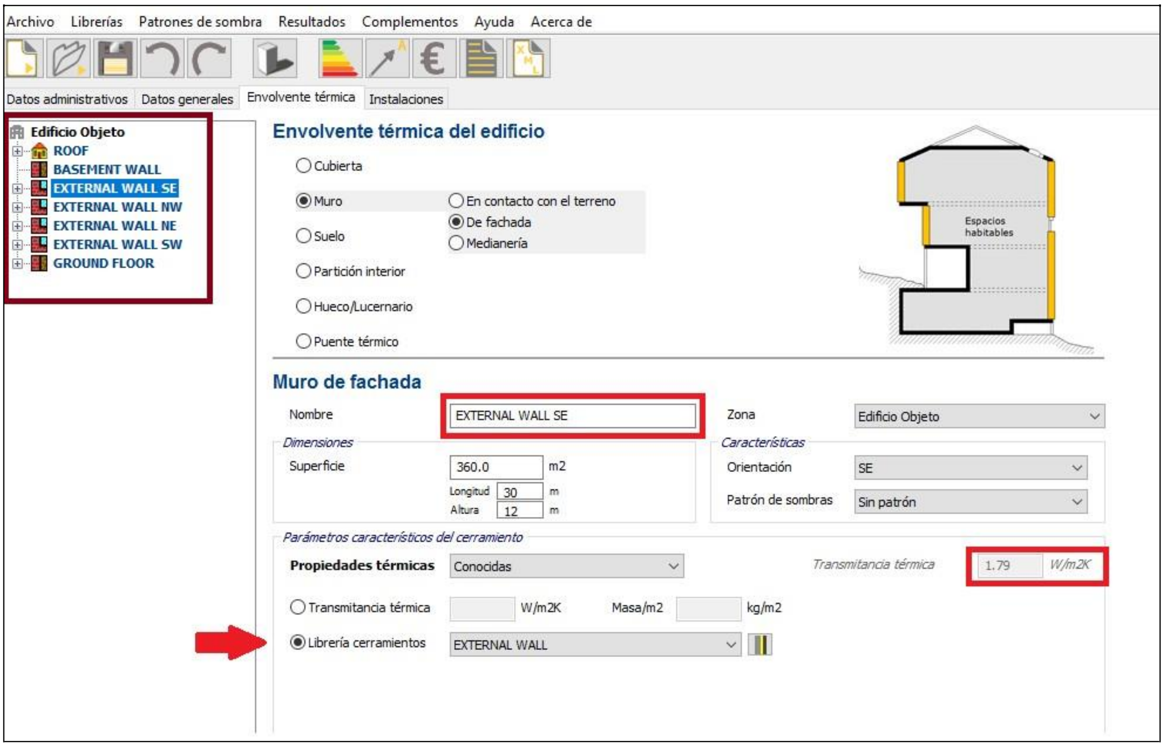


Figure 6.25 – Insertion of external wall. CE3X Screenshot

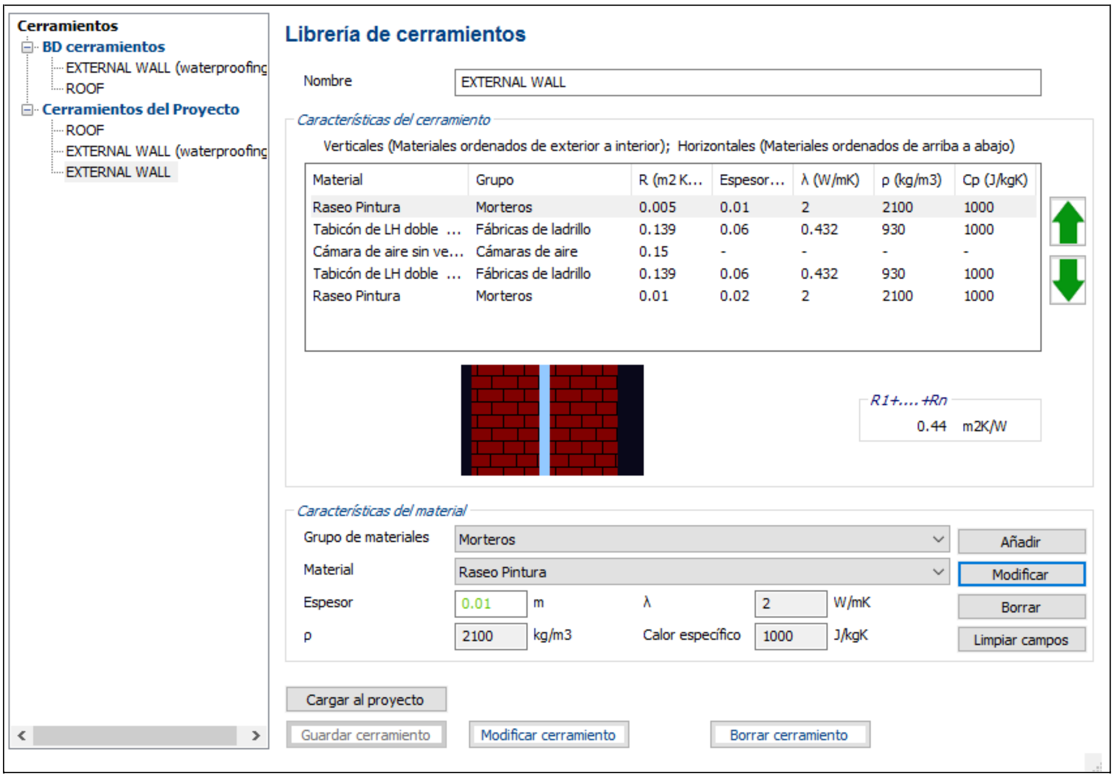


Figure 6.26 – Insertion of external wall details. CE3X Screenshot

- WINDOWS

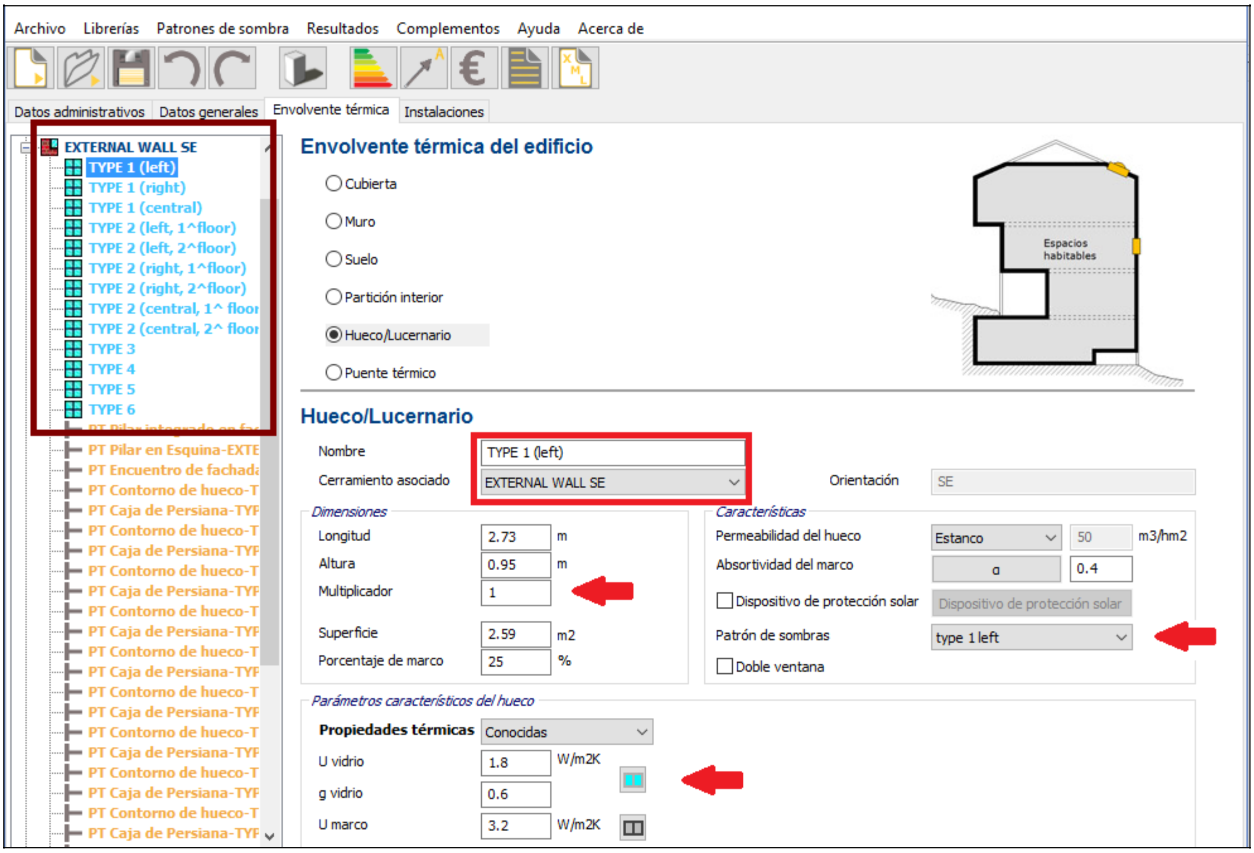


Figure 6.27 – Insertion of windows. CE3X Screenshot

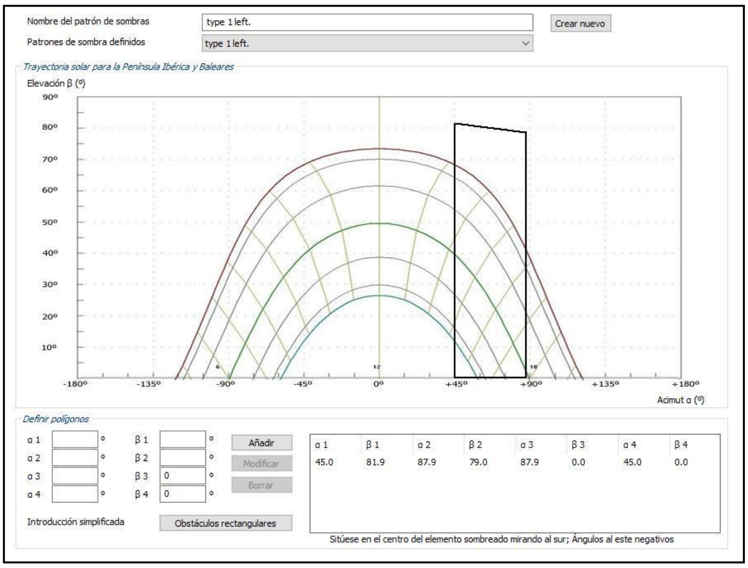


Figure 6.28 – Insertion of building shade. CE3X Screenshot

The windows have to be inserted for every different wall orientation. It affects the amount of heat and sunlight that enter in the building. Each window has a building shade, for its presence of vertical protrusions. The software will calculate the shade with the introduction of a specific geometric parameters, as shown in the Figure 6.28.

- THERMAL BRIDGES

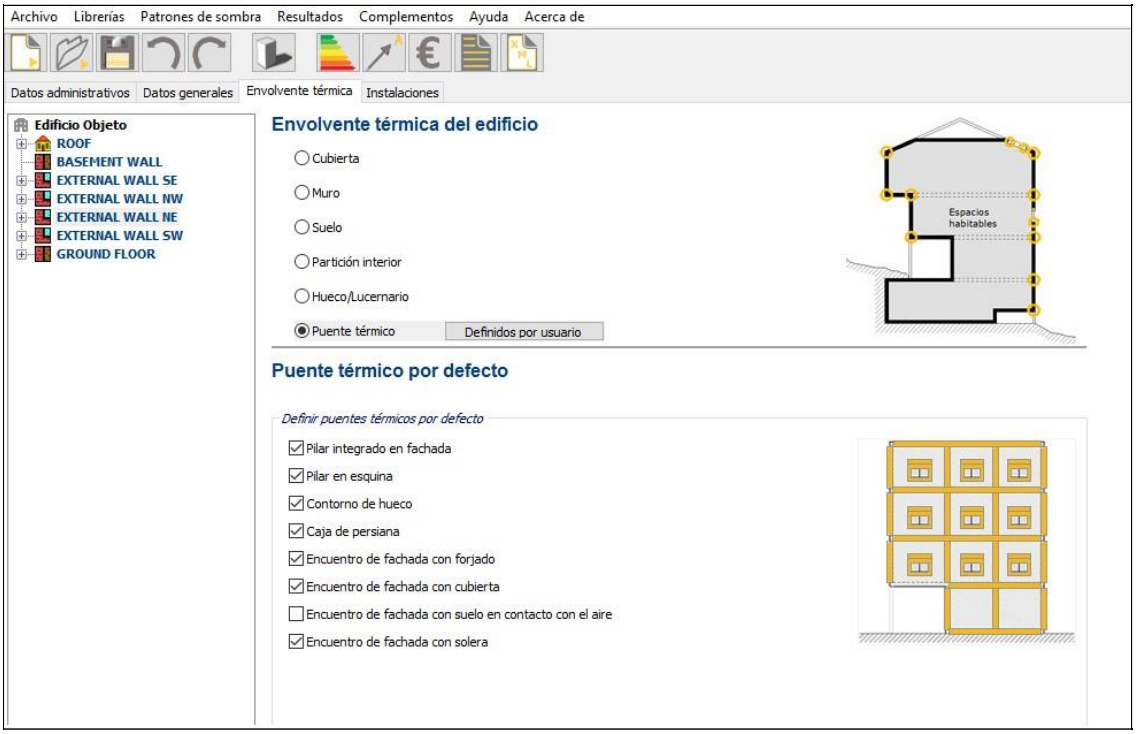


Figure 6.29 – Insertion of thermal bridges. CE3X Screenshot

At the low level and, the first floor, no interior walls have been introduced because the building is made up of a single thermal zone, except for the basement.

All the thermal bridges provided by the software have been introduced (except for the thermal bridge created with a balcony) by the year construction of the building.

The other information that the software needs, is about the building installations. In the subchapter 6.1.2 there are all the information about it.

As shown in the figure below, CE3X is able to calculate different type of installation, as:

- DHW;
- Heating System;
- Cooling system;
- DHW and heating mix system;
- Light system;…etc.

- CE3X INSTALLATION SYSTEM

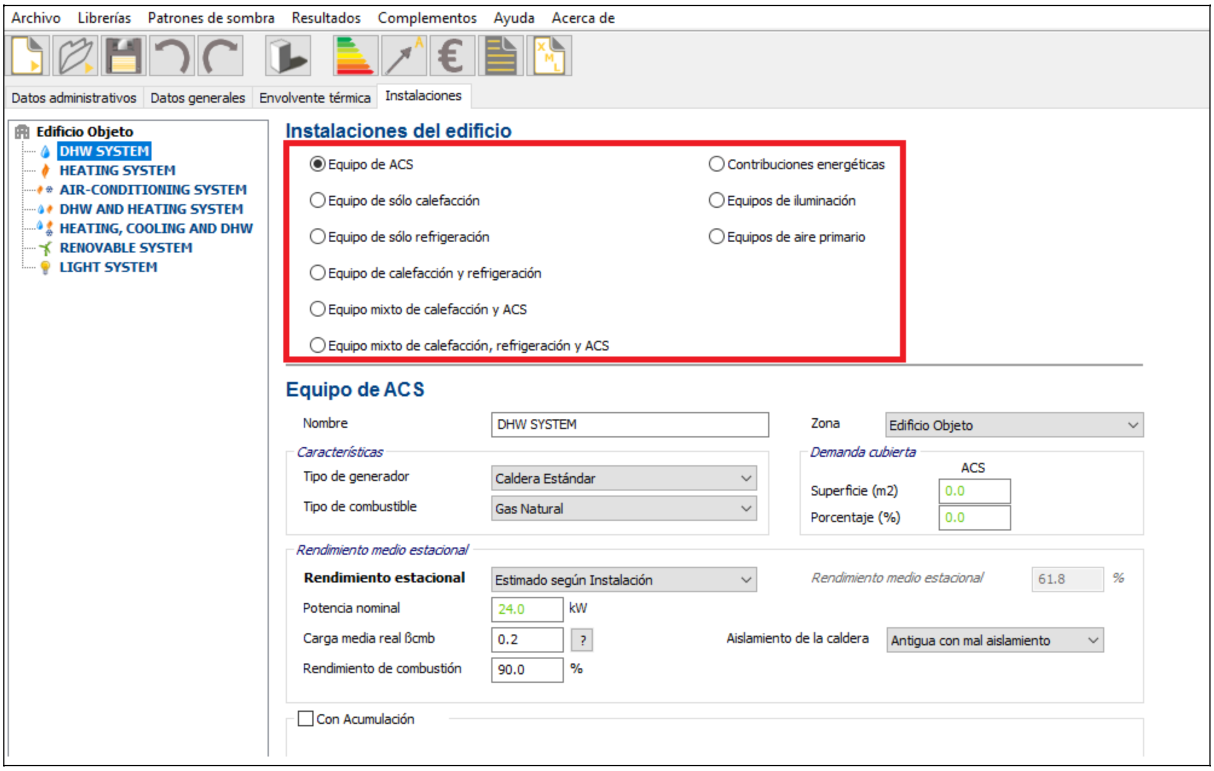


Figure 6.30 – CE3X installations. CE3X Screenshot

For the case study only the heating and light system will be included. The building has no other installation system.

