POLITECNICO DI TORINO

Master of Science in Civil Engineering

Thesis:
Building Renovation and Energy Analysis

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Table of Contents

Abstract

This is a cultural and creative project of multidisciplinary nature for the refurbishment of residential spaces with the idea of developing a model based on a collaboration and social innovation process. The aim is to promote the urban regeneration in territories with environmental fragility. This radical change added to the sanitary emergency Covid-19 contributes to a reflection about this topic, which is expected from the citizens hoping to create comfort and integration in the society. The main objects of this project of quality that enhance integration are:

- To create equipped spaces to transform the quality of residential spaces;
- To encourage the involvement of the community in the process of urban regeneration oriented to the improvement of the local economy;
- To experience and diffuse inclusive methodologies for the community.

This is a project that is being carried out in Turin, Italy, in cooperation with an architecture firm; so, the Italian standards will be adopted to structure the work through a continuous verification of the possible processes.

As a result, it is expected to obtain a model of the complete process of refurbishment. This model can be adapted to different categories of building with the intention of improving their energy performance.

Introduction

This work is a short description of the laborious project management that engineers do for complex projects as is the renovation of a building. A capacitated group of professionals have to work together to meet these objectives and have a high-quality result. In this particular project my objective was to merge the civil-engineer and energy aspects and analyse these two features in parallel. Of course, this is a great challenge given that I have not much experience working on a real project and interpreting the process from an energetic point of view. Before this work, I have not had the opportunity of developing an engineering project related to energy analysis, and even if such is not my main area of study, it is a topic of personal interest. This was a great motivation for choosing this issue, it is the opportunity to develop my skills in this other subject and to combine my knowledge on infrastructures with a more environmental concern.

The project looks to improve the energy level of old buildings by renovating the external structure and specific features of the building without doing an invasive intervention on the building. In Italy most of the buildings are of a great age, meaning that on their construction, the energy consumption was not a factor to consider. Different from that time, now a days, the environmental issue is of important mater, this is why the Italian government, as many other countries, has decided to make action about it. The government has implemented a bonus incentive to promote the renovation of buildings having this energetic objective. Due to this, many engineering and architecture firms are extensively working on this project.

Given that this project is a government direction it will follow the Italian regulations. Part of this report will be delivered to explain the policies and regulations for the design and renovation of energy efficient buildings. Having defined the framework for addressing this topic, the benefit of special methodologies and possible implementations will be understood. Knowing the regulations reigning over energy efficient buildings, interventions will be caried out optimizing at its best the process development, thus, having a quality result.

At continuation a brief description of the thesis structure is presented:

Chapter 1: Section reserved for the scientific investigation referring to the knowledge on the main topics. Research done over the principal objectives of the project.

Chapter 2: Normative and methodologies that are going to be used to govern the decisions of this work. In the construction filed is of main importance to follow the criteria of each region, in this case Italy. So, it's necessary to define which norms are going to be used for this project.

Chapter 3: The first stage of the project is the Pre-Feasibility study where the building is analysed in detail and the interventions to improve its energy level are defined. This is a theorical phase which provides all information needed for continuing with the practical phase.

Chapter 4: Second stage is the work on site, the project is now on its practice phase where the interventions previously analysed are being done to the building. A description of this process is detailed.

Chapter 5: Conclusions of the project having the real results. At the end of the complete process the economic, social and engineering aspects can be analysed as a whole.

Appendix A: Definition of some technical terms that are going to be used in the present report. Space assigned for the better understanding of some concepts and of the complete project.

Appendix B: After the Pre-Feasibility study, a simplified report of the energy analysis is provided to the occupants of the building. An example of this report is presented in this section.

As it will be deduced along the thesis, this project does not only aim an energy requalification, but it also has a great impact on different aspects of the community. By achieving the building energy improvement, the life quality of occupants of this building is also improved. Occupants will have better lifestyle possibilities; a greater awareness on the environmental matters; and, most important, they will realize how the individual action can have a huge impact.

CHAPTER

1

State of Art

Section reserved for the scientific investigation referring to the knowledge on the main topics. Research done over the principal objectives of the project.

In this section a deep investigation on leading topics was done. Working on the renovation of a building, the main client is the building occupant so a very important object of study is the occupant's comfort which should always be considered as a priority in the decided interventions. The second aspect to consider when choosing the building interventions is the improvement of the energy level, then an energy efficient design has to be analysed in order to achieve this important goal. Considering that the building is made of a passive fabric (envelope) and a technical part (ventilation and heating/cooling systems) the energy design is constructed by the following concepts: creating a bioclimatic architecture, ensuring a high-quality envelope, planning a good ventilation system, operating the heating and cooling systems in an efficient way, and inserting alternative energy sources. The energy design is an upgrowing tendency that has different benefits over the community, an environmental one by reducing the pollutants, a global one by creating awareness, and an economical by reducing the expenses costs for occupants.

In continuation, these topics will be expanded and a more detailed analysis will be provided to complement the work of the thesis.

Occupant's Comfort

When planning the construction of a residential building, not only the structural design is important, but also the social aspects. This must be an integration of many features. A very important characteristic to consider when designing the building is the occupants comfort given that they are the main clients are the ones that will be taking full profits of the property.

The principal conditions evaluated are the thermal comfort or indoor climate (temperature, moisture, air velocity), indoor air quality (odours, indoor air pollution, fresh air supply), acoustic (outside and indoor noise and vibrations) and visual comfort (view, illuminance, luminance ratios, reflection).[1]

[1] https://www.buildup.eu/en/news/release-ides-edu-course-instruction-guide-ides-edu-project-and-teaching-material-msc-programme

The IEQ (Indoor Environmental Quality) is important for the health, the indoor well-being and the productivity. Factors the influence the indoor environmental quality are the outdoor conditions: air pollutions, outdoor temperature, ambient noise, sun and daylight, green environment; building conditions: building materials, furniture, building services; or people and their activities: use of ventilation equipment's, use of glue or paint, cleaning and maintenance.[2]

The thermal comfort is a condition of the mind where satisfaction with the environment is expressed, having neither sensations of heat nor sensations of cold. The satisfaction of the uniform body temperature implies an equilibrium between individual parameters, environmental parameters and physiological parameters. This is a necessary condition but not sufficient to guarantee comfort. The heat exchanged between the body and the environment is described by the sensible heat and latent heat. The sensible heat refers to the thermal energy exchanged due to a variation in temperature (convection and radiation) while the latent heat is the thermal energy exchanged due to a phase change (sweat and precipitation).