- HEATING SYSTEM

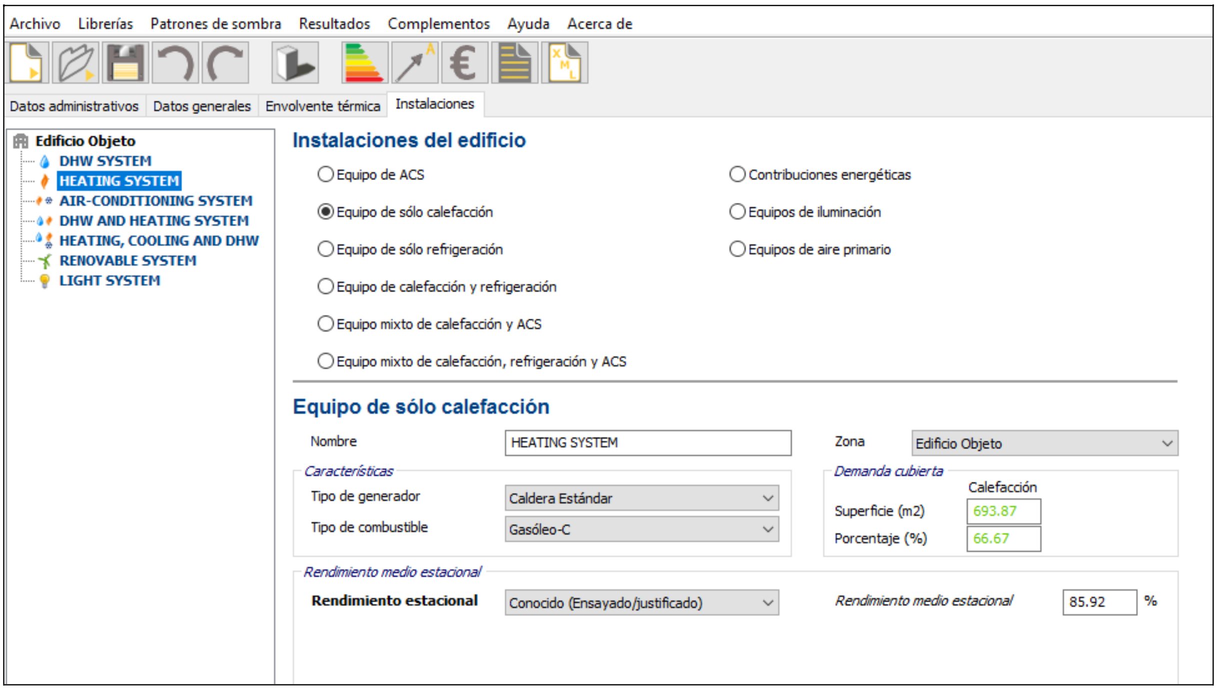


Figure 6.31 – Insertion of heating system. CE3X Screenshot

- LIGHT SYSTEM

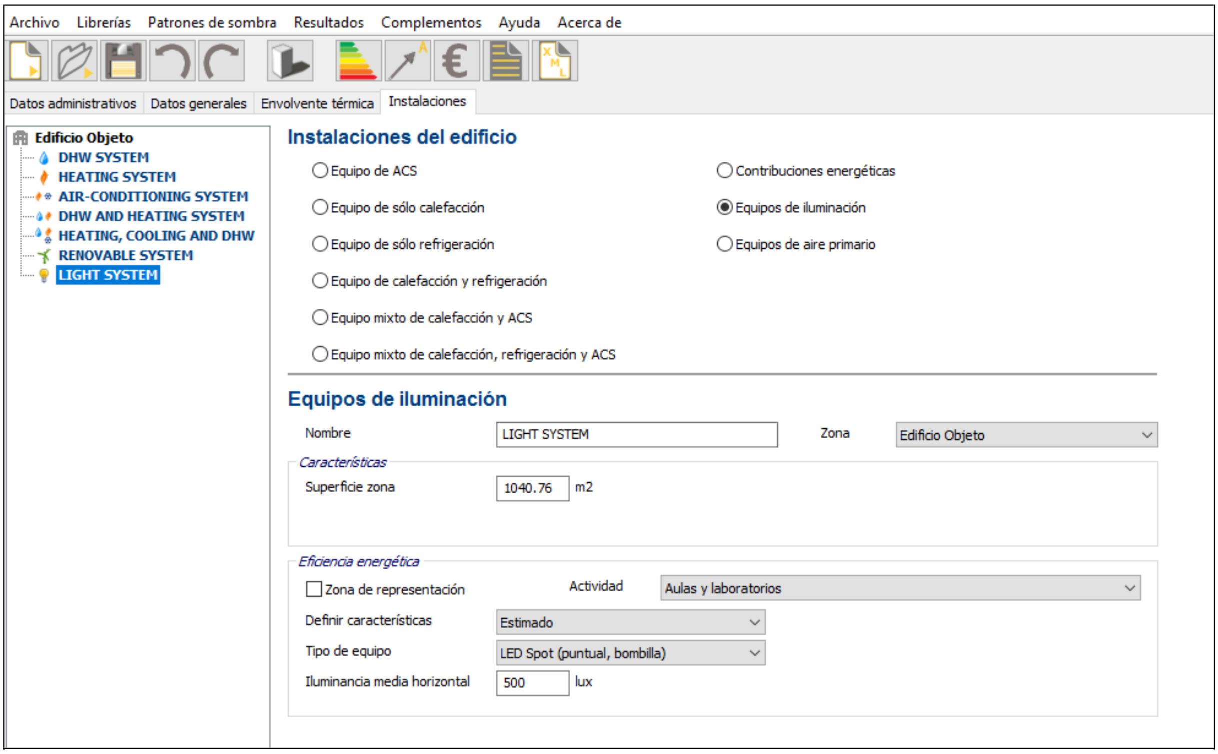


Figure 6.32 – Insertion of light system. CE3X Screenshot

When all parameters required for the software have been entered, the calculation of the energy classification is carried out:

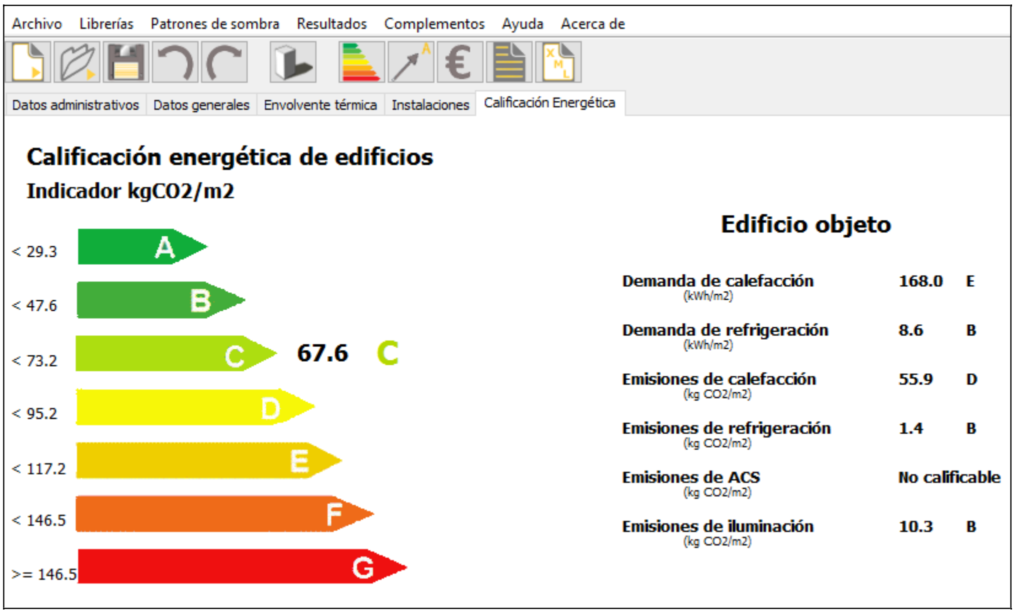


Figure 6.33 – Energy classification

The final result corresponds to a C, equivalent to an emission of $kgCO_2/m^2$ of 67.6.

As we can see, the worst emissions calculated by the software are the heating demand and its correspondent energy source. It derives from the characteristics of the building envelope: in spite of the thermally-enhanced windows (recently changed), the interior environment continues to have significant heat losses due to the presence of a façade constructed of obsolete techniques.

The program calculates the cooling demand and its consumption even though there is no cooling installation. It is because the software DOES NOT WORK with IT building. The software looks for simulations with characteristics more similar to those of the building object and interpolates with respect to them the demands of heating and cooling, thus obtaining the demands of heating and cooling of the object building.

Finally, the program generated a document in which appears the most important information and results obtained.

CERTIFICADO DE EFICIENCIA ENERGÉTICA DE EDIFICIOS

IDENTIFICACIÓN DEL EDIFICIO O DE LA PARTE QUE SE CERTIFICA:

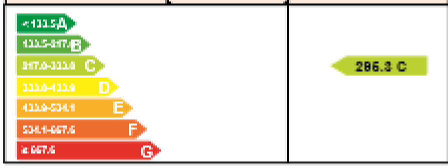
Nombre del edificio	Azkorri ikastola		
Dirección	Zientoetxe Errepidea, S/N		
Municipio	Getxo	**Código Postal**	48993
Provincia	Vizcaya	**Comunidad Autónoma**	País Vasco
Zona climática	C1	**Año construcción**	1980
Normativa vigente (construcción / rehabilitación)	Anterior a la NBE-CT-79		
Referencia/s catastral/es	getxo		

Tipo de edificio o parte del edificio que se certifica:	
○ Edificio de nueva construcción	● Edificio Existente
○ Vivienda ○ Unifamiliar ○ Bloque ○ Bloque completo ○ Vivienda individual	● Terciario ● Edificio completo ○ Local

DATOS DEL TÉCNICO CERTIFICADOR:

Nombre y Apellidos	raffaella dalterio	**NIF(NIE)**	Y5139668-B
Razón social	tesis	**NIF**	.
Domicilio	avenida universidades 4, 1A		
Municipio	BIBLAO	**Código Postal**	48007
Provincia	Vizcaya	**Comunidad Autónoma**	País Vasco
e-mail:	r.dalterio92@gmail.com	**Teléfono**	0034632030088
Titulación habilitante según normativa vigente	ingeniero		
Procedimiento reconocido de calificación energética utilizado y versión:	CEXv2.3		

CALIFICACIÓN ENERGÉTICA OBTENIDA:

CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE [kWh/m² año]	EMISIONES DE DIÓXIDO DE CARBONO [kgCO2/ m² año]
	

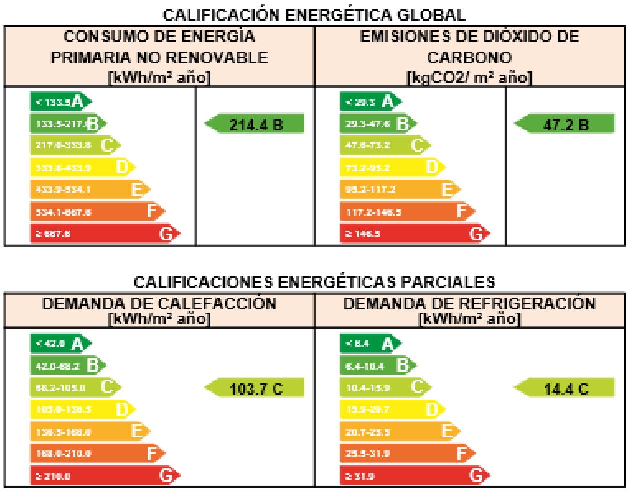
El técnico abajo firmante declara responsablemente que ha realizado la certificación energética del edificio o de la parte que se certifica de acuerdo con el procedimiento establecido por la normativa vigente y que son ciertos los datos que figuran en el presente documento, y sus anexos:

Figure 6.34 – Energy performance certificate

CE3X allows to choose building improvement measures and makes an estimate of them. I have choose to improve the façade:

ANEXO III
RECOMENDACIONES PARA LA MEJORA DE LA EFICIENCIA ENERGÉTICA

aislamiento en facahada



ANÁLISIS TÉCNICO

Indicador	Calefacción			Refrigeración			ACS			Iluminación			Total		
	Valor		ahorro respecto a la situación original	Valor		ahorro respecto a la situación original	Valor		ahorro respecto a la situación original	Valor		ahorro respecto a la situación original	Valor		ahorro respecto a la situación original
Consumo Energía final [kWh/m² año]	118.05		38.3%	7.19		-67.3%	0.00		-%	31.12		0.0%	156.36		31.0%
Consumo Energía primaria no renovable [kWh/m² año]	139.59	C	38.3%	14.04	C	-67.3%	0.00	-	-%	60.81	B	0.0%	214.45	B	27.4%
Emisiones de CO2 [kgCO2/m² año]	34.50	C	38.3%	2.38	C	-67.3%	0.00	-	-%	10.30	B	0.0%	47.18	B	30.2%
Demanda [kWh/m² año]	103.71	C	38.3%	14.37	C	-67.3%									

Nota: Los indicadores energéticos anteriores están calculados en base a coeficientes estándar de operación y funcionamiento del edificio, por lo que solo son válidos a efectos de su calificación energética. Para el análisis económico de las medidas de ahorro y eficiencia energética, el técnico certificador deberá utilizar las condiciones reales y datos históricos de consumo del

Figure 6.35 – Building improvement measures. Insulation of façade

The next chapters will show the rehabilitation of the building façade and then re-classification through the Spanish CE3X and Italian Edilclima softwares.

6.2.2 Improvement measure: façade rehab

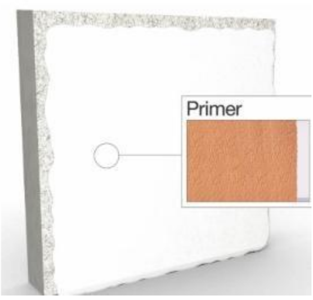
*Professional building facade and exterior rehabilitation begins with a thorough examination **of the structure's existing condition including the underlying facade support, exterior surface,** roofing, windows and any attachments such as porches, overhangs and stylistic treatments. The examination generally includes a review of any original plans, related construction documents, previous repair work and updates to arrive at a comprehensive understanding of **the structure's current exterior condition***. [Source: Facade Maintenance Design, PC].

As described in the previous chapters, the façade of the Azkorri building has no isolation. Among the various types of existing façade in construction, already analyzed in the sub-chapter 3.3.2 the Exterior Insulation and Finishing System, knew as EIFS (or *External Thermal Insulation Composite System ETICS*), is chosen (spanish versión *SATE, Sistemas de Aislamiento Térmico por el Exterior*).

Figure 6.36 – EIFS façade

Exterior Insulation and Finish Systems are multi-layered exterior wall system. It provides superior energy efficiency and offer much greater design flexibility than other cladding products.

EIFS typically consist of the following components:

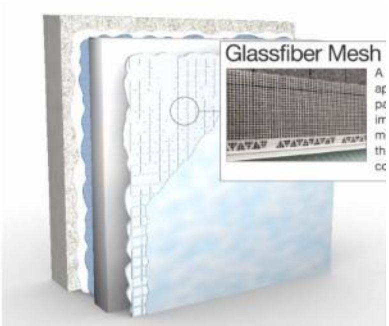


A silicone resin primer that permits diffusion and is based on SBS enhances drying and protects against harmful salts.

Adhesive mortar is used to attach the insulation system to the exterior wall.

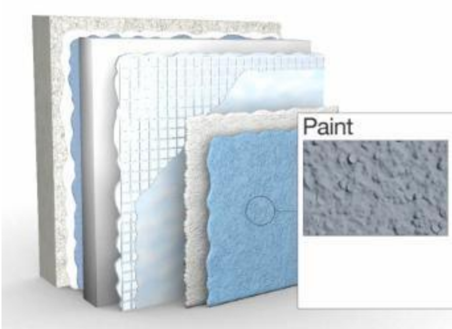
Insulation that guarantees the energy performance of buildings. There are different typologies according to the characteristics required.

Polymer modified dry-mix mortar is applied to secure the glassfiber mesh. The mortar makes for a composite base that is both secure and flexible.



The glassfiber mash is applied to the insulation panel to reinforce its impact resistance. The mesh is embedded in the base coat.

Typical coating include hydrophobic plasters made of mineral, acrylic, silicate or silicone. is one of the least expensive and most often used facade materials for new buildings and renovation projects in Europe.



Silicone resin emulsion paints are ideal because they are both water-repellent and water-vapor permeable. They thus help to protect the entire ETICS against weathering.

The choice of an ETICS system results from the benefits it brings to the structure: no reduces internal volume, eliminates thermal bridges, it is more cheap than the other solution and give an unlimited design flexibility, it comes in virtually limitless colors and a wide variety of textures. They also can be fashioned into virtually any shape or design.

ETICS literally wraps the exterior in an energy-efficient thermal blanket. By insulating outside the structure, EIFS reduces air infiltration, stabilizes the interior environment and reduces energy consumption.

In fact, ETICS can reduce air infiltration by as much as 55% compared to standard brick or wood construction. And since walls are one of the greatest areas of heat and air conditioning loss, improvement in the wall insulation can be very meaningful in terms of energy conservation.

To provide the system with a lasting service life, so as to maintain adequate internal comfort conditions, a periodic maintenance should include thorough checking of the flashing and sealing to ensure that the building envelope remains watertight. Damaged or missing flashing should be repaired or replaced immediately; likewise, cracked or deteriorated sealant should immediately be repaired, or removed and replaced.

For the Azkorri façade rehabilitation provides:

- insulation of wood fiber with thermal conductivity (λ) of 0,039 W/mK:

Figure 6.37 – Image of wood fiber

- fiberglass mesh interposed between two layers of mortar, to give greater resistance and protection to the insulation;

- mortar for exterior, arid projected or stone, indicated for areas sensitive to erosion as low plants or baseboards because it offers good surface resistance finish, with thermal conductivity (λ) of 1,16 W/mK:

Figure 6.38 – Image of mortar

In the subchapter below a new energy classification, with ETICS system, will be shown.

First of all, the building will be classified with the CE3X program, then with the Italian software.

6.2.2.1 Energy performance of building with CE3X

The data that will change, compared to the previous analysis, are those related to the opaque element, as showed in the figures 6.39 and 6.40:

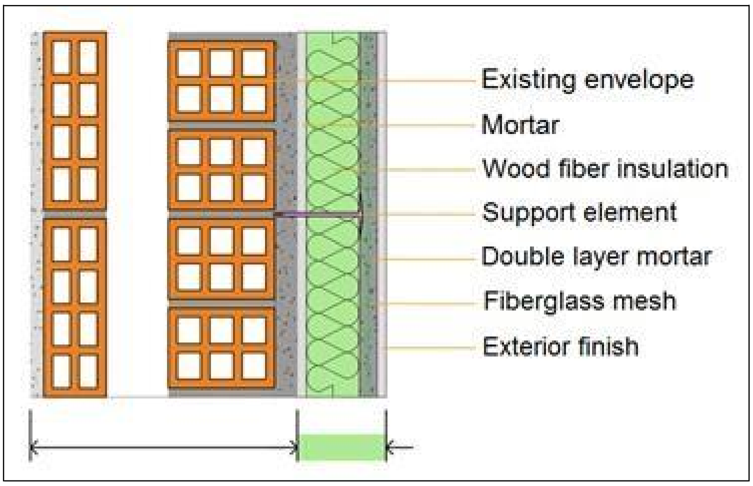


Figure 6.39 – New façade with ETICS solution

The thickness chosen for insulation is 80mm (0,08m):

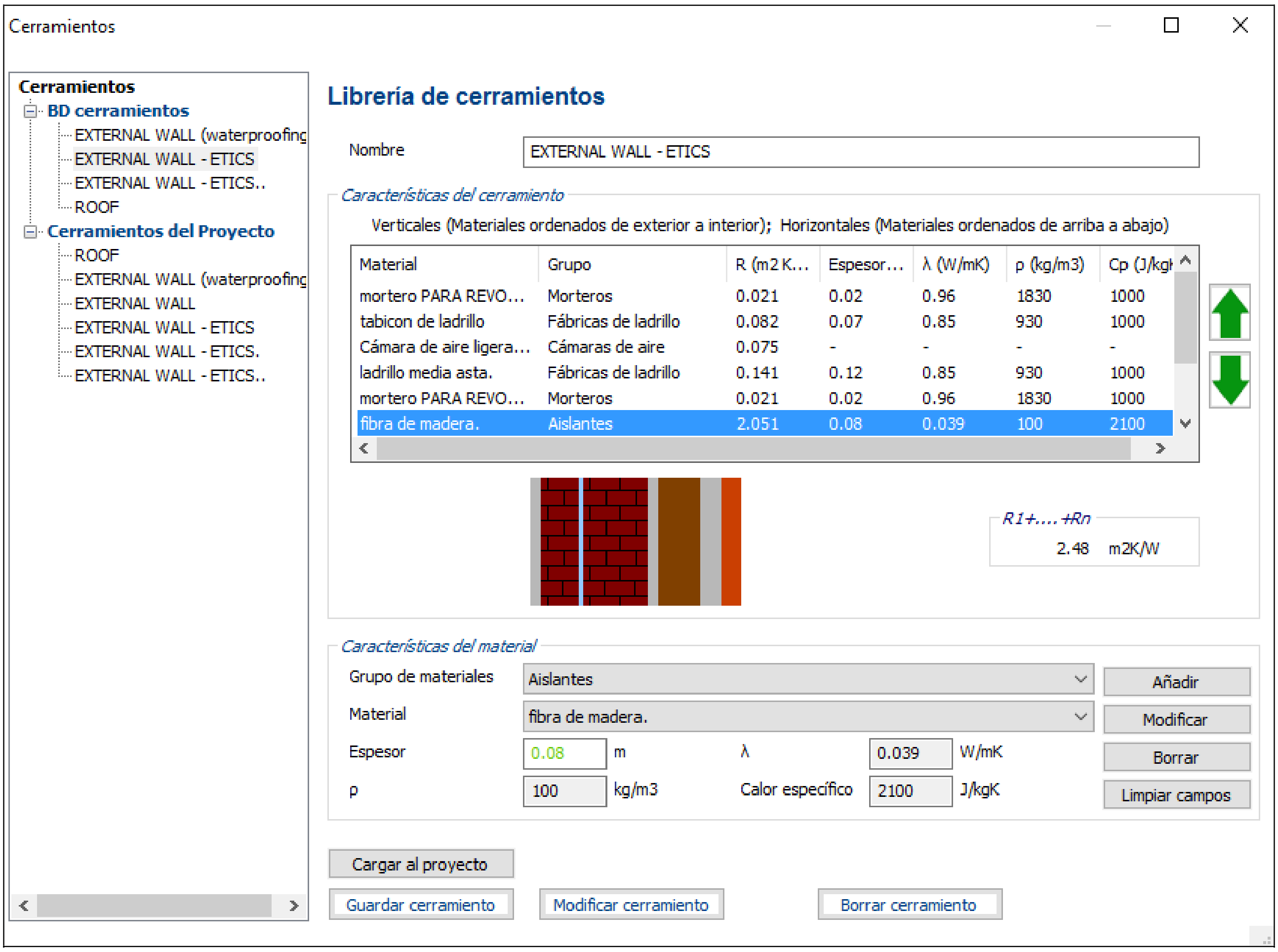


Figure 6.40 – New façade with ETICS solution (with CE3X)

The new opaque envelope transmittance is: $U= 0,38\ W/m^2K$. Improving façade insulation, in this case with an ETICS system, it gets better indoor comfort conditions as well as the risk of interstitial condensation. This avoids the presence of dehumidifiers during the winter season and decreases heating demand, its consumption, and cost.

The ETICS system reduces the thermal bridges as:

- Thermal bridge between pillar and external wall;
- Thermal bridge of an angle pillar;
- Thermal bridge between façade and slab.

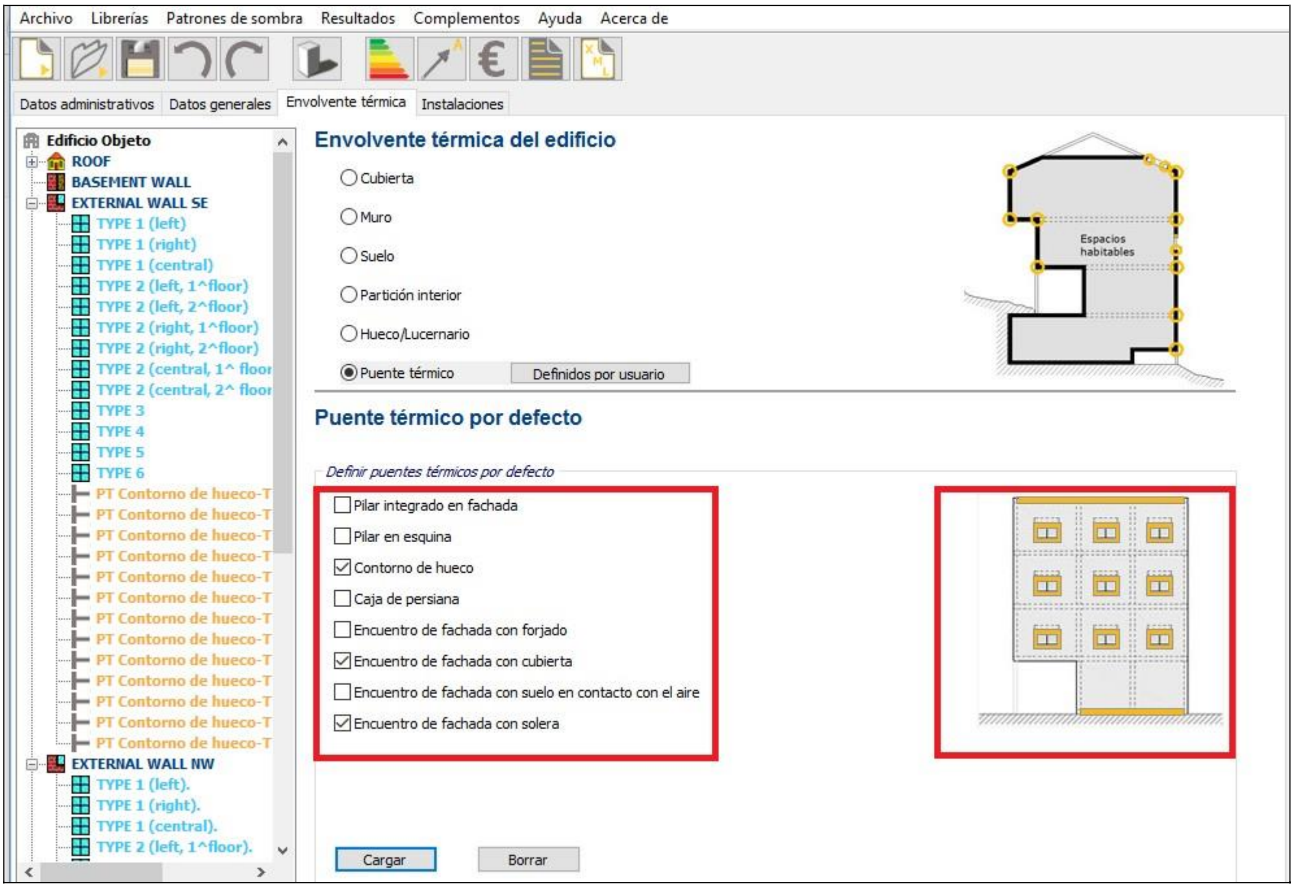


Figure 6.41 – Thermal bridge that still remain in the façade

Now, there are no other new parameters to introduced in the software, and a new classification can be carried out:

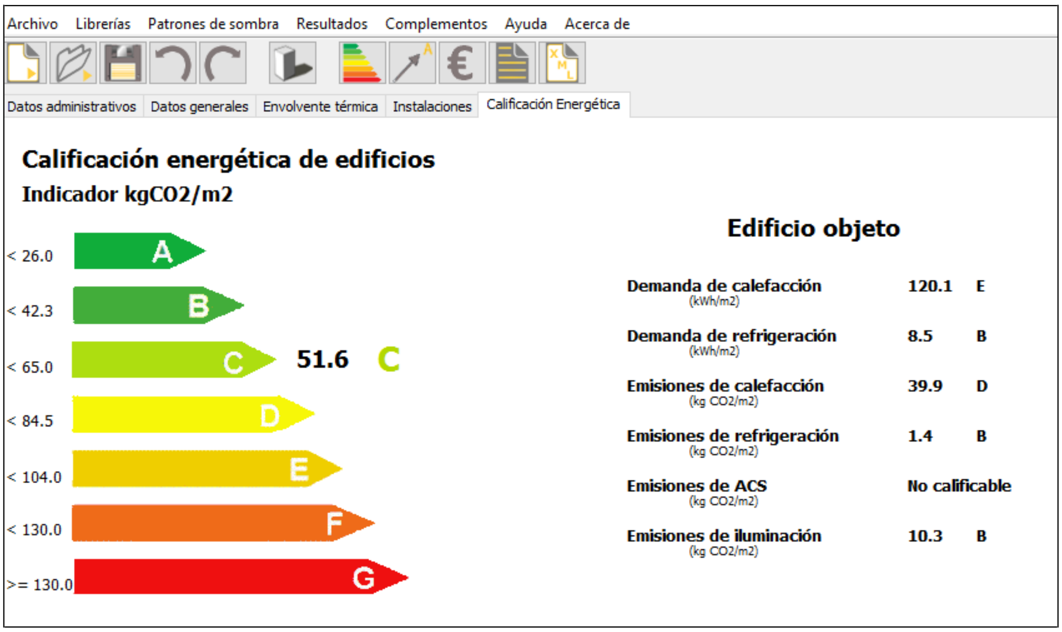


Figure 6.42 – Energy classification with ETICS system

The final result corresponds to a C, equivalent to an emission of $kgCO_2/m^2$ of 51,6, 16 $kgCO_2/m^2$ less than the previous classification.

If we want to do a comparison between after and before, the following figures can show the difference:

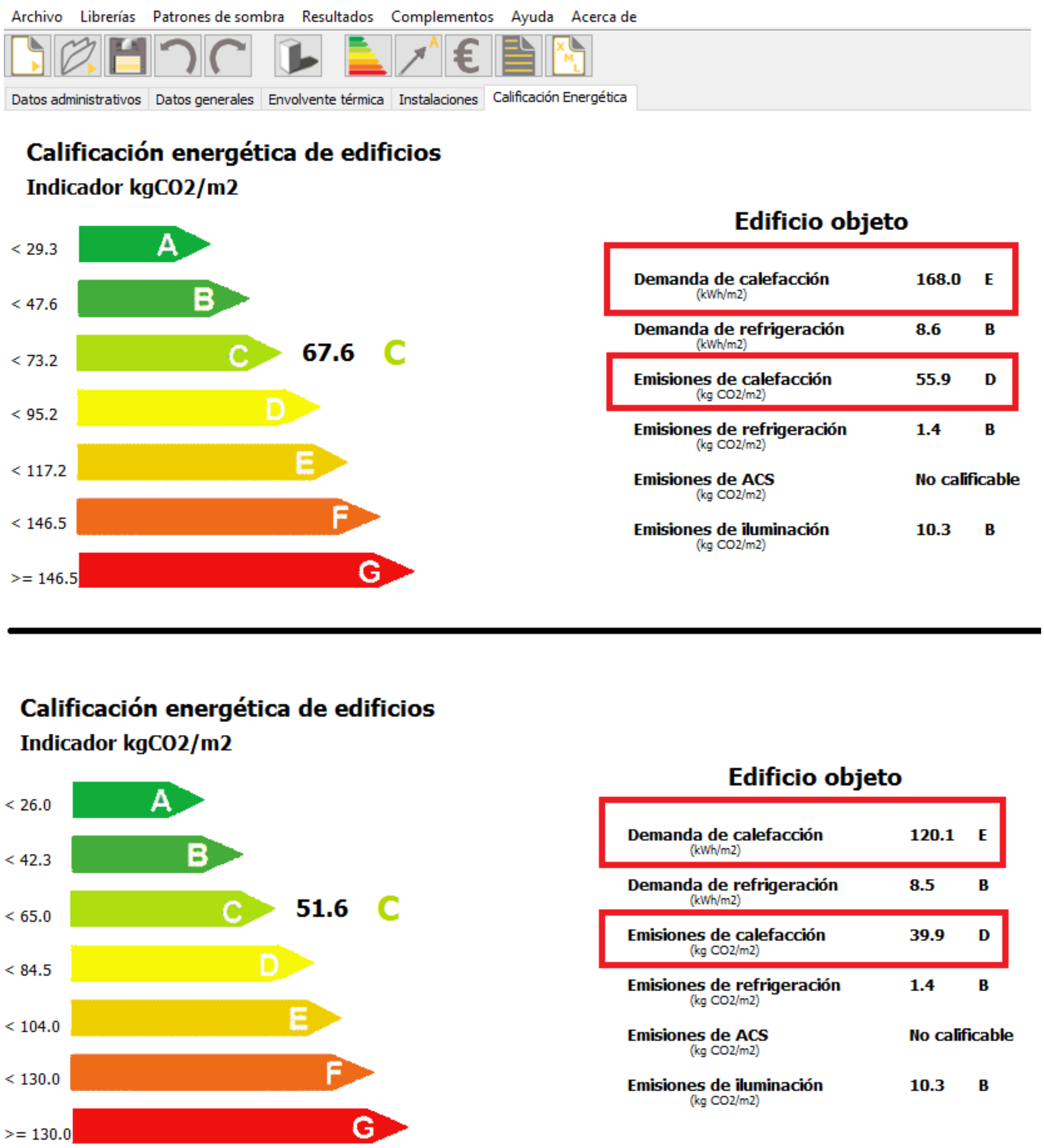


Figure 6.43 – Difference between after and before the ETICS system

6.2.2.2 Energy performance of building with Edilclima

This subchapter will show the Italian Energetic Certification with Italian software Edilclima. It calculates the energy performance of buildings in accordance with the Technical Specifications UNI/TS 11300 1-2-3-4, such as winter and summer cooling, hot water, lighting, and ventilation. Also, it allows for the energy audit, evaluating the actual consumption of the building in according to the actual heating season.

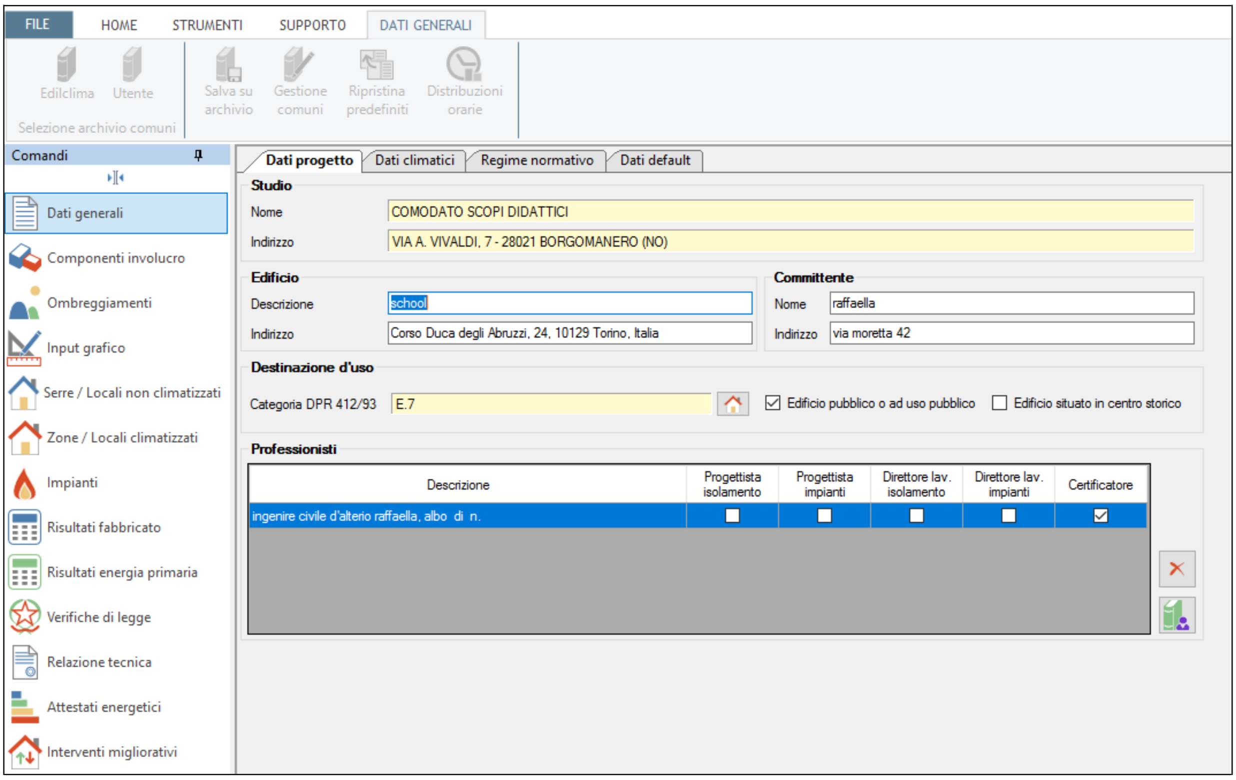
Figure 6.44 – Edilclima software

Finally it produces the Energy Performance Certificate (national or regional) and verification of the minimum requirements. At the certificate is attributed an energy efficiency class and score, which has ranges from a class A+ for greater energy efficiency (score 10), to class G for the least efficient (score 0), that is equivalent a primary energy demand very high.