Once the thermal comfort conditions have been established it´s necessary to identify the comfort and discomfort indexes which are introduce to deduce the possible deviations. PMV (Predicted Mean Vote) is an index corresponding to the thermal sensation of an amount of people, considering the relative humidity φ and air speed v_a but it may underestimate discomfort. This index ensures that the occupant does not complain of the environment but is not a sufficient condition to guarantee thermal comfort. Within thermal discomfort the considerations correspond to complains about high, low or varying temperature; radiation; hot or cold floors; …

The human body maintains in thermal equilibrium with the environment through thermoregulation processes. The individual has some adaptive functions that allow it to adapt to climatic conditions through behavioural, physiological and psychological action. The behavioural adjustment are all

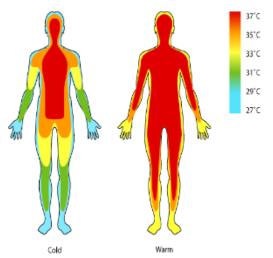

Figure 1. Thermal reading of body temperature

[2]https://cadmusgroup.com/news/cadmus-acquires-california-based-constructive-technologies-group/

actions made by a person to modify the body's thermal balance. Physiological adaptation is the acclimatisation after a prolongated exposure to the environment which improves the thermal tolerability. Last, the psychological adaptation refers to the different perceptions of climate due to past experience or expectations. [3]

The air quality in an indoor environment is considered acceptable when contaminants are not present at harmful concentrations. A pollutant or contaminant is any substance not normally present in the atmospheric air. In residential and commercial buildings, it's not enough for air to be healthy, olfactory quality is also required to achieve comfort. Sources of malodour are the occupants and their activity; building materials; furnishing; and cleaning chemicals. A strategy to improve the indoor air quality is to have a good ventilation system, however, in winter this produces a large heat loss because air is removed. Dimensioning the ventilation based on olfactory precipitation leads to an oversizing because this needs a very high airflow rate. Another efficient solution is to reduce the source of pollution using furniture and building materials with low pollutants emissions.

An inadequate thermal climate can have health effects over the occupants in a short term, and poor indoor air quality has health consequences in short to medium term. Some examples of these are, eye irritation, dry throat, running nose, headache, flu or colds, asthma attacks, infections, poisoning, between other.

Energy Efficiency Design

Energy efficient buildings are those buildings with a significant reduction of the heating and cooling energy need. A building can be upgraded as to meet the high-performance standards by doing different interventions to the construction that will help reduce the energy loss. "Energy performance" is defined as the energy consumption of per square meter of the building and it depends on the type of building and on climatic conditions.

[3]https://ec.europa.eu/easme/en/section/energy/intelligent-energy-europe

Energy and environmental impact of buildings are real and global challenges. Recent developments, mainly in Europe, show realistic solutions which take an important integrated design effort. For this, assessments of the building must be done to understand the consume, and this can be taken from the environmental systems, mainly the gas and electricity generators.

The aims of thermal and energy performance assessment of a building are many. Starting from the assessment of the building thermal behaviour as passive system; determination of the annual energy consumption having fixed the hygrothermal conditions required for the indoor environment; the assessment of energy performance requirements with laws, regulations and technical standards; comparing the energy performance of different design alternatives for the building and the thermal system; and estimation of the effect of possible energy saving measures on an existing building.

Energy improvements must consider the aspects that were taken into account in the design. First, a bioclimatic architecture should be considered by analysing the orientation of the building, its shape and the solar and wind incidence, between others. The second step is to create a high-quality envelope, this is done by constructing isolated walls, using efficient windows and doors that prevent the undesired air-flow, avoiding thermal bridges, and other characteristics. Last, the ventilation has to be controlled and it requires a high-quality performance. With all these characteristics, the building is design at its minimum energy loss, after this is considered, there are some other techniques to reduce even more the losses as including the use of renewable sources and improving the heating and cooling equipment's. In every case, the main objective is to avoid energy waste and to have an efficient use of fossil energy. This type of constructions promotes the ecological consciousness, are more comfortable for the occupants and less expensive due to the reduction of energy consumption.

Bioclimatic Architecture

Bioclimatic architecture analyses the climatic and environmental conditions as to take profit of natural energy instead of fighting it. This will provide a thermal and visual comfort for the building occupant. In this design the shape of the building is to be as compact as possible to reduce the external surface, thus to have less contact with the exterior. This is to avoid over heating or over cooling of external walls in the case of extreme temperatures (winter or summer) and during long exposures to sun or wind. Like this, less rooms will be exposed to such a big temperature difference avoiding the loss of thermal comfort. The building orientation is another important aspect to consider, giving a special importance to the opening's colocation. In this orientation it´s contemplated that the sun rises from the east and it culminates in the right-south, then the rooms which need more sun incidence for heating and luminating the spaces, will be located according to this. For example, a bed-room may be oriented to the east as to have the strong sun of the morning, avoiding the use of calefaction, and during the afternoon, when the sun is not so powerful, the heating systems can be used until the night when they are not so necessary. Like these, there is in evidence a great reduction of energy consumption. Then, during summer, big windows can be located in this room to permit ventilation to decrease the undesired heat of sun. For the windows installation, the wind flow can be analysed as to generate a good air-flow in the room. Like this, the cooling system consumption will be reduced during summer.

The external walls and the openings to the exterior must be adapted to protect the building from the heat both in summer and winter given that the sun radiation is desired in some proportions. The building can be protected from this by collocating some obstacles to the sun that produce shade, refreshing the temperature, this is the case of trees or window-covers. Another technique is to use reflective surfaces and colours in the building external walls, creating a self-protective building envelope. A way of taking advantage of these undesired radiation is to have some solar collector systems that produce renewable energy for the building.

High Quality Envelope

Creating a high-performance building envelope is done by having a good thermal environment, this will depend on the thermal insulations, thermal inertia, solar control, air tightness, and responsivity, between other characteristics.

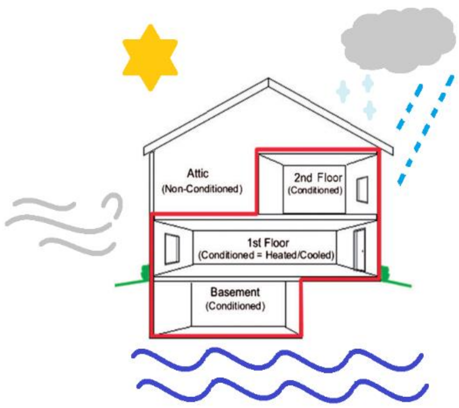

Figure 2. Diagram of building envelope

Thermal insulations are of low cost due to its widely availability, and by using this technique not only the energy consumption will be reduced, but also, because of the new technologies, they produce low installation emissions. Is important to have a good insulation both in hot and cold environments to maintain the comfort temperature inside the building. The thermal difference between the inside and the outside will generate an energy transfer from the hotter environment to the colder until reaching a thermal equilibrium, this is only when heating and cooling systems are not working. Then, rooms with external walls will suffer a faster loss of the desired temperature if there is a great temperature difference between the internal and external environment. By having a good insulation, this loss of thermal energy is reduced, so the desired comfort temperature can be maintained for a longer period of time without the need of cooling or heating systems, thus reducing the energy consumption. Insulations are classified by its thermal resistance which is denominated with the R value and the U value (U = 1/R) which is indirectly proportional to the first regulation. A good-quality insulation has a high R value meaning that the thermal resistance is high.