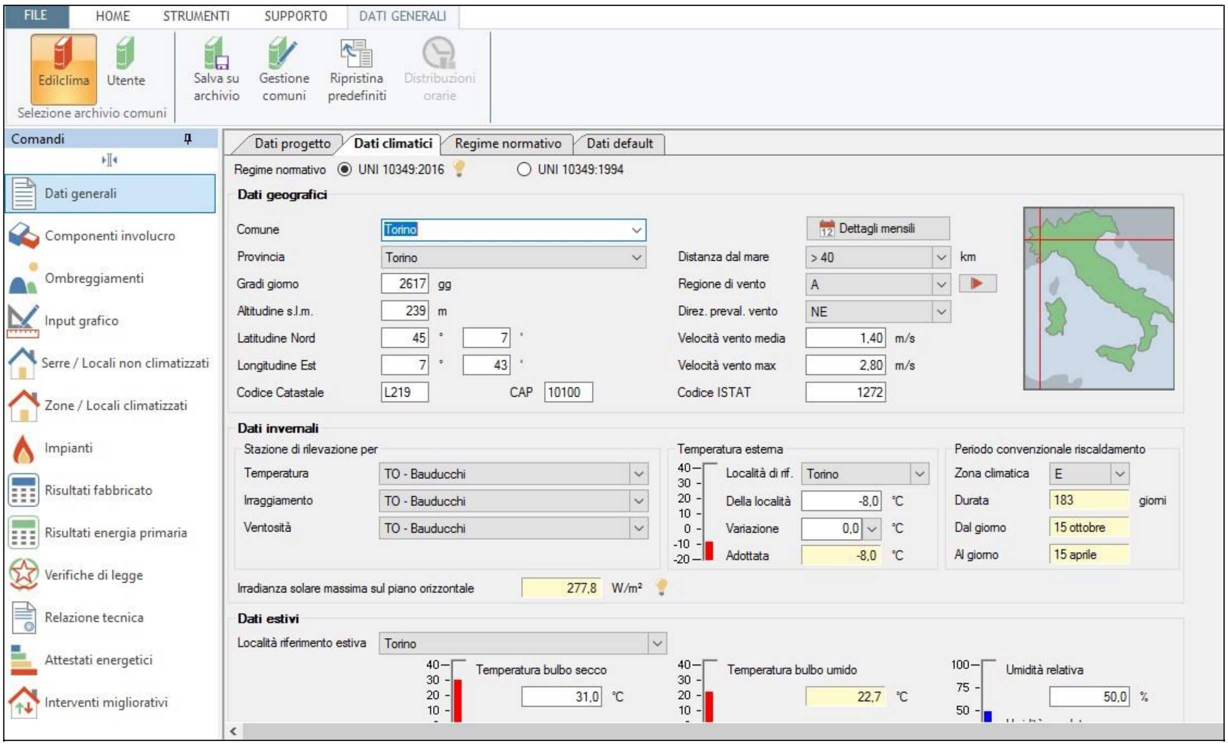
To start the Energy Certification it begins with the collection of data that define the thermal behavior of the existing building and the efficiency of its thermal installations.

The first data to introduce are the General data, as shown in the figure 6.45:

- Certificatory data, Building location and its use;
- Climatic data;
- Reference legislation;
- Default data.



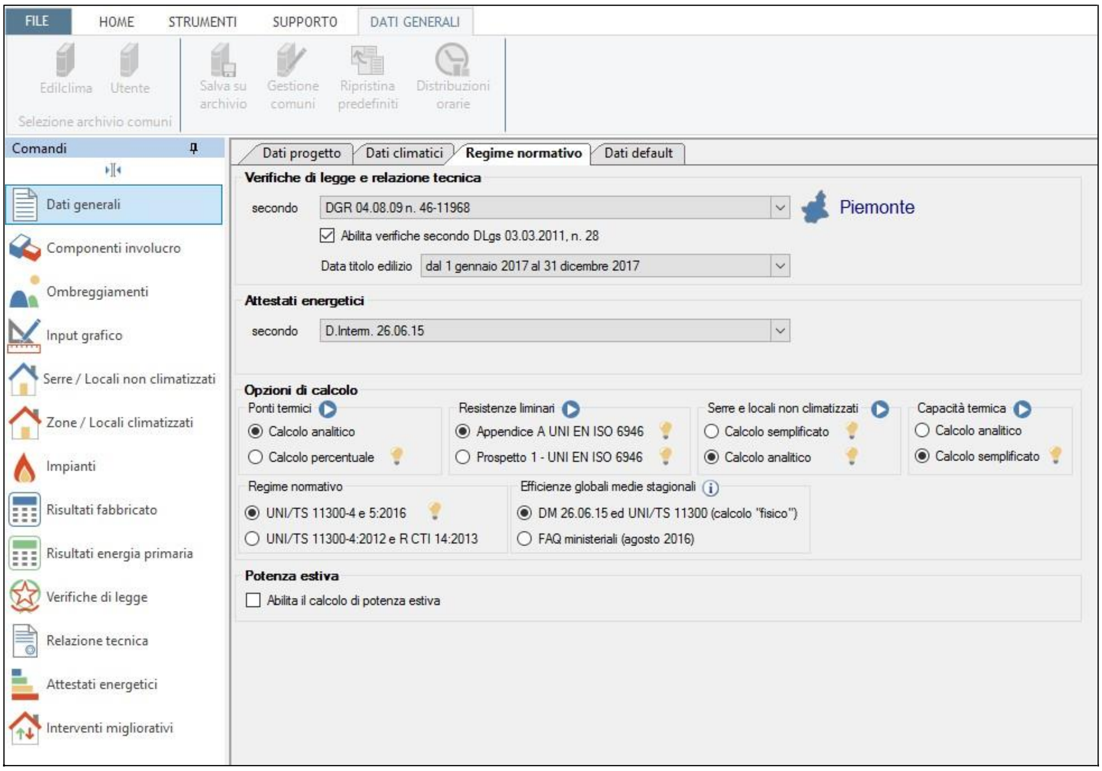
6.45 - Certificatory data, Building location and its use



6.46 – Climatic data

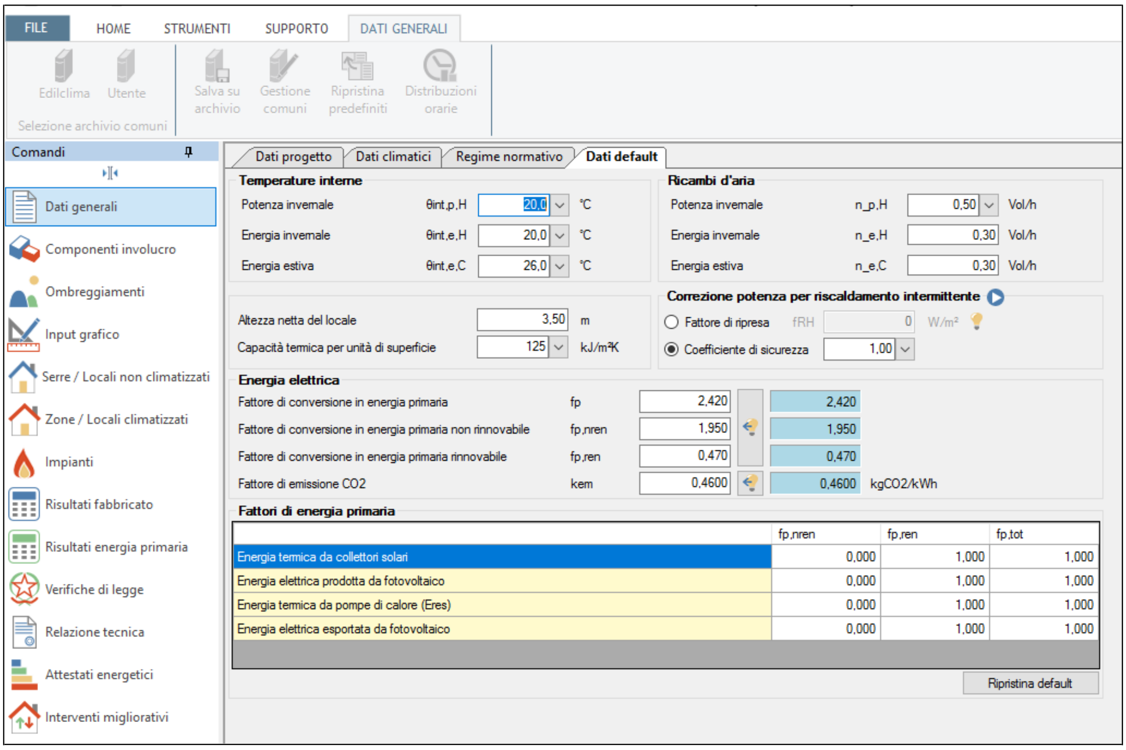
The software allows the insertion of the location in which where the building, and it automatically defines the climatic data of the area (temperature, radiation, wind, dry and wet bulb temperature, climatic zone…)and planimetric information like altitude, longitude and latitude, according to the "UNI 10349-2016 Dati climatici", as shown in the figure 6.46.

Then the Regulatory regime have been chosen, in order to confirm: the verifications of law in according to the DGR n. 46-11968, the technical report and the certificate of energy qualification for buildings whose request for title of the building is later than 01.10.2015 according to the Interministerial Decree of 26.06.2015. For thermal bridges has been chosen an analytical calculation in according to UNI EN ISO 14683, and the liminal resistance has been concerned to Appendix A of the UNI EN ISO 6946. The building has a no air conditioned zone and the analytical calculation was selected in reference to the legislation UNI EN 12831 and UNI/TS 11300-1. Instead for internal heat capacity was selected the simplified calculation only for existing building with no building structure informations.



6.47 – Reference legislation

In the last paragraph *Default data* has been defined the information of areas of building, such as the internal temperature in respect of law the UNI EN 12831, the air changes according to UNI 10339, the heat capacity for area, the correction of the power for intermittent heating, the conversion factor in primary energy, renewable and nonrenewable and emission factor of CO2 related to electricity, the factors in non-renewable primary energy conversion, renewable and total relating to the energy produced by solar thermal or photovoltaic.

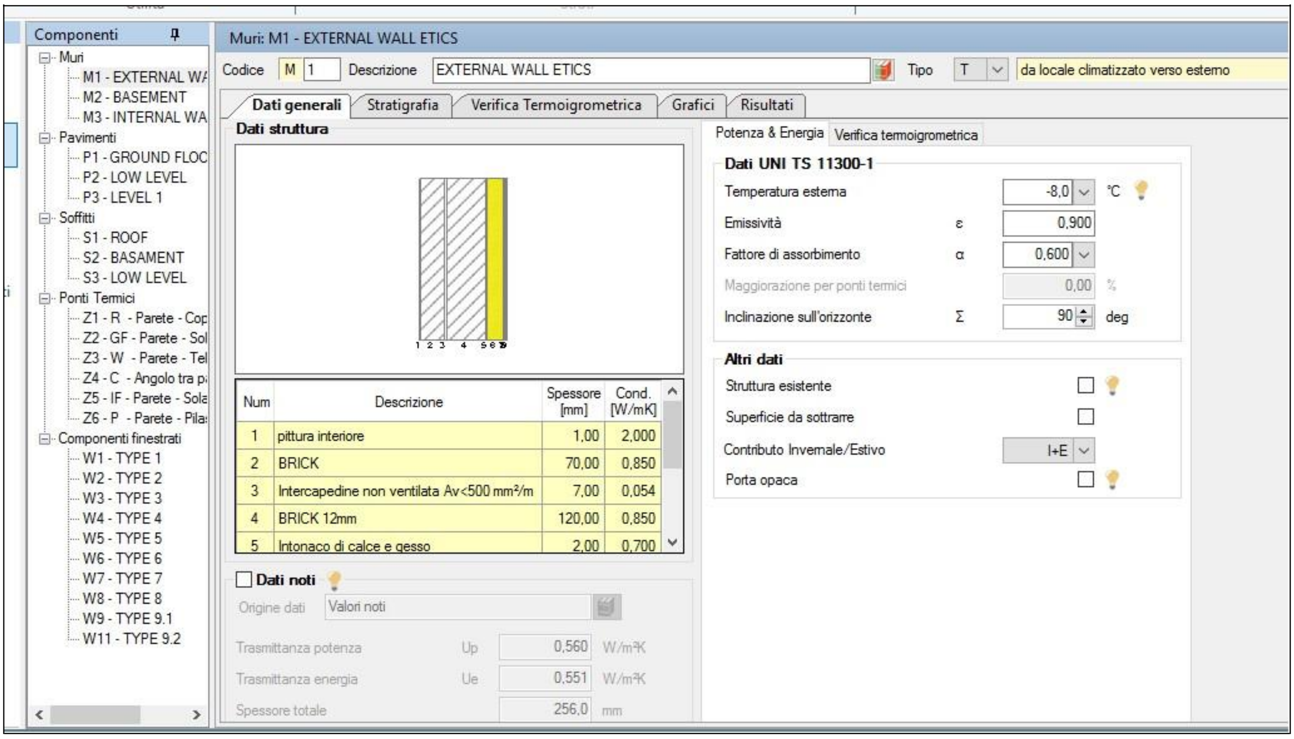


6.48 – Default data

Then the buildings component will be defined:

- external and internal walls;
- ceilings;
- floors;
- thermal bridges;
- windows.

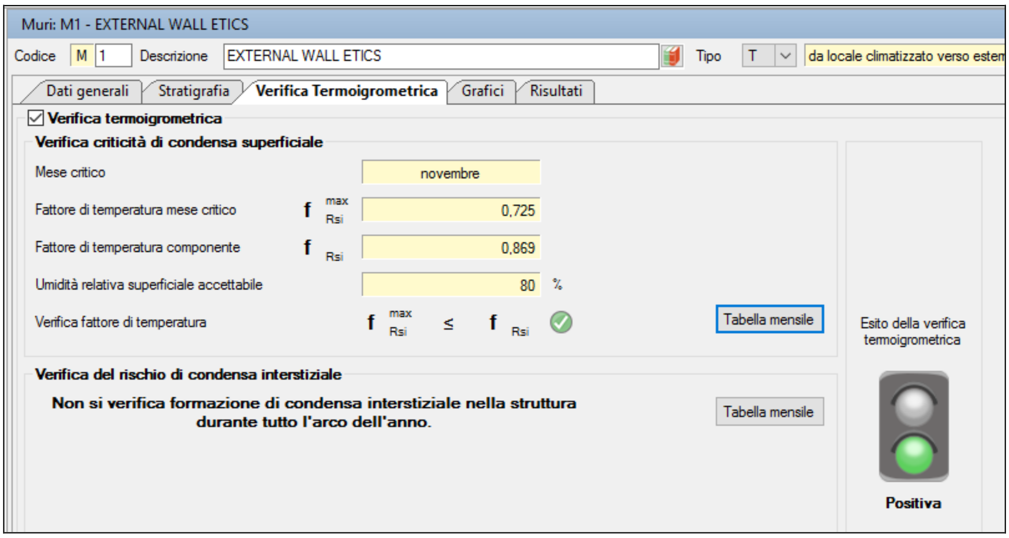
- EXTERNAL WALLS WITH ETICS SYSTEM



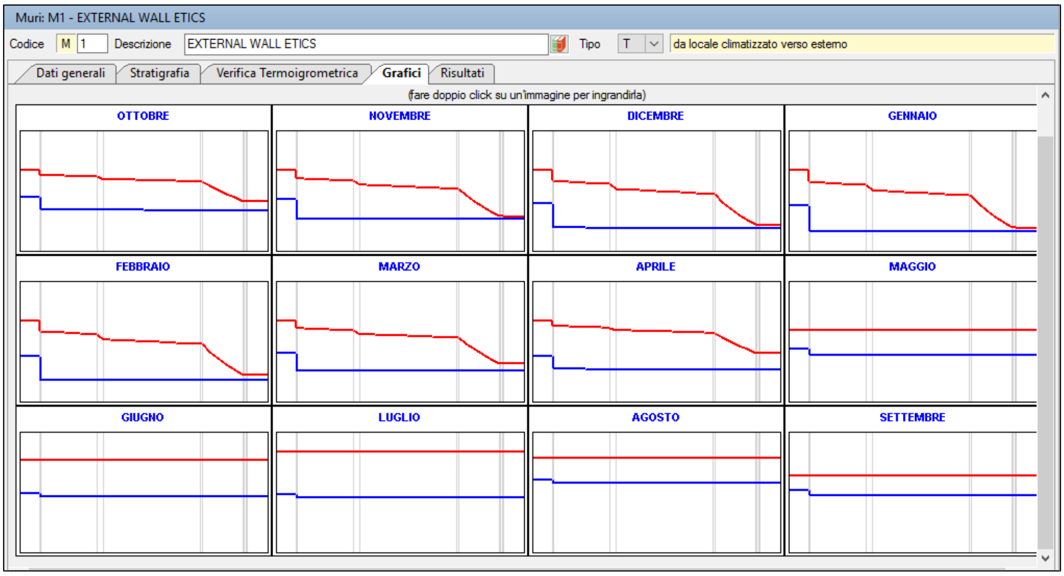
6.49 – Definition of wall stratigraphy

First of all the wall stratigraphy has been defined, the program permits to choose a different type of wall: in contact with the ground or with the air-conditioned/ no-conditioned zone, external, internal, etc...

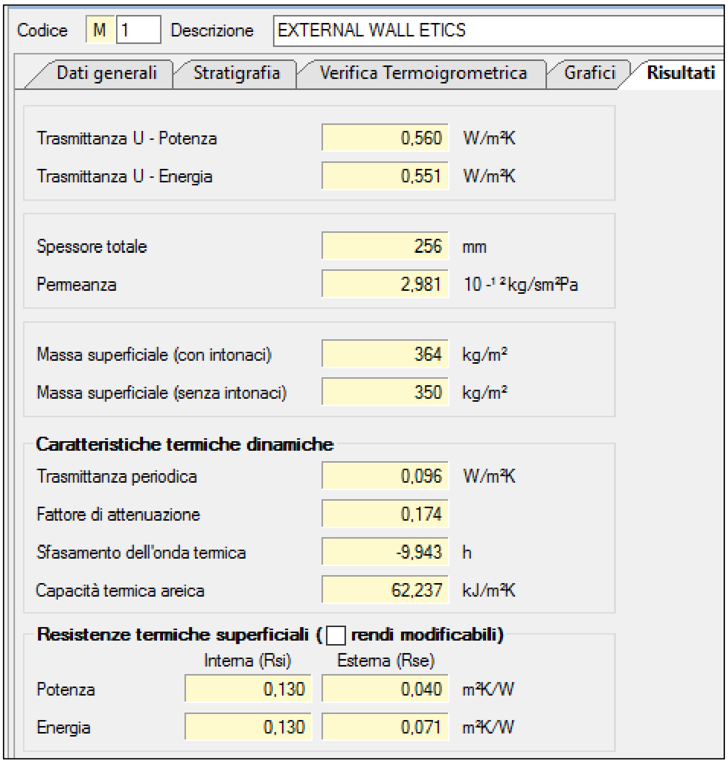
EC700 allows the hygrothermal verification and the vapor pressure in the stratigraphy of the wall, that the corners of the graph never cross, and so this means the absence of condensation as shown in the pictures below:



6.50 – Hygrothermal verification of wall



6.51 – Vapor pressure in the wall



Codice M 1 Descrizione EXTERNAL WALL ETICS

Dati generali | Stratigrafia | Verifica Termoigrometrica | Grafici | Risultati

Trasmittanza U - Potenza	0,560	W/m²K
Trasmittanza U - Energia	0,551	W/m²K
Spessore totale	256	mm
Permeanza	2,981	10^{-12} kg/sm²Pa
Massa superficiale (con intonaci)	364	kg/m²
Massa superficiale (senza intonaci)	350	kg/m²
Caratteristiche termiche dinamiche		
Trasmittanza periodica	0,096	W/m²K
Fattore di attenuazione	0,174	
Sfasamento dell'onda termica	-9,943	h
Capacità termica areica	62,237	kJ/m²K

Resistenze termiche superficiali (rendi modificabili)

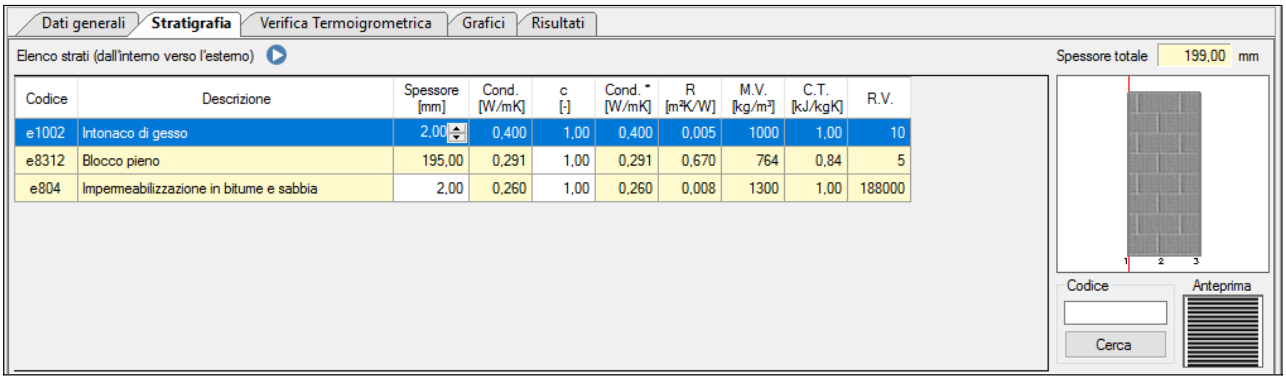
	Interna (Rsi)	Esterna (Rse)	
Potenza	0,130	0,040	m²K/W
Energia	0,130	0,071	m²K/W

6.52 –Thermal transmittance of the external wall

Finally the thermal transmittance is carried out in according to the UNI EN ISO 6946.

Moreover it was estimate the total thickness, the permeability, the surface mass, periodic transmittance, the factor of attenuation, the thermal gap, thermal capacity and the surface thermal resistance both internal and external.

For the basement wall, the same passage will be repeated: the stratigraphy will be defined, the hygrothermal and vapor verify will be done, and finally, the transmittance will be calculated.



Dati generali | Stratigrafia | Verifica Termoigrometrica | Grafici | Risultati

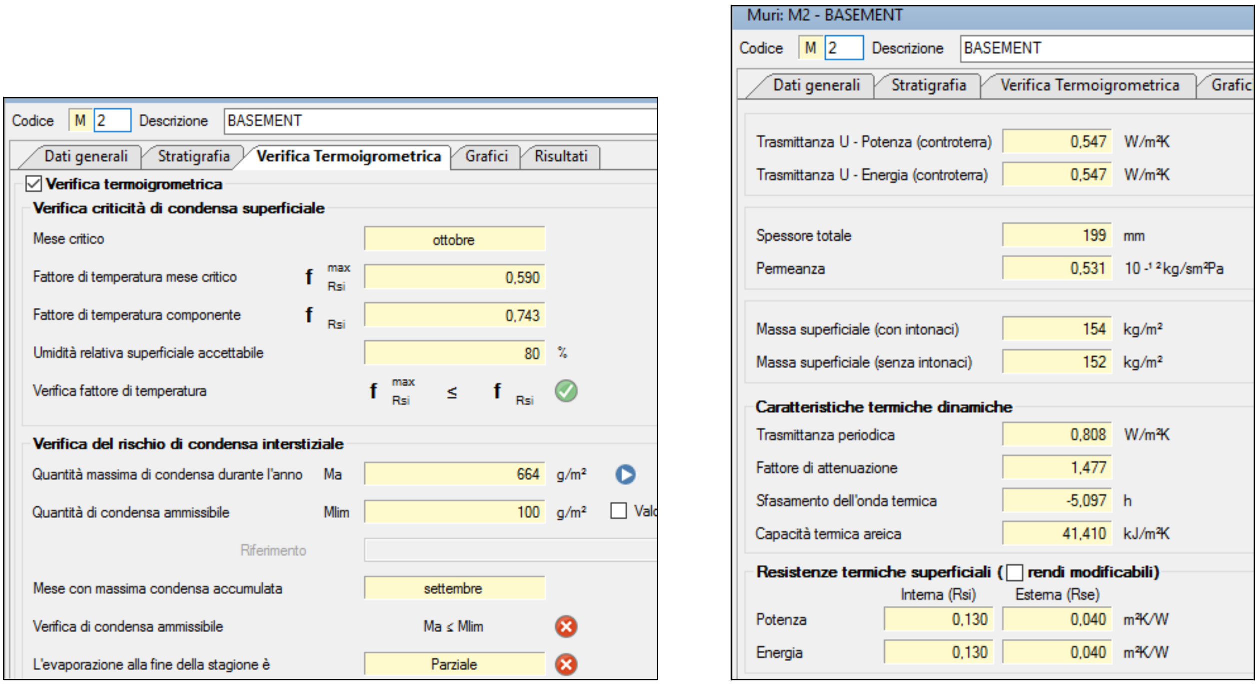
Elenco strati (dall'interno verso l'esterno)

Spessore totale 199,00 mm

Codice	Descrizione	Spessore [mm]	Cond. [W/mK]	c [-]	Cond. * [W/mK]	R [m²K/W]	M.V. [kg/m³]	C.T. [kJ/kgK]	R.V.
e1002	Intonaco di gesso	2,00	0,400	1,00	0,400	0,005	1000	1,00	10
e8312	Blocco pieno	195,00	0,291	1,00	0,291	0,670	764	0,84	5
e804	Impermeabilizzazione in bitume e sabbia	2,00	0,260	1,00	0,260	0,008	1300	1,00	188000

Codice Anteprima Cerca

6.53 – Basament wall stratigraphy



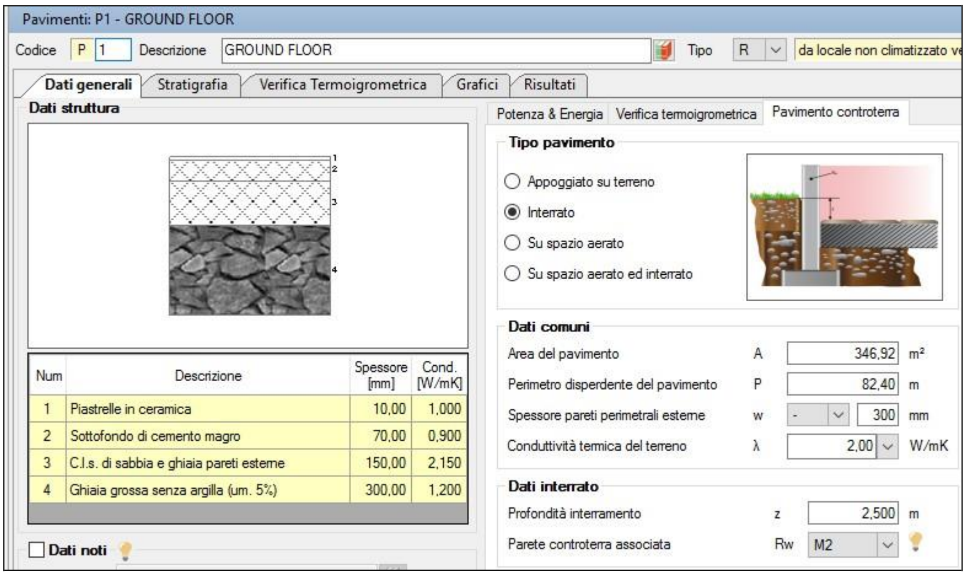
6.54 – *Hygrothermal verification (left) and Transmittance value (right)*

It can see that the basement wall pass the superficial condensation verify, but not the interstitial. The software permits to see in with months there will be this phenomenon.

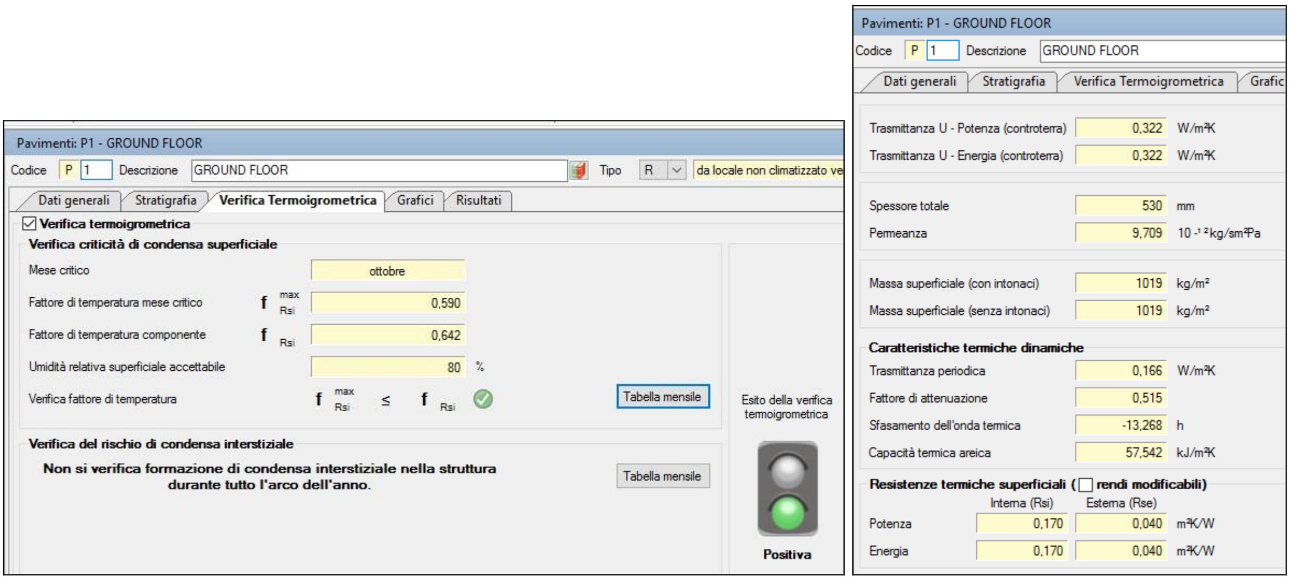
When the structure has a wall in contact to the ground, the software needs to know what the ground floor associated with it.

- FLOOR

First of all the ground floor will be shown, it is the floor associated to the basement wall:



6.55 – *Ground floor stratigraphy.*



6.56 – Hygrothermal verification (left) and Transmittance value (right)

The steps are equals for the other floors and for ceilings.

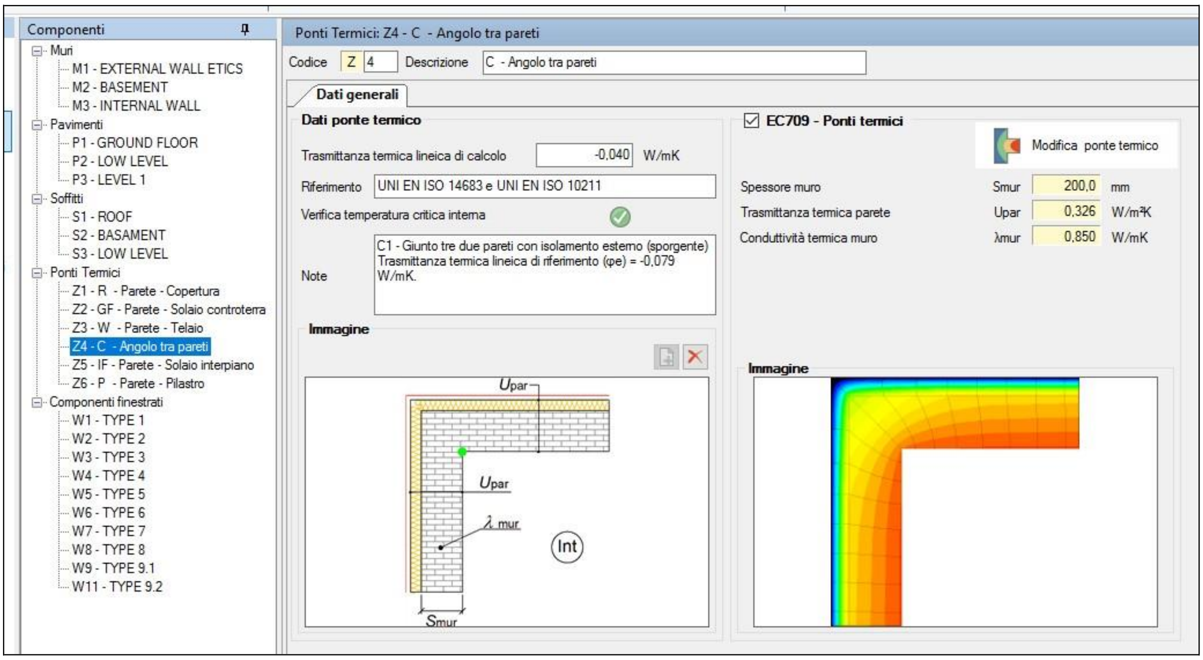
Now the thermal bridge will be defined.

- THERMAL BRIDGE

There are introduced the following thermal bridges:

- Thermal bridge between pillar and external wall;
- Thermal bridge of an angle pillar;
- Thermal bridge of corner between walls;
- Thermal bridge between façade and slab;
- Thermal bridge between façade and frame;
- Thermal bridge between façade and ground floor;
- Thermal bridge between façade and roof.

The first three have been greatly reduced by the ETICS system, in fact, its calculated rate is almost 0, as shown in the figure **below. They are calculated by reference to the standard “EC709 –** Ponti **termici”, for the purpose of evaluating the thermal transmittance value reported by the UNI EN ISO** 10211.



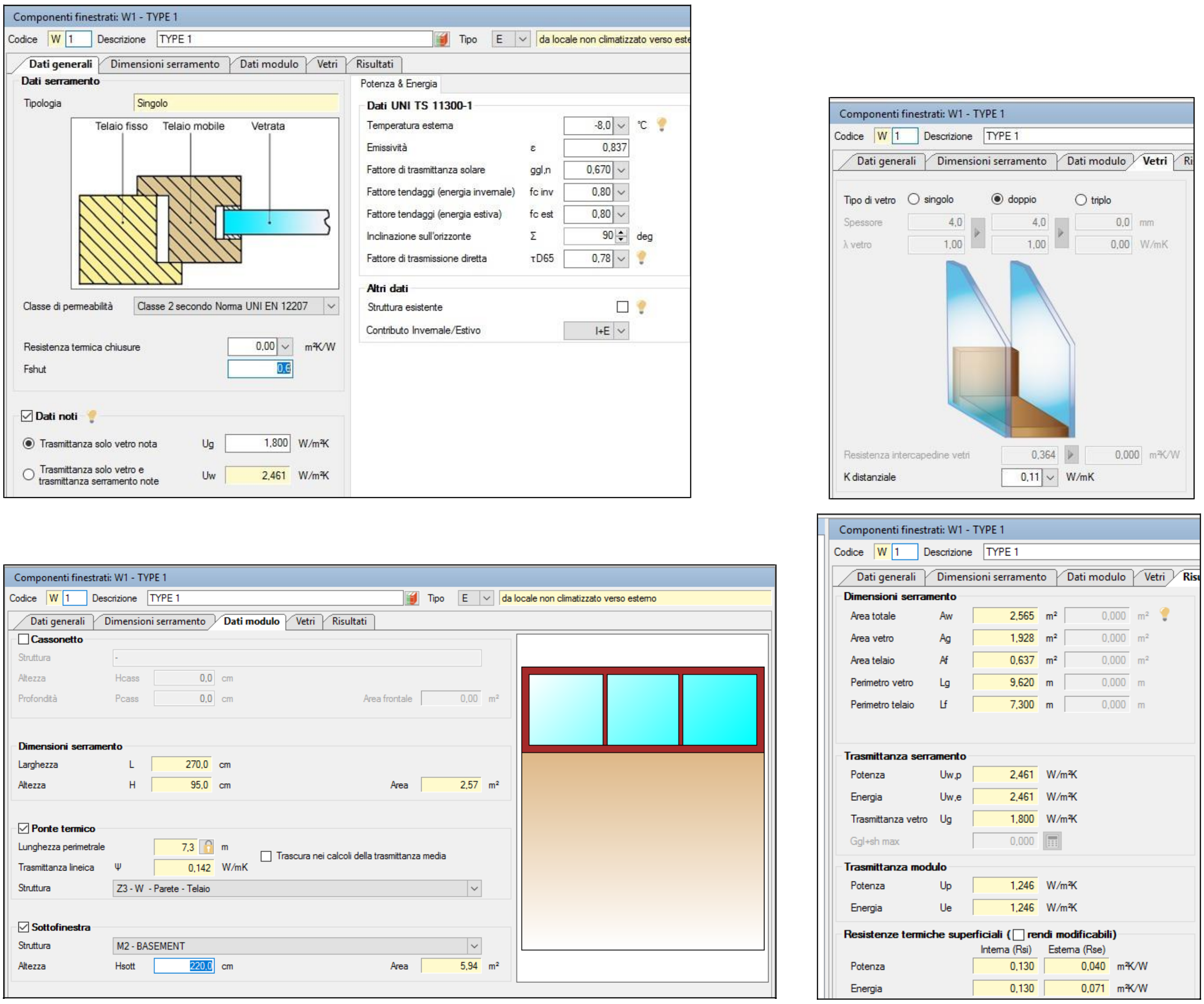
6.57 – Thermal bridge of corner between walls

If we want to introduce a thermal bridge between pillar and external wall or thermal bridge of an angle pillar, the software has the option to insert the pillar with '*Input grafico*'. This option automatically associates a value of thermal bridge.