The thermal inertia is the "capacity of a material to store heat and to delay its transmission" – C. Ferrari. This term can be interpreted as the thermal mass in an analogy to the mechanical inertia, where the speed that the heat wave requires to pass through the material is analysed. This is an important parameter when defining the thermal comfort, and a good thermal inertia will reduce the heating and cooling loads. The diffusion of heat trough a material depends on the thermal resistance of it that will reduce the transferred heat, and on the thermal inertia which produces a delay of the instantaneous transferred heat and reduction of it the thermal wave amplitude. These two effects are treated in parallel to keep the desired internal conditions, and to reduce the energy consumption of heating or cooling systems. There is not one value representing the thermal inertia, but this can be characterized with different terms depending on the subject of study. For indoor thermal conditions, the inertia can be represented with the phase shift that measures the time needed for a wave to propagate through a material, and with the thermal damping (D_p) that is measures the amplitude variation between the external and internal thermal waves.

$$D_p = \frac{A_e - A_i}{A_e}.100$$

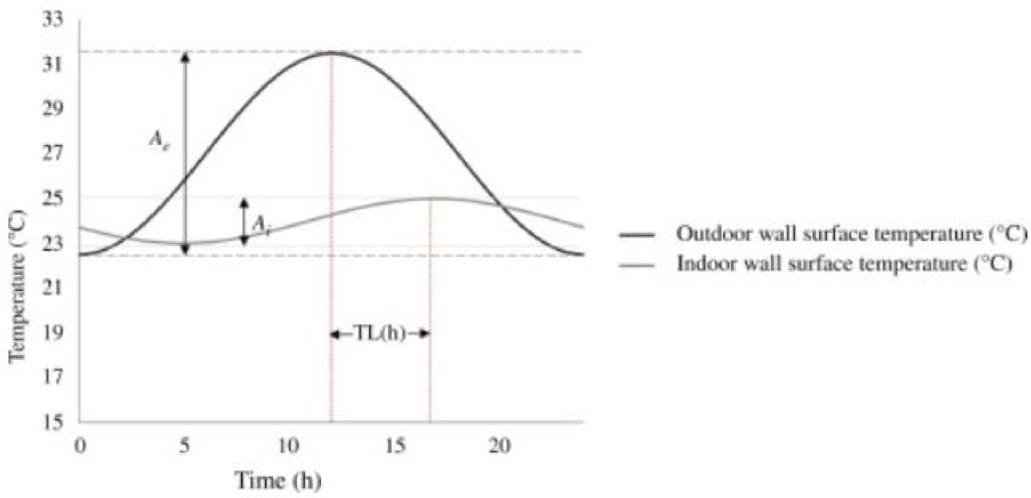

Figure 3. Thermal wave behaviour

There is also a difference between the transmission inertia and absorption inertia. The first one represents the transmission of heat through the material and how this is diffused, the lower the thermal diffusivity of the material, the higher is the thermal damping. On the other hand, the absorption inertia refers to the capacity of a material to store the heat provided by the outside, and redistribute it later restoring the energy.[4]

The solar control system is an interesting tool to reduce the energy consumption of cooling systems and artificial lightning, to promote visual comfort in the indoor environment and to produce solar heat and electricity. Transparent components are an essential part of the solar control system that must be considered in the design of the building, some important parameters of it are its size, orientation with respect to the sun, obstacles that can block the sunlight, and the thermal characteristics of this transparent material. This controller should reduce the solar gains as to maintain the thermal comfort, prevent peak temperatures in the indoor surface of an external wall as to avoid discomfort, protect from the direct solar irradiation which can be irritant to

[4] https://www.sciencedirect.com/topics/engineering/thermal-inertia

the eye and produces a despair distribution of temperature. Window blinds, shutters or panels of different types can be installed to manually regulate the solar incidence. Another part of the solar control system are the photovoltaic panels (PV) which produce electricity when exposed to solar energy. The solar gain of the façade is reduced by this new controller because part of the solar light will now have incidence on the PV instead.[5] This are some of the many solar controllers that can be applied to improve the building internal conditions.

Another aspect to consider is the air tightens which should be controlled as to avoid air leakage which responds to around the 20% of energy loss. To achieve a correct air tightness the following factors must be considered. Air barriers must be continuing and accessible, from the inside they should be airtight and from the outside windtight, this are usually made of insulation materials. The different membranes should be perfectly sealed avoiding the entrance of air or water, wind and air membranes can be added to complete the sealing. In the replacement of openings, the frame of the window or door must be correctly sealed, this is done using compatible gunned in sealant or expanding foam. Draghtstrip external doors and windows using excluders to stop the cold air from entering the building. All the services holes that pass through the building envelope have to be sealed, for example pipes, electrical cables, … Close with insulant materials the fireplaces or chimneys that are oat of use. Seal all joints between ceiling and external walls, or any other possible thermal bridge. [6]

Figure 4. Example of a window draghtstrip

Ventilation

Ventilation has to be controlled, if this is uncontrolled and not desired then it is an air leakage. Ventilation is the process of supplying or removing air from a space as to control the contaminant level within the local. Contrary, infiltration is the uncontrolled inward air leakage through unintentional openings in ceilings, floors or walls. This

[5] https://www.sciencedirect.com/science/article/pii/S0038092X1630648X
[6] https://www.greenspec.co.uk/building-design/refurb-airtightness/

situation is very frequent in gaps or cracks in the construction so it´s important to have a neat work when building the structure. This has to be reduced as much as possible because an undesired air-flow will generate a thermal difference, then the loss of the desired comfort temperature. By losing the desired atmosphere in a room, cooling or heating systems will be required to restore that condition, and this is the situation that should be avoided. There for, is important to be careful in the construction phase to elude this undesired effect thus sealing all the gaps as to have a homogeneous air barrier. This will be the more delicate stage regarding infiltrations.

Not only can the air leakage break with the desired atmosphere, but it may have other effects. For example, if in the external space there is a cold temperature, by infiltration, the surfaces of elements in the building are cooled and this contrasted to the warm of the inner atmosphere will produce condensation. Other consequences of air leakage are that, if using a cooling or heating system, in presence of an infiltration, this artificially tempered air will leak outside the building having a waste of energy. This would be as trying to keep the external temperature at the comfort level, which is impossible and generates a bigger energy consumption leading to a higher cost for the occupant. This inconvenience can also produce localized discomfort, having some places of the room, those closer to the infiltration, colder or hotter, generating an uncomfortable atmosphere. Another negative effect of uncontrolled air leakage in excess is that this can invade the building structure and damage it provoking a loss of effectiveness in the envelope insulation.