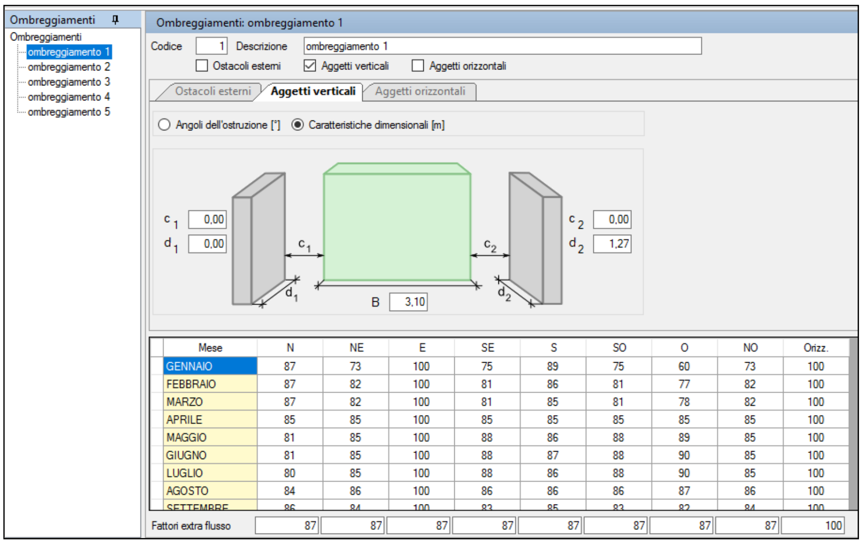
- WINDOWS

First of all the type of frame and its permeability class are defined, in compliance with UNI EN 12207. Then the thermal resistance of the closures according to the values provided in Appendix G of the UNI EN ISO 10077-1, and finally the value of f_{shut}, in reference to the UNI/TS 11300-1.

After that, the value of the glass transmittance will be introduced and the window transmittance value will be obtained in according to the UNI EN ISO 10077



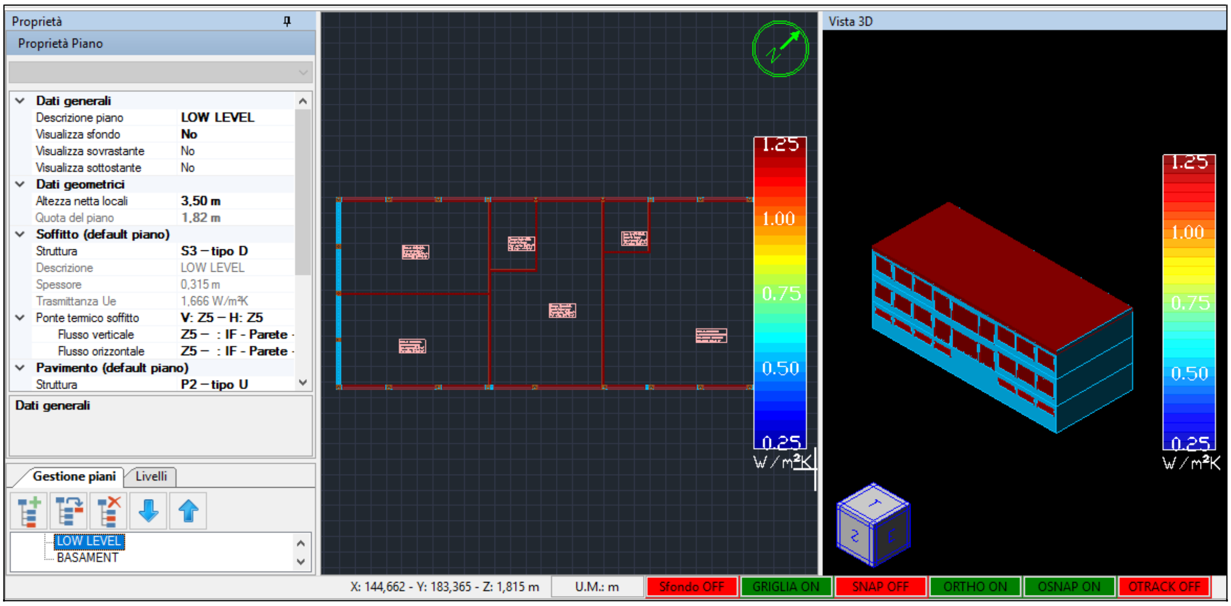
6.58 – Definition of window features



When the buildings component are all defined, theirs shadows will be introduced. The building has vertical bosses that will be inserted in the program. The dimension of bosses and the distance between them will be put. The building has 5 types of shading.

6.59 – Definition of shading

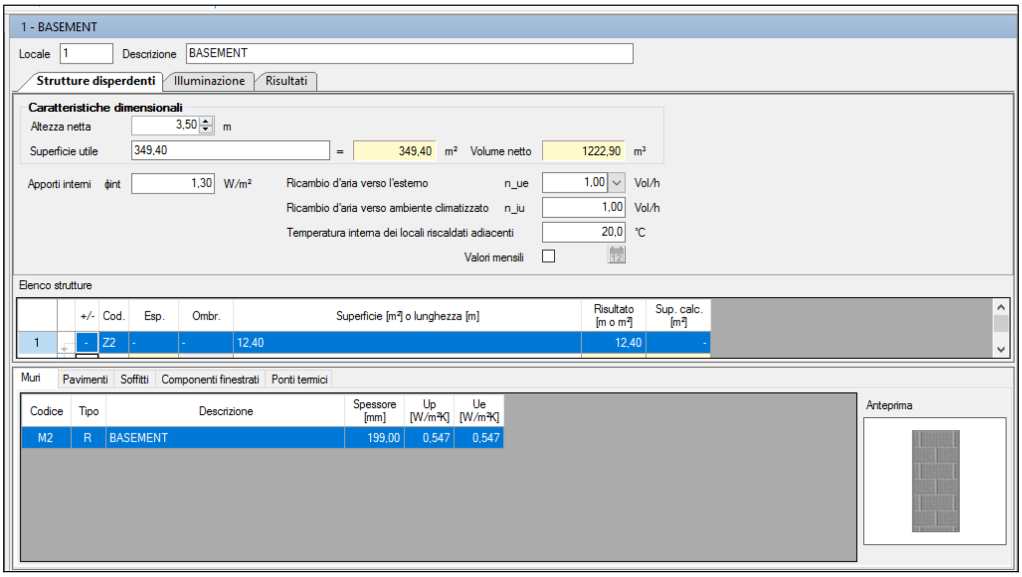
Thanks to the graphic input, the structure can be designed and, according to right orientation, it was possible to determine the dispersive surfaces of both individual area and the entire building. The thermal visualization, choose from the software, shows the progress of the elements (opaque and glaze) thermal transmittance. This representation makes it possible to identify the more dispersants elements (red) and to take appropriate action on them of energy saving measures.



6.60 – Thermal visualization of the building

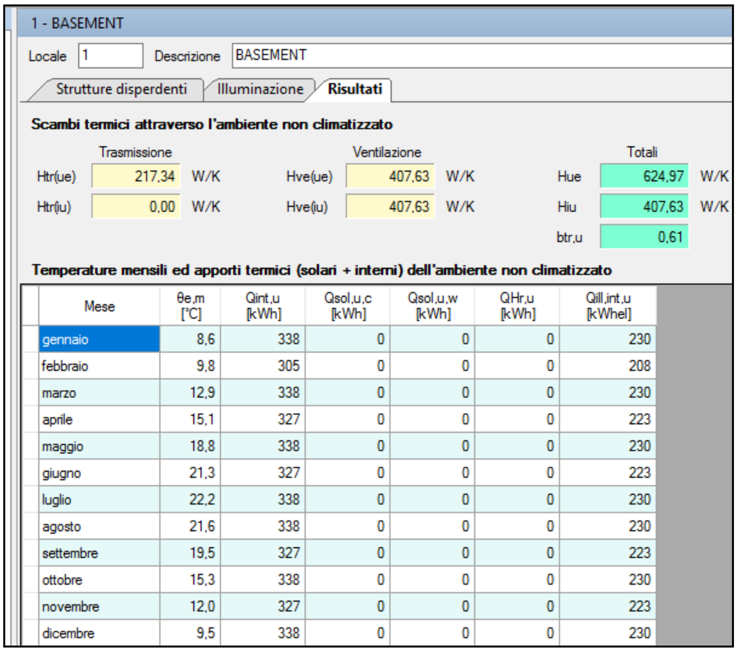
The building is made of two different thermal zone: unconditioned basement, and conditioned classrooms and administrative areas. For each room have been reported the category of use in reference to DPR 412, the internal temperatures, any internal contributions determined in accordance with the technical specification UNI/TS 11300-1 of the space and the data relating to ventilation and lighting. For each spaces have been inserted the dispersing elements specifying the exposure, shading and the surface.

The basement as an unconditioned room:



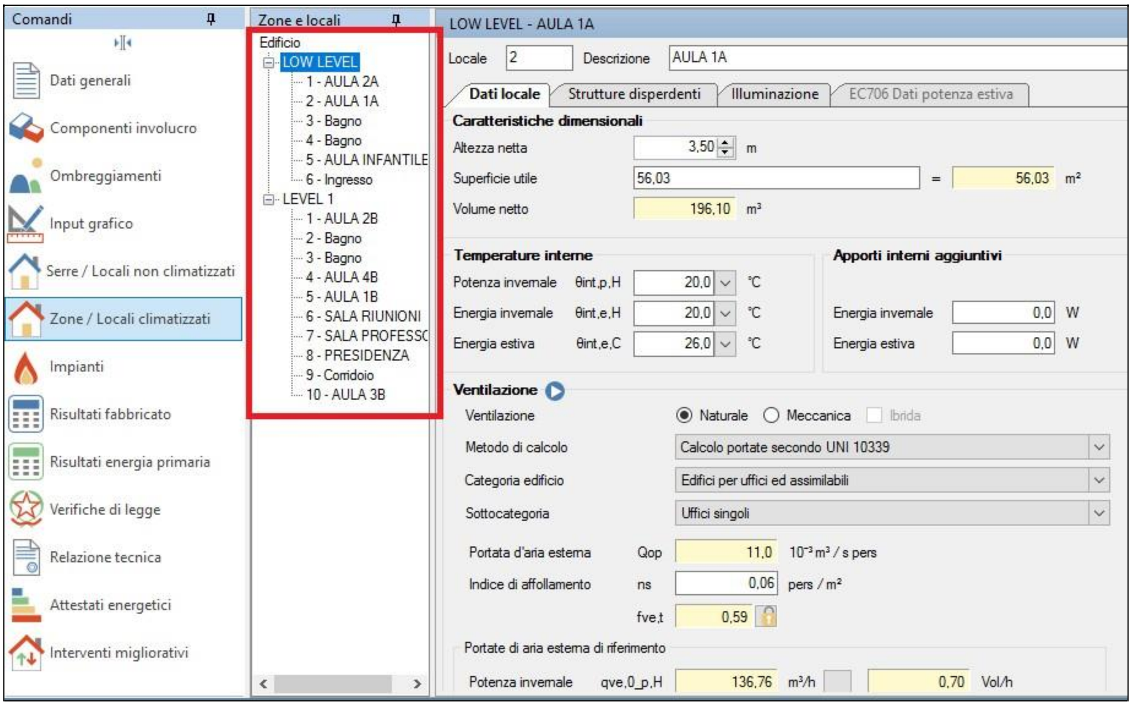
6.61 – Basement as an unconditioned room and its results (down).

The result are the thermal exchanges that occur for transmission and ventilation between the unheated room and the exterior air. The coefficient $b_{tr,u}$ are automatically defined.



Mese	θe,m [°C]	Qint,u [kWh]	Qsol,u,c [kWh]	Qsol,u,w [kWh]	QHr,u [kWh]	Qill,int,u [kWhel]
gennaio	8,6	338	0	0	0	230
febbraio	9,8	305	0	0	0	208
marzo	12,9	338	0	0	0	230
aprile	15,1	327	0	0	0	223
maggio	18,8	338	0	0	0	230
giugno	21,3	327	0	0	0	223
luglio	22,2	338	0	0	0	230
agosto	21,6	338	0	0	0	230
settembre	19,5	327	0	0	0	223
ottobre	15,3	338	0	0	0	230
novembre	12,0	327	0	0	0	223
dicembre	9,5	338	0	0	0	230

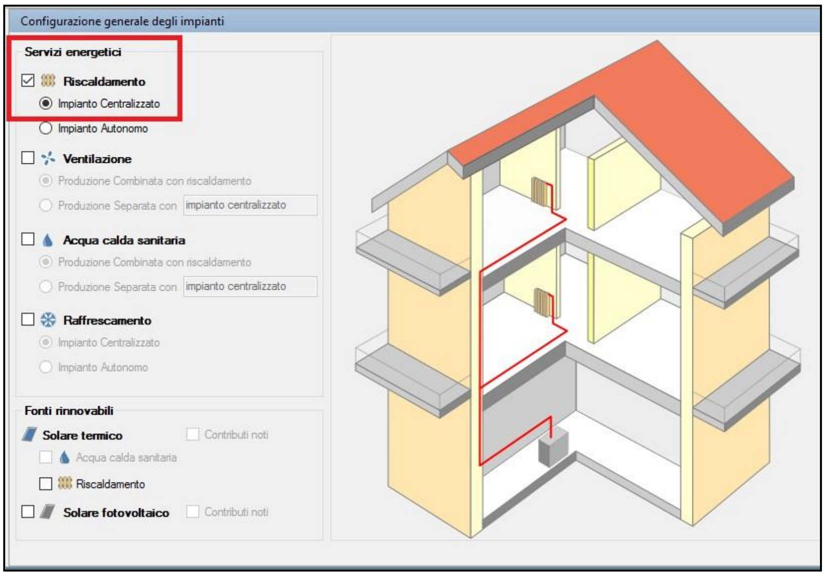
The conditioned rooms are distributed in the low and first floor, as shown in the figure below. Each floor has been assigned the respective conditioned rooms of which the lighting and the dispersing structures must be defined.



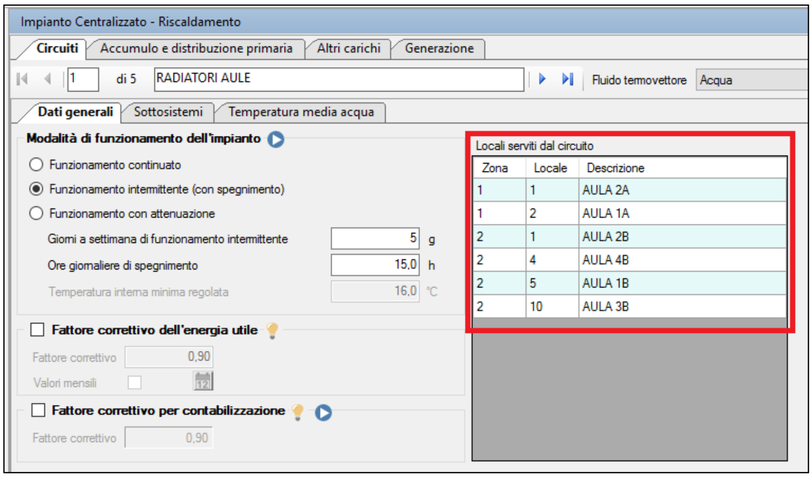
6.62 – Air-conditioned rooms and their data.

The next important step is defined the installation, in order to calculate the profit in the building, although the installation about heating, ventilation, hot water, cooling and use of renewable sources (solar thermal or photovoltaic).

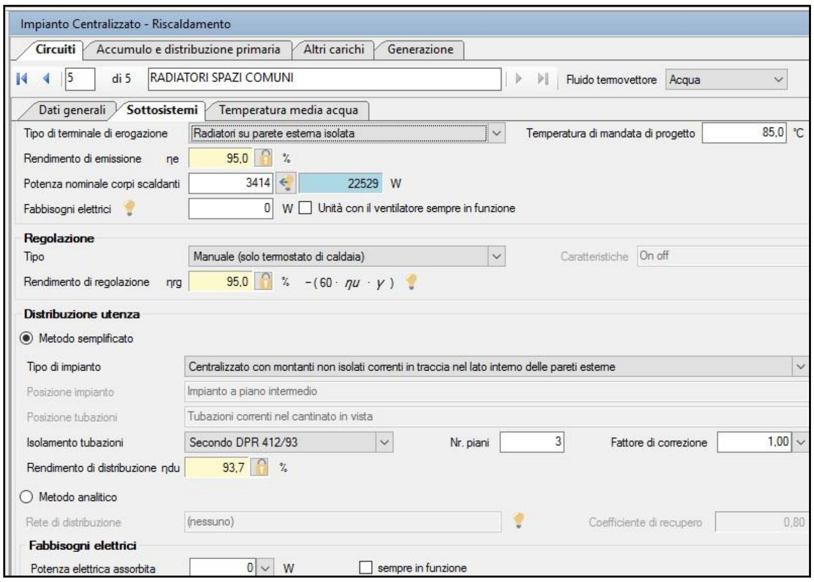
The building, as already know, only has central heating installation.