Having a good ventilation system is the key to reach a comfort atmosphere in a room. Different from the topic worked before, ventilation is the controlled and desired air-flow intended to renovate the fresh air of a closed place. This is required to ensure balance between energy efficiency and indoor air quality. It´s important to minimize the amount of air leakage through the building envelope and to install a controlled system that provides the necessary level of ventilation.

With ventilation purity and odour of the air will be regulated. This is the reason why ventilation systems in the building must be design parallel to the cooling and heating systems, humidity controls and the building envelope structure. This must be a pre-studied combination of the different elements with influence on the air. If air is not changed the contaminant concentration will increases linearly over time, making it necessary to resort ventilation. There are regulations that indicate the requirements for fresh air in the insides of a building, following these, the ventilation should be designed, without taking into account air infiltration or windows to be part of the ventilation system. [7]

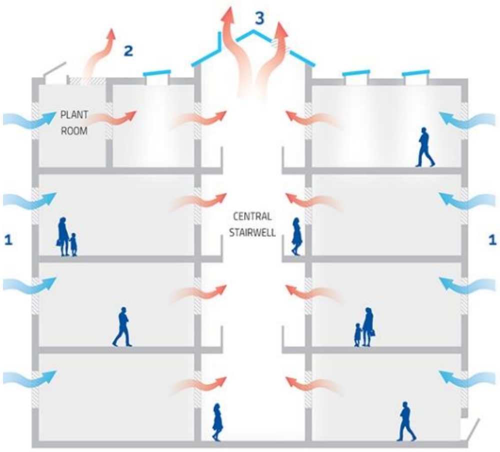

Figure 5. Ventilation system diagram

In the case of perfect mixing, ventilation air flow is diffused uniformly in the whole space, this is an ideal case. The required air flow rate is expressed as a function of the number of occupants or of the floor area of the room. To correct this restrictive hypothesis the concept of ventilation efficiency is introduce, a variable that takes into account the fact that in real cases the distribution of pollutants in the environment is not uniform.

Natural ventilation is the use of wind and temperature differences to create airflows, this is inexpensive when compared to operational and maintenance costs of mechanical systems, has a minimum maintenance, no plant room space is needed, not noise discomfort, but there is no control over the ventilation rate leading to excessive heat loss, may present a security risk, and it’s not suitable for severe climatic regions. Larger openings are required at upper floors to achieve equal airflow due to smaller pressure differences; contrary lower floor openings can be smaller.

[7] https://www.isover.com/how-design-and-build-energy-efficient-building

Heating and Cooling

Some other indoor environmental control systems are air conditioning, heating systems, and cooling systems. Water systems are used for radiators, radiant panels, fan coils, and air heaters; these controls temperature but not humidity. Air systems have an effective control of environmental parameters like temperature and humidity ratio, the ability to filter all the air introduce, perform the function of ventilation and allow energy recovery. However, they have a poor energy performance and significant dimensions of the ducts compared to the water systems.

"[…] heating and cooling in buildings and industry accounts for half of the UE's energy consumption, making it the biggest energy end-use sector ahead of both transport and electricity."[8] Between the heating and cooling of spaces and the hot water, a lot of energy consumption is needed for residential buildings, and during winter or summer this demand grows. If the aim is to have energy efficient buildings, then this issue has to be addressed, these systems have to reduce the energy need and the use of fossil fuels. Like this, energy expenses will be reduced, benefiting economically to the occupant, and there is a grew for incentive to use renewable energies. By reducing the energy consumption, less greenhouse gases are emitted for the extraction of this energy, then, this also aims to approach the environmental care. [9]

The first thing to consider is the use of these systems, people should be aware of the big impact of their bad habits. Shades or fans can be used to cool a space without having a high demand of energy, the over cooling or over heating should be avoided, don´t climatize rooms that are not being used, make use of the natural sun to warm a place, ... This are some recommendations that the individual should consider.[10] Another possible solution is to replace the actual heating and cooling systems of buildings for new equipment's with a better energy level. Else, the use of renewable heating and cooling systems should be considered, as are the solar heaters and biomass boilers. Like this, the use of non-renewable energy is reduced.

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[8] https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling_en

[9]https://www.energystar.gov/sites/default/files/asset/document/HeatingCoolingGuide%20FINAL_9-4-09_0.pdf

[10] https://carbontrack.com.au/guides/energy-efficiency-guide/heating-and-cooling/

Knowing the demand for heating spaces and water, it can be analysed the alternative to modify some aspects as the implementation of solar plants, upgrade of the equipment, improvement of the building envelope, between others. The energy need is computed as the amount of heat needed to keep a constant temperature in a room for a month. Then, the average temperature of each month has to be calculated with climatic information, which will be compared to the comfort temperature desired in the inside. And having this, the annual energy need can be deduced. The energy need of the heating system regarding heating of spaces and of water, depends on the waste of thermal energy by transmission, solar thermal gain, internal thermal gain, and waste of thermal energy by ventilation. With these parameters it´s possible to evaluate the correct distribution and circulation of heat through the spaces.

The waste of thermal energy by transmission depends on the thermal conduction of the system elements and thermal convection of surfaces absorbing this heat. First, the heat transfer coefficient has to be considered, that is the thermal exchange that a material allows between one space and the other which can be defined by the thermal conductivity and thermal resistance of materials. For this, all the elements of the structure are considered as the thermal bridges. This coefficient refers to the amount of heat exchanged over time in $1m^2$ for a difference in temperature of 1K. For example, when analysing a wall that has non-homogeneous layers, an average limit resistance between each weighted material is taken. Different is the case of windows where the transfer coefficient is given by the fabricant.

The solar thermal gain is given by the solar radiation that passes through transparent elements by month. This is influenced by the sun irradiation over the horizontal surfaces, and it can also be analysed the degree of elevation of the sun which refers to the deviation from the vertical respect to the window surface. For the sun incidence in roof windows, depending on the window inclination, the radiation can be considered with some orientation, or if the window has a small inclination, the radiation is considered horizontal. To this solar energy, it should also be taken into account the shadows that will reduce the thermal gain depending on the shadow orientation.

Internal thermal gain is based on the heat produced by the use of electro domestics, the artificial light and heat produce by the human body. All this are contributions of the internal heat of a building, that together they must be inside a limit range defined depending on the type of building.

Thermal energy waste by ventilation is the result of the exchange between the warm air in the inside environment and the cold air in the outside. This exchange depends on the use that is given to the room. For example, a bathroom won't have the same ventilation as a bed-room; or the kitchen, due to the use of gas needs a higher ventilation. This energy waste will also depend on the mechanic system used for ventilation, if this is of continues function, the volume that is ventilated, and other similar aspects.

On the other hand, for the energy need of cooling systems it´s important to know the sensible and latent loads, the refrigeration units, absorption plants and related installations. The thermal load for cooling is calculated as a relationship of the sensible environmental load and the power needed for refrigerating the space. Knowing the cooling system used and the surface of incidence, it´s possible to determinate the electric power needed.[11]

Effect over the Community

A tendency for considering the energy performance as an important characteristic of a building has grown with the years and it´s directly correlated with an economical emergency given by the high demand of unrenewable energy. This is why it´s necessary to reduce the energy need in general, and being buildings a big source of consumption, they have been a chosen target for treating this environmental issue. People live in buildings, go to work at an office in a building, in their free time go to shop at a building, … this shows the amount of time that is spent in these structures. Then, it's evident the huge energy consumption that they require, and why it's so important to regulate the energy performance of buildings. This will ensure an environmental benefit in the local and global sense. On one hand, if the building energy need is reduced, then the local energy supply can be lowered causing less pollution. On the other hand,

[11] http://lexbrowser.provincia.bz.it/all/all.ashx?path=Allegato%203%20-%20167405.pdf&mimetype=application/pdf

by creating a global awareness, the impact of this environmental act will have a stronger effect.[12]

Another benefit of having this type of buildings is related to the economical profit for the occupant who will be reducing the energy expenses. This leads from the reduction in the consumption of energy for heating and cooling systems, sometimes from integrating some renewable sources of energy as solar panels, and by investing on the renovation for having a building of higher quality this will have a longer life cycle saving the cost of future arrangements. And even if the cost of this renovation it may seem a big investment, at the end this cost is recovered in a couple of years.[13]

As mentioned before, in most countries there is a big problem with the energy supply which in short will be failing to satisfy the energy demand. The need for energy is increasing with time, different from the reserve of non-renewable energy. This is why renewable sources of energy are a good alternative to offer energy at a low economic and environmental cost. However, it is more difficult to extract energy from renewable sources.

Energy sources

The energy consumed by a building can derive from different sources, some more pure than others, and this will define the environmental impact of the building which is registered by the energy assessment of the building.

The origin of energy sources is nuclear, having the geothermal and tidal energy as exceptions, the solar energy and the derived solar energy forms (chemical of fuels, eolic, hydraulic, …) originate from thermonuclear fusion process that lay in the Sun corresponding to the transformation of hydrogen into helium. There are energy vectors for useful energy such as hot water, cold water, electric energy; and other vectors for energy that needs conversion like gas, diesel oil, biomass; … Primary energy sources are those available without the need of conversion and can be renewable or non-renewable.

[12] https://www.unido.org/sites/default/files/2009-02/Module18_0.pdf
[13] https://energyeducation.ca/encyclopedia/Energy_efficient_building_design

On the other hand, secondary sources derive from conversion processes of primary sources and represent the energy carriers.

Non renewable energy sources are divided in fossil flues having oil, natural gas; coal; and nuclear energy. Renewable energy sources (RES) are those that can be constantly taken from the external environment and their exploitation takes place in a time comparable to that necessary for their regeneration. They are subject to significant annual or daily variations; therefore, they usually require supplementary and back-up systems. Examples of RES are: wind; solar; geothermal; ambient; tide, wave and ocean energy; hydropower; biomass; landfill gas; sewage treatment plant gas; and biogas. On site renewable energies are the solar energy captured within the on-site perimeter by thermal solar collectors and transformed into useful thermal energy; solar energy captured in the on-site perimeter by photovoltaic panels that is converted into electricity; mechanical energy transformed into electricity by wind micro-generators or any other on-site generation system; and energy drawn within the perimeter from an aerothermal, geothermal or hydrothermal source.

Solar energy derivates from thermo-nuclear fusion reactions in the Sun, the solar irradiation is directly collected to be converted into thermal or electrical energy. However, only a part of the radiant energy of the Sun reaches the ground which can be estimated at around 7.5 10^{11} TJ per year, per unit of land area this is 1390 kWh/(m^2 year) which is equivalent to an average flow density power of 160 W/m^2. The solar energy received is much greater than the annual consumption of world primary energy for about 2000 times. Until the moment this is not possible to fully exploit because it's a form of energy subjected to daily and seasonal variants, it's composed of a vector quantity which has to be correctly intercepted in order to be captured, it has a low specific power and there is a clear impossibility to cover all the landmass.

PV Photovoltaic technology makes it possible to directly transform solar radiation energy into electrical energy exploiting the photovoltaic effect based on the particular properties of some semiconductor materials that are easily found in nature such as silicon. These materials when interfaced and subjected to solar radiation in a properly way, are able to generate electricity by equipping photons with a sufficient energy capable of inducing an electrons movement resulting in flow of charges in the circuit outside the cell. A PV module is identified by its peak power value that is the maximum produced electrical power under conditions of solar irradiance of 1 kW/m^2, air mass equal to 1.5 and air temperature of 25°C. The PV panel cost is about 1000-1500 €/kW_p

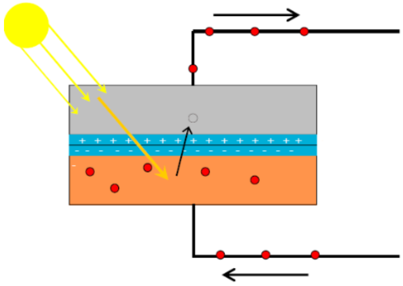


Figure 6. PV technology

Biomass refers to any organic material originated from a biological process that can be exploited for the production of energy. This is considered renewable energy since through the photosynthesis process there is accumulation of solar energy in the plant in the form of chemical energy of bonds between the organic molecules. This solar energy form of exploitation, although it has a very low efficiency (about 0.6%), it has considerable inexpensive cost and allows to overcome the intermittent nature of solar radiation because the energy is accumulated in the vegetable.

"Primary energy is energy that has not been subjected to any conversion or transformation process"" – ISO 5200 – 1. Primary energy will need a conversion as to produce an energy currency so it can be used. The energy conversion technologies are all the before mentioned which permits the manipulation of this basic forms of energy and transforms it into something useful for society. To understand how this primary energy is used for the production of some efficient energy, the idea of primary energy factor (PEF) appears.[14]

The primary energy needed delivered by a specific energy carrier is the primary energy factor and there is a variety of possible energy carriers, then changing the value

[14] http://download.dalicloud.com/fis/download/66a8abe211271fa0ec3e2b07/2e71fed6-5124-4fc2-8163-b643c3ee98f6/Co-signed_PEF_Statement_final-2017.pdf

of the primary energy factor. This value is computed as the inverse ratio between the measured delivered energy and the primary energy needed to provide the before mentioned.[15] The energy efficiency evaluation depends on the PEF which is important when analyzing the limit performance requirements.

The establishment of PEF and the coefficient of CO_2 emissions is dictated by the international standard EN 17423. This provides an understanding of the different methodologies to compute the PEF and the CO_2 emissions for different energy vectors, this can be analyzed for the exported energy as well as for the imported energy. The main objective of this standard is to complement the standard EN ISO 52000 – 1 in these two points (PEF and CO_2 emissions) which are the weakest in explanation.