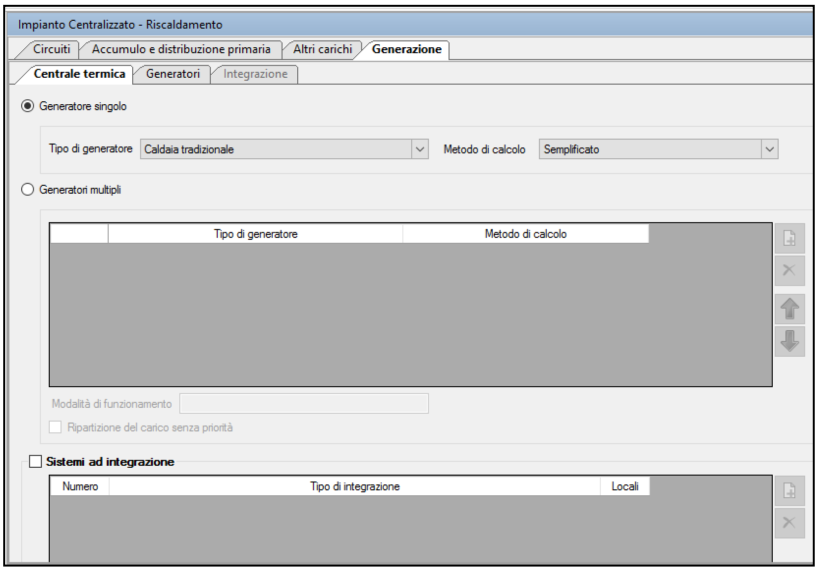
6.63 – Central heating system



6.64 – *General data of heating system*



6.65 – *Subsystems of heating system*



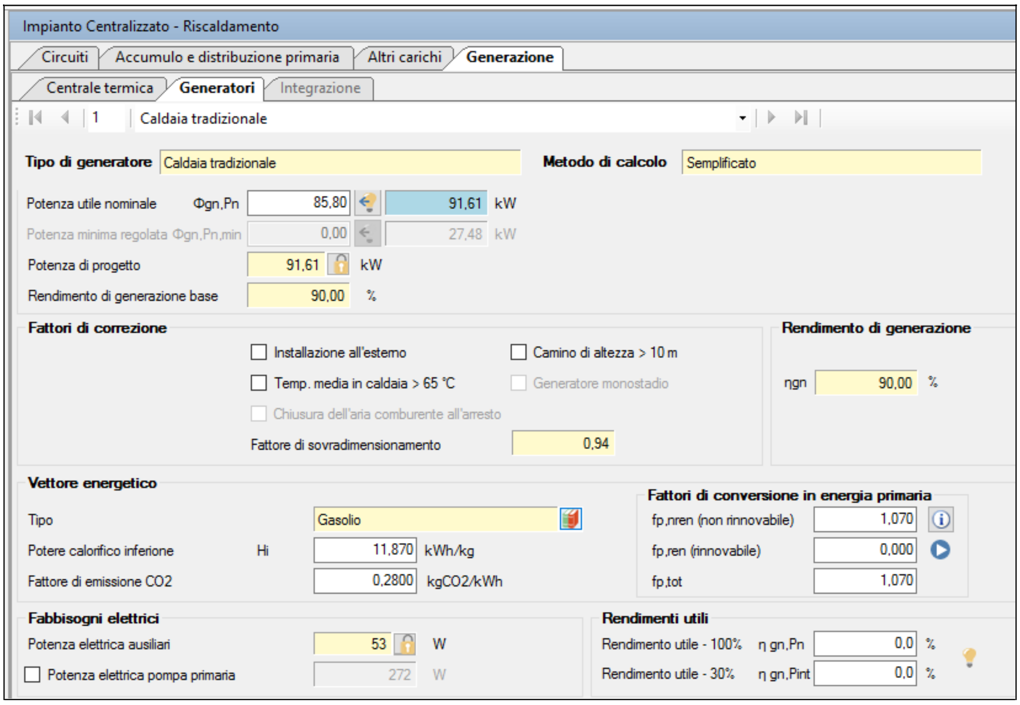
6.66 – *Generation of heating system*

First of all I have defined the circuits and their features as operation days and shutdown time, subsystems to calculate the performance and the loss of each subsystem.

It starts from the calculation of the emission subsystem, determining the average height of the space, the type of control terminal (radiant panels and radiators), the emission efficiency ηe (%), the nominal power of terminal (w), electrical requirements, all following the UNI / TS 11300-2.

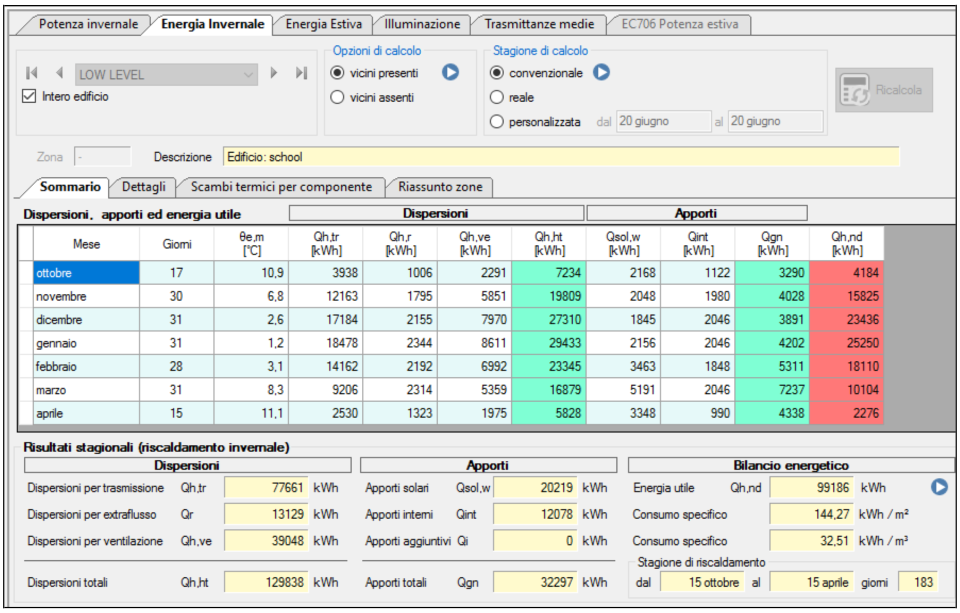
Due to lack of information and knowing that the heating installation is old, it is assumed a manual shutdown with no insulated piping.

Finally, I defined the generation. The installation includes a traditional boiler powered by gasoline. The nominal power data, generation efficiency, and boiler power supply has been entered and the conversion factors into primary energy have been automatically input from the program.



6.67 – Generation subsystem

When all the building information and features are inserted, the software can calculate the '*results*'. In the "Winter Energy" there are the results relating to the external building structures that delimiting a defined volume of space and internal structures that share the above volume, excluding installations and the technological system. They have calculated the winter power with dispersions for room or component or orientation. The calculation of the dispersion is based considering the internal temperature, net volume, dispersed power for transmission, ventilation, to intermittently and dispersed by space.



Dispersioni, apporti ed energia utile

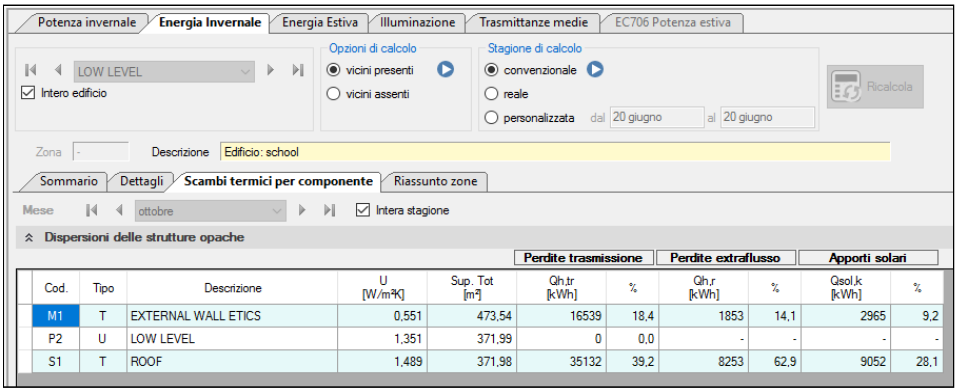
Mese	Giorni	θe,m [°C]	Qh,tr [kWh]	Qh,r [kWh]	Qh,ve [kWh]	Qh,ht [kWh]	Qsol,w [kWh]	Qint [kWh]	Qgn [kWh]	Qh,nd [kWh]
ottobre	17	10,9	3938	1006	2291	7234	2168	1122	3290	4184
novembre	30	6,8	12163	1795	5851	19809	2048	1980	4028	15825
dicembre	31	2,6	17184	2155	7970	27310	1845	2046	3891	23436
gennaio	31	1,2	18478	2344	8611	29433	2156	2046	4202	25250
febbraio	28	3,1	14162	2192	6992	23345	3463	1848	5311	18110
marzo	31	8,3	9206	2314	5359	16879	5191	2046	7237	10104
aprile	15	11,1	2530	1323	1975	5828	3348	990	4338	2276

Risultati stagionali (riscaldamento invernale)

Dispersioni			Apporti			Bilancio energetico		
Dispersioni per trasmissione	Qh,tr	77661 kWh	Apporti solari	Qsol,w	20219 kWh	Energia utile	Qh,nd	99186 kWh
Dispersioni per extraflusso	Qr	13129 kWh	Apporti interni	Qint	12078 kWh	Consumo specifico		144,27 kWh / m²
Dispersioni per ventilazione	Qh,ve	39048 kWh	Apporti aggiuntivi	Qi	0 kWh	Consumo specifico		32,51 kWh / m³
Dispersioni totali	Qh,ht	129838 kWh	Apporti totali	Qgn	32297 kWh	Stagione di riscaldamento: dal 15 ottobre al 15 aprile	giorni	183

6.68 – Winter energy calculation

Finally EC700 allows a more detailed view of the thermal exchanges of the various components.

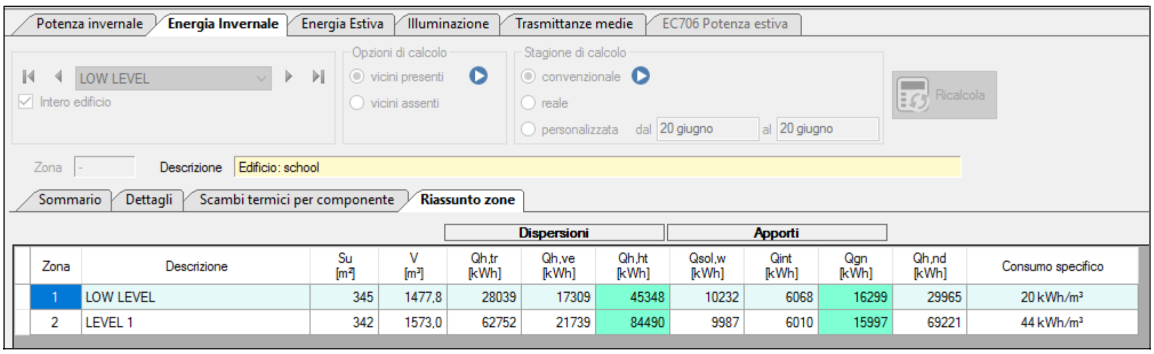


Dispersioni delle strutture opache

Cod.	Tipo	Descrizione	U [W/m²K]	Sup. Tot [m²]	Perdite trasmissione Qh,tr [kWh]	%	Perdite extraflusso Qh,r [kWh]	%	Apporti solari Qsol,k [kWh]	%
M1	T	EXTERNAL WALL ETICS	0,551	473,54	16539	18,4	1853	14,1	2965	9,2
P2	U	LOW LEVEL	1,351	371,99	0	0,0	-	-	-	-
S1	T	ROOF	1,489	371,98	35132	39,2	8253	62,9	9052	28,1

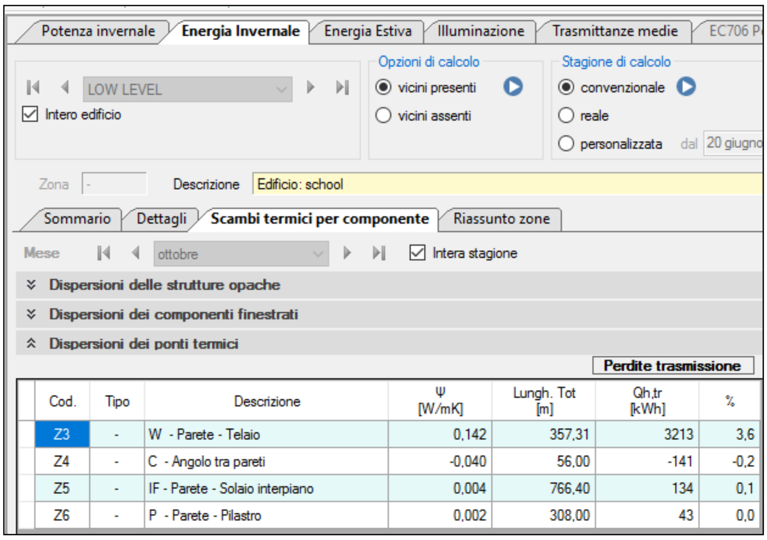
6.69 – Thermal exchange of opaque element

Here are showed the thermal exchange of the opaque elements in which the roof ha more losses, for this reason the Level 1 has 44 kWh/m³ of energy consumption.



Zona	Descrizione	Su [m²]	V [m³]	Qh,tr [kWh]	Qh,ve [kWh]	Qh,ht [kWh]	Qsol,w [kWh]	Qint [kWh]	Qgn [kWh]	Qh,nd [kWh]	Consumo specifico
1	LOW LEVEL	345	1477,8	28039	17309	45348	10232	6068	16299	29965	20 kWh/m³
2	LEVEL 1	342	1573,0	62752	21739	84490	9987	6010	15997	69221	44 kWh/m³

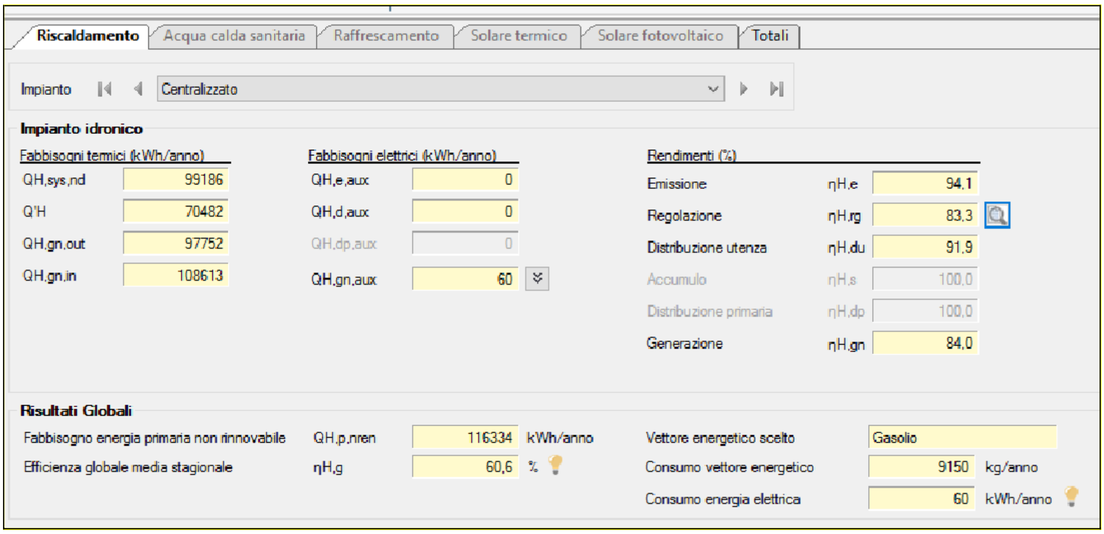
6.70 – Thermal exchange of opaque element, zone summary



6.71 – *Thermal exchange of thermal bridge*

Let focus on what happen to the thermal bridge. As already mentioned, The ETICS systems reduces them, so their values in nearly zero, except for the thermal bridge between wall and frame.