EN ISO 52000 – 1 is a technical standard for the global evaluation of the energy efficiency of buildings. It aims to establish a transparent and systematic frame to analyze the energy performance of buildings, both new or in existence, seen as a whole. The energy consumption of the building can be measured or computed, considering as a base of analysis the primary energy or any other energy indicator. It provides some boundary limits to take into account on the design of the building or in the renovation of an already existent building.[16]

Global Awareness

There are some very efficient solutions to reduce the environmental impact of buildings, as all the above mentioned. However, it may be difficult to make people aware of the huge negative impact that buildings can have over the environment. And creating a global awareness of this situation is one of the most effective solutions to the problem. People should understand not only the effect of this high energy demand, but also that they can make a change to restore this situation. A possible way to spread the need of a solution could be to show the CO_2 emissions of each building to its occupants.

The impact of a building in the environment is significative, this is why measuring the carbon footprint is important to reduce this effect. The carbon print computation is

[15] https://epbd-ca.eu/wp-content/uploads/2018/04/05-CCT1-Factsheet-PEF.pdf
[16] http://store.uni.com/catalogo/uni-en-iso-52000-1-2018

a Life Cycle Assessment (LCA) and by presenting it the user is allowed to understand the environmental consequence of what is consumed. The searching of an easy and fast calculation of the carbon footprint is ongoing, the aim is to communicate and make available this information as to reduce the emissions. Making public this data to demonstrate that it´s possible to offer a sustainable solution provides the consumer the opportunity to decide considering this factor. [17]

Footprint calculators use a database with information about the CO_2 emissions generated by the row materials, elaboration process, and logistics. The calculation is made by associating the material weight with the necessary energy to produce the final product considering some external influences as the commercial factor, geographic area, quantity, … To measure the environmental impact different analytic methodologies can be used such as PEF (Product Environmental Footprint) or OEF (Organization Environmental Footprint) that use specific indicators through all the life cycle of the product to analyse the emissions.[18]

Figure 7. Example of CO2 labelled in a product

The carbon footprint of an infrastructure is defined as the total amount of greenhouse gases emitted over the life cycle of the building expressed as an equivalent of CO_2 in kilograms. The term "greenhouse gases" (GHG) refers to different gases in the atmosphere that trap heat permitting the passage of sunlight but preventing the heat of it from leaving the atmosphere. These gases are necessary to maintain the earth temperature, but in excess it brings high consequences to the planet. The main GHG are water vapor, carbon dioxide, methane, ozone, nitrous oxide and chlorofluorocarbons. CO_2 is the most important contributor to human-cause global warming. [19]

[17] https://www.industry4business.it/esg/esg-come-misurare-limpatto-ambientale-di-prodotti-e-servizi/

[18] https://www.ifu.com/en/umberto/lca-software/?gclid=Cj0KCQiAs5eCBhCBARIsAEhk4r4ReDIBTx_CkjZeTnhnCJVDk_4TjI0aEla4fRnqPQ1cFR98aaE_USsaAhY0EALw_wcB

[19] https://climatekids.nasa.gov/greenhouse-cards/

The life cycle carbon footprint of an infrastructure is a metric performance that should be monitored and optimized. The modelling of buildings footprint generally includes in the analysis the following key features[20]:

- Necessary energy and GHG emissions in the building including the continues use of services related to heating or cooling the environment, heating of sanitary water, use of electricity, and other necessities;
- Carbon emissions due to maintenance operations of greater impact which may require water and electricity use, and in some cases land-use changes;
- Solid and water waste generated during the maintenance process or for the proper function of energy generators which are in continues use.

By normalizing carbon print reports, the community will be more familiar with the energy impact of buildings, and hopefully they will opt for more energy efficient buildings. This is a change that starts from the individual, and ends with the state who will regulate the energy performance required and will guide the community as to have an optimal process.

[20] https://www.cleanmetrics.com/html/building_carbon_footprints.htm

CHAPTER

2

Norms and Methodology

Normative and methodologies that are going to be used to govern the decisions of this work. In the construction filed is of main importance to follow the criteria of each region, in this case Italy. So, it’s necessary to define which norms are going to be used for this project.

Along this paper, the renovation of buildings to improve the energy level will be described. This engineering work will be done in the frame of some standards and legislations that are a guide for analysing every aspect of the project. The first step is to identify what type of building is being analysed, for this the DPR 412/93 is followed, a national decree with the proper regulations to categorized the building. Knowing this the energy performance of the building is studied using the UNI/TS 11300 technical standards that are the main frame giving a structure to all the project. The CIT:14 are two new technical standards that complement the before mentioned ones, and are part of the same international structure for the understanding of the energy performance. At the national level, the Italian legislation regulates these standards with the D. interm. 26/06/15 presenting the corresponding energy certifications demanded for buildings through the national territory. In the energy assessment process, the climatic information will have a big impact on the thermal energy consumption which covers a great part of the total energy need of a building. The climatic characteristics will be computed with the methods provided by the standard UNI 10349.

Having the energy assessment completed, the possible interventions to improve the energy performance of the bundling are analysed. Between them a very popular option is the installation of insulation layers on the external surface of the building. This insulation will be regulated by the Italian criteria CAM that defines the material to be used. This standard is supported by two technical specifications: the UNI EN ISO 6946 that analyses the thermal transmittance and thermal resistance of an element; and the UNI EN ISO 14683 that defines the thermal transmittance of thermal bridges.

Buildings have a big impact on the environment and this is finally being noticed. This is why the Italian government has launched an incentive to take action and reduce the negative impact of them with a new proposal called Superbonus 110%. This is aimed for construction companies to renovate already existing buildings with the objective of improving the energy performance. The Superbonus is a guide that must be used to achieve a correct performance in the renovation of a building. However, this has to follow certain standards and legislations given both by international and national organs to ensure a proper work, as before explained.

Throughout this work, which studies the specific case of Italy, for analyzing the energy level of a building in study, the software Edilclima EC700 is going to be used. The input information that has to be inserted in the software is going to be described later, now, the regulations that frame this software are going to be presented. Along the project, this tool will be used for the analysis of residence buildings, this is an important specification that will define the methodology of study for other standards and regulations.

Building Category – DPR 412/93

This project analyses the energy performance of residential building only because it follows the Superbonus incentive which is given to buildings of this type. The "type" of building is defined by its utilization and it´s classified with a code respected by all the norms and programs where this property is an important factor. To this use, the Italian legislation followed by the DPR 412/93, normalizes a codification that represents the use of each building to simplify them in categories.

Using the Decreto del Presidente della Repubblica N° 412 from the year 1993, in the article 3 the general classification of buildings by categories is described.