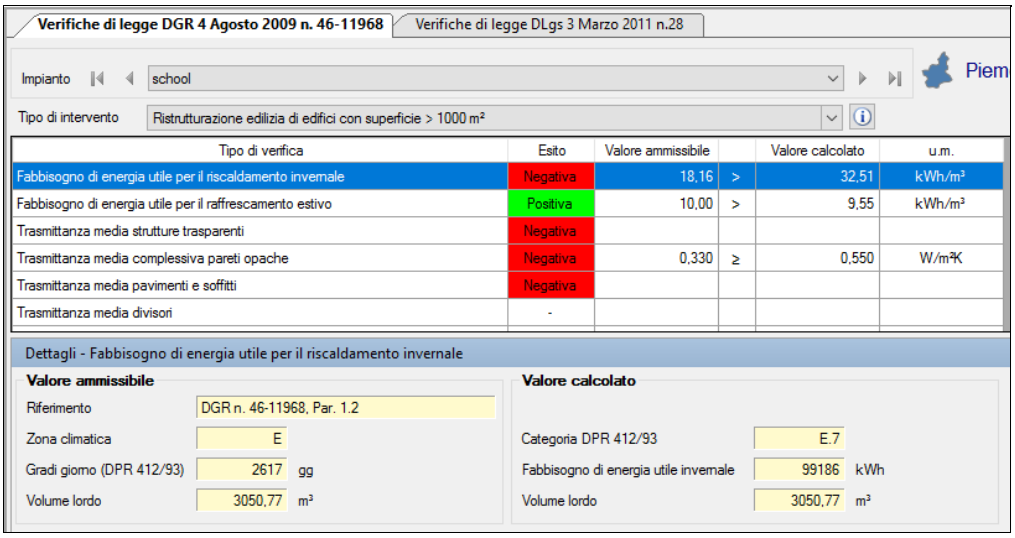
Instead in the primary energy calculation, they are calculated performances and primary energy demand for the building according to the Technical Specification UNI / TS 113002 and UNI / TS 11300-4



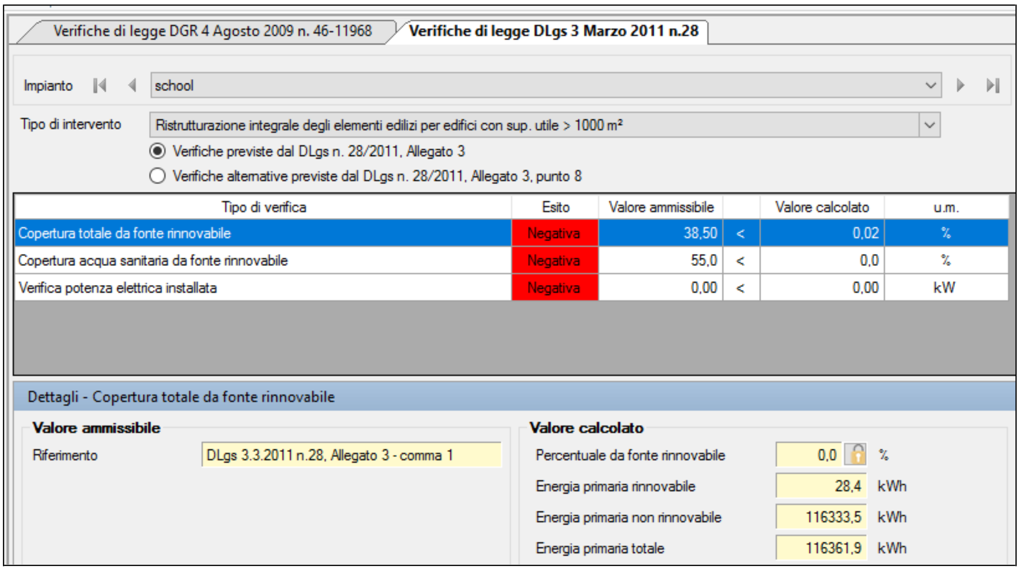
6.72 – *Primary energy calculation*

After completing the information about the useful and primary energy of the building, it moved to compare the performance of the building with the minimum requirements established by national legislation, through the verification of the law. The regional law checks are all negative, except for the energy needs for summer cooling. The reason is simple, the building has been built to meet the needs of the Getxo climatic requirement, whose is less rigid than in Turin.

The verification of DLgs 3 Marzo 2011 n.28 is totally negative for the absence of removable source.



6.73 – Low verification(DGR 4 Agosto 2009)



6.74 – Low verification (DLgs 3 Marzo 2011)

Finally the software generated the certificate of qualification energy of the building in accordance with Annex 5 of the national leader for energy certification of buildings (Ministerial Decree of 26.6.2009). In the certificate is calculated the thermal performance index useful for heating and cooling of the building, that in the this case appears as bad quality.

In conclusion, the software defines the energy class of the building, depending on the index of not renewable global energy performance, based on an alphabetical indicator where the letter G represents the class characterized by the index of the highest performance, and the letter A represents the class with the best performance index (lower power consumption), until A4 that representing the highest energy performance.

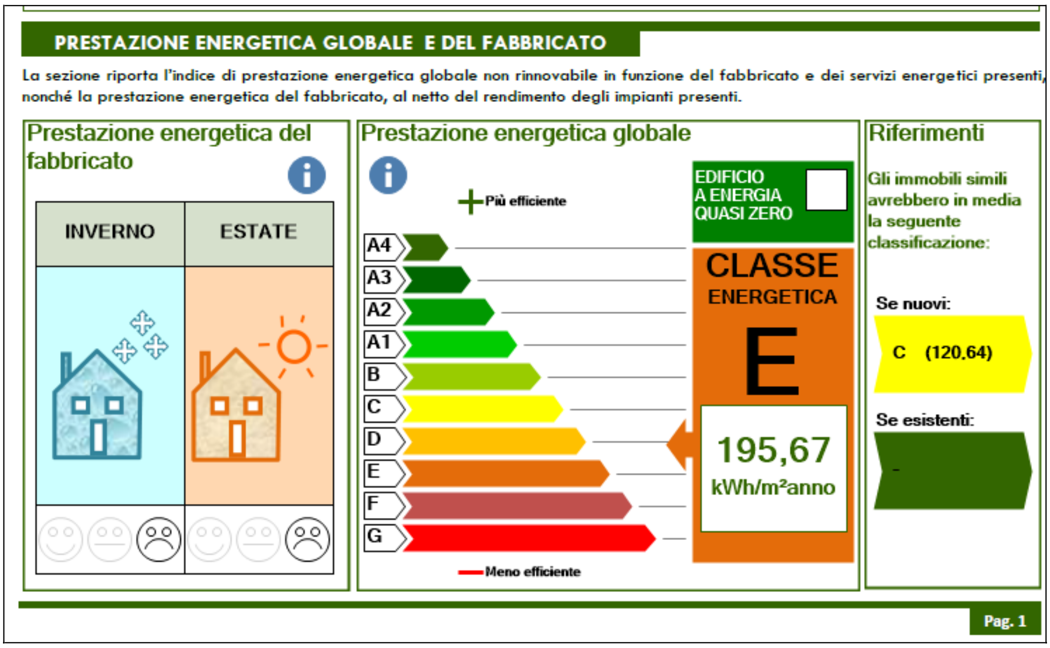
The software gives the possibility to separate the different levels that made up the building and see the classification level of each one.

Riepilogo

Nr. zona	Descrizione	Cat. DPR 412	Sup. netta [m²]	Vol. lordo [m³]	EPgl,nren	U.M.	Classe energetica
1	LOW LEVEL	E.7	345,39	1477,77	128,70	kWh/m²anno	D
2	LEVEL 1	E.7	342,10	1573,00	263,28	kWh/m²anno	E

6.75 – Energy classification of building's levels

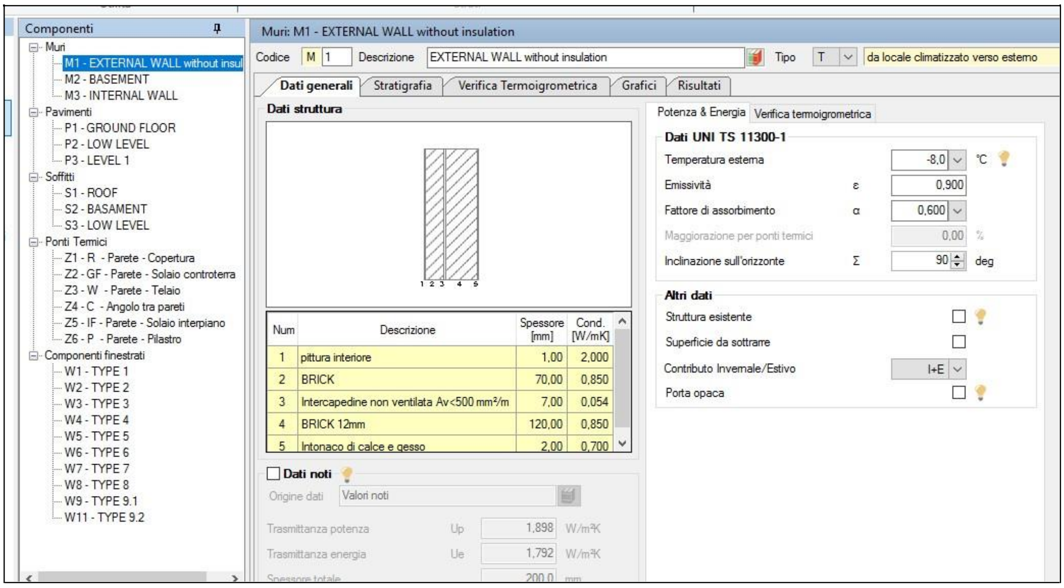
EC700 has associated a letter E to Azkorri building. It corresponds to an annual energy consumption of 195,67 kWh/m²anno.



6.76 – Energy performance certificate of Edilclima Software

This certification is done with ETICS wall with the result of E energetic class. Below there is a certification with no ETICS system.

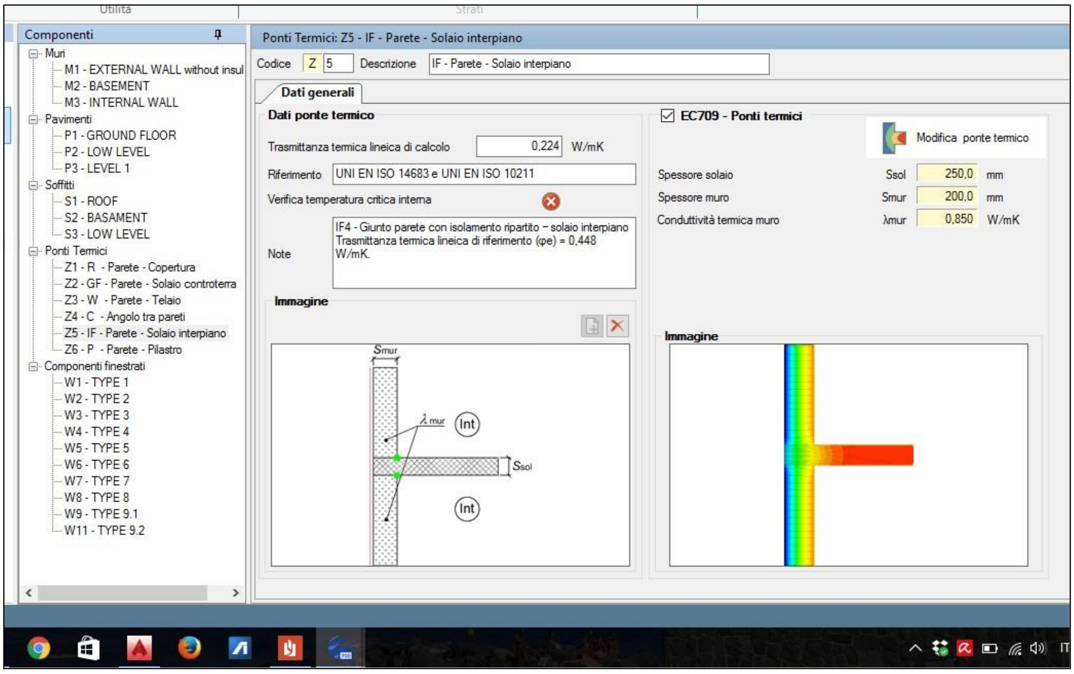
- EXTERNAL WALLS WITH NO ETICS SYSTEM



6.77 – Definition of wall stratigraphy without etics system

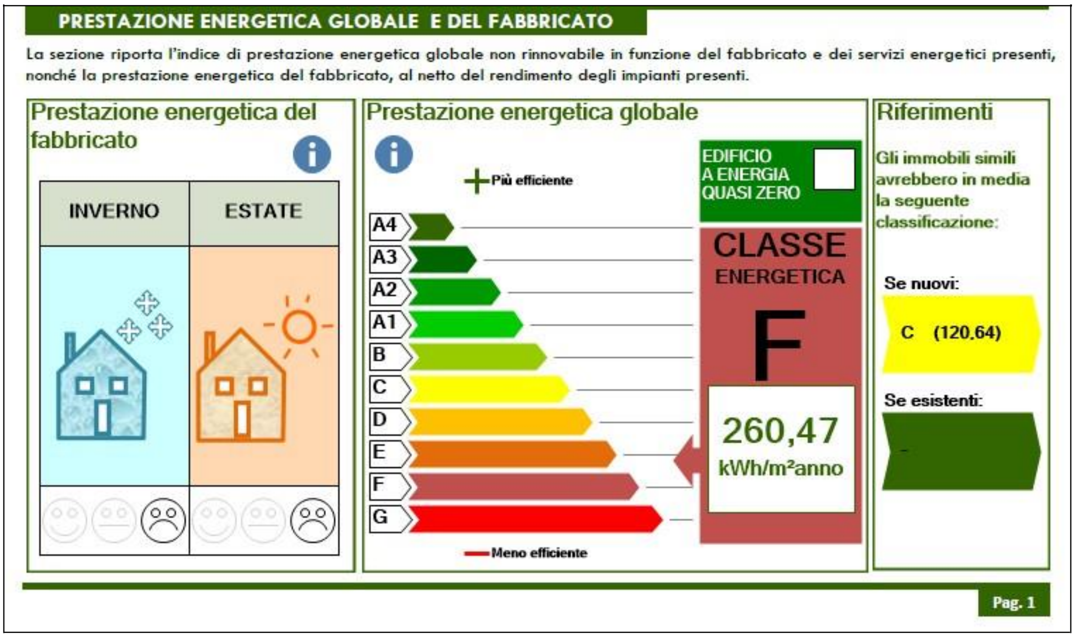
- THERMAL BRIDGES

With no ETICS system, the thermal bridges worsen and they allow to pass more energetic exchanges.



6.78 – Thermal bridge without etics system

Finally, the program defines the energy class of the building, as it has done before:



6.79 – Energy performance certificate of Edilclima Software

7 Conclusions

The aim of this thesis work is focused on the buildings energy efficiency after and before their refurbishment, in fact, the building case of study, has been subjected to an energy refurbishment of the façade.

It is also interesting to be able to carry out the energy classification of the study building using two different software:

CE3X, software used in Spain, useful for energy classification of existing buildings, and Edilclima, Italian software that can be used indiscriminately for new buildings, energy upgrades, renovations etc ... With the use of this software, it was able to compare the results obtained after and before the façade refurbishment, that consists in an ETICS system with a finer wood insulation of 8 cm. The reduction in energy consumption is about 25% while CO2 emission reductions are 30%.

It is interesting to see the difference between the two software as well as on the climatic differences between Spain and Italy and their regulatory regimes.

Comparing the two software, you immediately realize how different they are and how much one is more detailed than the other. Both software is based on current regulations and has a default data (climatic zone, outdoor temperature, relative humidity, etc.) that will be used to make calculations. The two programs also allow the insertion of the envelope's opaque and transparent elements. In this case, Edilclima allows to detail the windows much better than CE3X. It gives the possibility to insert internal or external blinds, Venetian blinds or other shading elements.

The other difference between these two can be found when Edilclima is able to consider air-conditioned and non-conditioned rooms. These will be useful for calculating energy losses between these spaces.

Both software allow the insertion of thermal bridges, but CE3X inserts them by default while Edilclima presents a number of different typologies that differ in shape and position of the insulation.

Another important distinction can be seen in the installation data, the Italian software requires more detailed data than the Spanish.

The climatic difference between the two cities and their reglementary regimen is the essence of why we have so high different qualification of the same building. Here are two tables taken from Chapter 6:

City	Getxo
Province	Bizkaia
Region	Basque Country
Country	Spain
Latitude	43°21'24.8"N
Longitude	3°0'41.26"W.
Altitude	10 m
Average Temperature minimum	-1,4
Average Temperature maximum	29,9
Relative humidity	70%
Climate zone	C1

City	Turin
Province	Turin
Region	Piedmont
Country	Italy
Latitude	45°04' N
Longitude	7°42' E.
Altitude	240 m
Average Temperature minimum	-8
Average Temperature maximum	31
Relative humidity	73%
Climate zone	E

Figure 7.1 – Comparison between the two cities

The substantial difference between your cities is undoubtedly the outdoor temperature. Turin has a minimum calculation temperature of -8 °C while in Bilbao it is -1.4 °C. As far as the maximum calculation temperature, Torino has 31 °C while Bilbao 29.9 C. The European legislaion will be use to calculate the transmittance of opaque and glazed elements and the thermal bridges, but, to calculate the Energy performance, the regionals laws will be used.

REGIONE PIEMONTE

b) Isolamento termico

Tab. 5. Trasmittanze termiche massime (U) dei singoli componenti (W/m^2 K)

	1° Livello	2° Livello
Trasmittanza termica delle strutture verticali opache	0,33	0,25
Trasmittanza termica delle strutture opache orizzontali o inclinate	0,30	0,23
Trasmittanza termica delle chiusure trasparenti (valore medio vetro/telaio) (§)	2,0	1,7
Trasmittanza termica delle chiusure trasparenti fronte strada dei locali ad uso non reidenziale (valore medio vetro/telaio) (§)	2,8	2,0

Figure 7.2 – Regional legislation of Turin. Thermal transmittance

From UNI 10349 and prEN 12831 the Italian climatic data will be obtained and it assigns the thermal zone and the respective monthly temperatures that will be used in the building performance calculation.

The regional limits will establish the permissible transmittance value for the various enclosure components. The first level is compulsory for all, and the second one will be tax incentives if it is reached.

Spanish legislation is based on CTE (Código Técnico de la Edificación) and the energetic part is in DBHE (Documento Básico de Ahorro de Energía), which gives the climatic zone C1 and the following legislative limits:

D.2.9 ZONA CLIMÁTICA C1

Transmitancia límite de muros de fachada y cerramientos en contacto con el terreno	**U_{Mlim}: 0,73 W/m^{2}K**
Transmitancia límite de suelos	**U_{Slim}: 0,50 W/m^{2}K**
Transmitancia límite de cubiertas	**U_{Clim}: 0,41 W/m^{2}K**
Factor solar modificado límite de lucernarios	**F_{Llim}: 0,37**

	Transmitancia límite de huecos U_{Hlim} W/m^{2}K				Factor solar modificado límite de huecos F_{Hlim}					
					Baja carga interna			Alta carga interna		
% de huecos	N/NE/NO	E/O	S	SE/SO	E/O	S	SE/SO	E/O	S	SE/SO
de 0 a 10	4,4	4,4	4,4	4,4	-	-	-	-	-	-
de 11 a 20	3,4	3,9	4,4	4,4	-	-	-	-	-	-
de 21 a 30	2,9	3,3	4,3	4,3	-	-	-	-	-	-
de 31 a 40	2,6	3,0	3,9	3,9	-	-	-	0,56	-	0,60
de 41 a 50	2,4	2,8	3,6	3,6	-	-	-	0,47	-	0,52
de 51 a 60	2,2	2,7	3,5	3,5	-	-	-	0,42	-	0,46

Figure 7.3 – Limits of thermal transmittance. CTE, DBHE

Concluding, energy certification depends on many factors. First of all by the geographic location and its climatic conditions and regulatory limits, secondly on the software that will be used and its degree of detail.

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