Art. 3. Buildings are classified based on the use of them:

Categ.	Description	Subcat.	Description
E.1.	Buildings used as residences and similar;	E.1.1.	Residences with character continuous, such as civil and rural homes, colleges, convents, prison houses, barracks;
		E.1.2.	Spaces used as residences with occasional occupation, such as holiday homes, weekends and the like;
		E.1.3.	Buildings used as hotels, guesthouses and activities similar;

E.2.	Office buildings and similar: public or private, independent or contiguous to buildings also used for activities industrial or artisanal, provided they are of such buildings separable from the effects of thermal insulation;		
E.3.	Buildings used as hospitals, clinics or nursing homes and similar, including those used for hospitalization or care of minors or elderly, recovery of drug addicts and other subjects entrusted to public social services;		
E.4.	Buildings used for recreational activities, associations or of cult and similar;	E.4.1.	Cinemas and theatres, meeting rooms for congresses;
		E.4.2.	Exhibitions, museums and libraries, places of culture;
		E.4.3.	Bars, restaurants, dance halls;
E.5.	Buildings used for commercial and similar activities such as shops, wholesalers or retail stores, supermarkets, exhibitions;		
E.6.	Sports buildings;	E.6.1.	Swimming pools, saunas and similar;
		E.6.2.	Gyms and similar;
		E.6.3.	Support services for sporting activities;
E.7.	Buildings used for school activities at all levels and similar;		
E.8.	Buildings used for industrial and artisan activities and similar.		

If a building is made up of parts that can be identified as belonging to different categories, they must be considered separately. [21]

Energy Performance of Buildings – UNI/TS 11300

Knowing the category for the building to be analyzed, the process can be continued. Next, Edilclima EC700 is going to be used as a tool to compute the energy

[21] https://www.gazzettaufficiale.it/eli/id/1993/10/14/093G0451/sg

performance of a building. For this, a frame to work all the normative about the energy performance is necessary, and this will be delimited by the technical specification UNI/TS 11300. Working with different technical normative both national and European, it's possible to have a complete framework to better analyse the energy performance of buildings.[22]

The UNI / TS 11300 Technical Specification was created having as aim the defining of an accurate calculation methodology for the energy performance of buildings.[23]

In this project, the heated spaces of a building will be studied, and the thermal energy demand is a key element to understand if there is an exceeding use of energy related to the thermal consumption. Knowing this value, it's possible to compute the energy level of the building in its actual condition, and the energy level of the restructured building after the interventions.

The renovation of the building to improve the energy level is based on interventions which must be analysed considering particular aspects of the building, the occupants needs and the technical standards. No intervention can be caried out if it doesn't verify this standard.

Following, a brief description of the technical specifications is presented.

- UNI/TS 11300 – 1:

Determination of the building's thermal energy demand for summer and winter air conditioning. The national specification defines the method for calculating the monthly energy demand for heating and cooling, this is used for design rating and energy assessment of buildings under standard conditions or under particular climatic conditions.

The thermal energy need for heating and cooling systems (Q_{nd}) is defined by the monthly thermal balance of wasted energy due to transmission (Q_{tr}), waste of thermal

[22] https://www.edilclima.it/software-termotecnica/prog-termotecnica-energetica/scheda/700
[23] https://www.cti2000.eu/la-uni-ts-11300/

energy due to ventilation (Q_{ve}), internal thermal gain (Q_{int}) and the solar thermal gain (Q_{sol}):

$$Q_{H,nd} = (Q_{H,tr} + Q_{H,ve}) - \eta_{H,gn}\,(Q_{int} + Q_{sol}) = Q_{H,ht} - \eta_{H,gn}\,Q_{gn}$$

$$Q_{C,nd} = (Q_{int} + Q_{sol}) - \eta_{C,ls}\,(Q_{C,tr} + Q_{C,ve}) = Q_{gn} - \eta_{C,ls}\,Q_{C,ht}$$

This method provides an equilibrium between monthly measured conditions and a parameter (η) that permits to analyze this relationship in a non-static frame, bringing it closer to reality.

- UNI/TS 11300 – 2:

Determination of primary energy demands and yields for winter air conditioning, for the production of domestic hot water, for ventilation and for lighting in non-residential buildings, always with aiming an efficient design of the energy performance. It provides data and methods for computing the thermal energy demand for domestic hot water production; energy supplied and primary energy of winter air conditioning and domestic hot water services; primary energy requirement of ventilation service; primary energy requirements of lighting service, and the yields and losses of each system. This applies to newly designed, refurbished or existing systems of: only, mixed or combined of heating and domestic hot water production; only hot water production for sanitary use; only or combined ventilation systems and winter air conditioning; and lighting systems in non-residential buildings.

For the calculation of the thermal energy need of hot water a relationship between the daily consumed volume (V_W), the delivering temperature (θ_{er}) and the cold-water temperature (θ_0) is studied:

$$Q_{W,nd} = \rho_w \cdot c_w \cdot V_w \cdot (\theta_{er} - \theta_0) \cdot G$$

- UNI/TS 11300 – 3:

Determination of primary energy demand and yields for summer air conditioning. It applies to fixed summer air conditioning systems with electrically operated or absorption refrigeration machines that can be newly designed, refurbished or existing systems.

- UNI/TS 11300 – 4:

Use of renewable energy and other generation methods for winter heating and for the production of domestic hot water. The standard refers to systems alternative to traditional combustion and calculates the primary energy demands for winter heating and domestic hot water using renewable energy. The following sources are considered useful for the production thermal energy: solar thermal; biomass; aeraulic, geothermal and hydraulic sources in the case of heat pumps; and solar photovoltaic for the production of electricity. [24]

Solar thermal: the method considers prefabricated systems for the production of domestic hot water and heating, and the calculations imply detail information as the exact inclination and orientation of the collector.

Photovoltaic: for calculating the energy performance of buildings, the contribution of electricity produced by solar photovoltaics decreases the electricity requirement used directly for air conditioning, domestic hot water, auxiliary energy production, and lighting. The production of photovoltaic electricity cannot be greater than the sum of the desired electrical energy, the energy produced is:

$$\text{Photovoltaic Energy} = \frac{E_{sol}\, p_{pk}\, f_{pref}}{l_{ref}}$$

E_{sol}: solar radiation incident on the photovoltaic solar panel; p_{pk}: installed peak power; f_{pref}: efficiency factor of the photovoltaic solar panel; $l_{ref} = 1\frac{kW}{m^2}$: reference solar radiation

Biomass: solid biomass generators with automatic or manual loading are considered and generators with blown air burners (liquid biomass, vegetable

[24] https://www.edilizianamirial.it/nuove-uni-ts-11300-2016/

or gaseous oils, biogas). The calculations of production yield are standardized, and the conversion factor into primary energy is indicated.

District heating: this is divided into a central and thermal network, and a heat exchange substation. Between these two subsystems there will be an energy balance for which $Q_{ss,out} = Q_{ss,in} - QI_{ss,env}$

$Q_{ss,in}$: input energy; $QI_{ss,env}$: thermal energy in the environment in the exchange substation

Energy requirement in the calculation period: $Q_{ss,p} = Q_{ss,in}\ fp\ \ el$

fp, el: conversion coefficient which are declared by the supplier.

Heat pumps: the systems that use heat pumps are divided according to type of cold source; type of service; energy vectors; heat carrier fluid. [25]

CTI 14:2013

The technical specifications framing the energy efficiency design, are constantly changing as to have a better fit to the new technologies and the actual situations on field. This is important because it must be considered the climatic conditions of each country, the national normative, cultural influences and other factors that have a strong incidence in the construction of a building. However integrated it may seem, this flexibility brought many problems for the general application of standards due to the lack of homogeneity of methods. Like this, the standards where poor in explanation, thus bringing difficulties in the implementation and uncertainty in the method to be used. This is the reason why most of the European countries have chosen to use the European regulation as a guide but to apply the national regulations with more accuracy.

After noticing this negative reception of the nations, the European committee decided to review the standards having as main objectives to: distinguish the methodology that must be follow independent of the country of application from the methodology that can variate in the different regions; to impose a common structure

[25] http://www.gas.it/tutte-le-news/50-normativa-e-leggi/1243-pubblicata-la-norma-uni-ts-11300-parte-4-

for every norm and every country thus providing a clear frame of work; and to clarify the description of each calculation as to eliminate ambiguity and be able to use different software's within the same diagram. Another interesting fact is that this new update was done in complementation with the International Standardized Organization (ISO), so it has an extra-European collaboration which is important as to have a wider view and compatible methods with more countries. [26]

The determination of the energy performance of buildings calculated with the UNI/TS 11300 is complemented with the CTI 14:2013 as to calculate the building classification. The CTI has published in the year 2013 some new technical specifications using the UNI/TS 11300 as a base. The main regulations are three:

- A complementation of the UNI/TS 11300 – 4 where there is an improvement of the methodology for the calculation of renewable energy need for the generation of the different services; and the admission of two new sections.

- UNI/TS 11300 – 5:

Calculation of primary energy and the amount of energy from renewable sources. Uniquely calculation method to determine the demand of primary energy by evaluating the renewable energy contribution in the energy balance; exported electricity; and the electricity produced by cogeneration units. The standard specifies the building's evaluation boundaries, the energy sources to be considered inside or outside the building; renewable and non-renewable energy sources and internal or external energy carriers at the boundary of the building; the methods for defining the performance indices; and the services included in the calculation of the energy demand (winter and summer air conditioning, production of domestic hot water, ventilation, lighting and transport of things and people);

- UNI/TS 11300 – 6:

[26] Corrado Vincenzo; UNI/TS 11300, cosa cambia?; Aicarr Journal; november 2014

Determination of the energy needs for elevators and escalators. Provides data and methods for computing the electricity demand of operational systems intended to lifting and transporting people or things in a building, taking into account only the electricity requirement in the movement and rest periods of the operational phase. This specification applies to the following systems: lifts, stairlift, lifting platforms, goods lifts, car lifts, escalators, moving walkways; and it applies to the types of buildings: residential building, hotel, office, hospital, building used for school and recreational activities, shopping centre, building used for sports activities, building used for industrial and craft activities, building used as a public transport service (station, airport, etc.).

In Italy each energy service has been divided (heating of air, heating of water, cooling, ventilation, illumination) and, using national Italian regulations, the different types of energies (energy need, delivered energy, exported energy, primary energy) are computed using different parts of the UNI/TS 11300 and CIT 14:2013

Energy / Service	Cooling system	Heating system	Water heating	Other
Need	UNI/TS 11300 – 1	UNI/TS 11300 – 1	UNI/TS 11300 – 2	
Delivered	UNI/TS 11300 – 3	UNI/TS 11300 – 2/4	UNI/TS 11300 – 2/4	ventilation UNI/TS 11300 – 2
Exported				UNI/TS 11300 – 4
Primary	UNI/TS 11300 – 5	UNI/TS 11300 – 5	UNI/TS 11300 – 5	

Then, for the generator systems described in CTI 14:2013 the Italian regulation defines a relationship between the produced energy and the energy source. For the production of thermal energy on site, renewable sources are used generated with solar collectors and heat pumps; the thermal energy can also be produced by non-renewable sources using fossil fuel boilers, and heat pumps; or by renewable energy using biomass boiler. Then, the electric energy is produced on site with renewable energy using photovoltaic and eolic micro generators. Last, for the production of combined thermal and electrical energy, non-renewable energy is used created by micro generators. [27]

Energy Performance Normative – D. interm 26/06/15

These technical standards are applied according to the legislation of each country, for the Italian nation the D. interm 26/06/15 is respected, this uses the energy performance of buildings and provides energy ratings as to control the energy use. The reform D. interm 26/06/09 introduces the Energy Certification of buildings through the national territory, this is done having as reference the calculation methods of the UNI/TS 11300 series standards. The purpose of this is to organize the results of different standards used to compute the energy consumption of specific services; to register the energy generated inside the building and the energy consumption of the whole building; and rate the building energy levels by analyzing the building emissions, energy need and primary, renewable and non-renewable energy. The regulation defines which energy services must be analyzed in a performance rating and for this, it supplies with specific methods to compute the energy ratings inside the building and outside in the environment; methods for the energy rating of delivered and exported energy; to generate confidence in the energy-efficiency building model; and to assess different improvements as to reach effectiveness.[28]

The energy classification of buildings is defined in this decree, using this is possible to place each building on a performance scale knowing the energy quality defined by its characteristics, energy consumptions and energy sources. As the degree imposes, the evaluation will be done based on measures caried out on the existing building. This is why a survey on site is done, and the real consumption of electricity and gas are required for the energy analysis, between other characteristics.

As a result of the energy classification, some possible interventions are suggested to improve the quality of the building that will be caried out in the renovation

[27] Corrado Vincenzo; La normativa tecnica sulla prestazione energetica degli edifici alla luce delle nuove UNI/TS 11300; I quaderni dell'ambiente e dell'energia; 2015

[28] http://store.uni.com/catalogo/en-15603-2008?josso_back_to=http://store.uni.com/josso-security-check.php&josso_cmd=login_optional&josso_partnerapp_host=store.uni.com#

considering not only the best energy performance but also the best economical solution and the legal standards that must be achieved. The before indicated, are the main aspects to contemplate when deciding which interventions to apply. Being this an engineering project, the energy evaluation cannot be alienated from other important features such as the economic and social ones, this is why the regulation clarifies that the interventions are chosen considering all the possible aspects of incidence.

The main points of the norm are described below.

- The degree D. interm 26/06/09 proposes:

Art. 1 – Homogeneous, coordinated and immediately operational application of the energy certification of buildings throughout the national Italian territory.

Art. 3 – The aim of this regulation is to ensure the adequate promotion of quality levels related to the energy consumption; to impose the usability, dissemination and increasing comparability of energy certifications; and to make aware of the importance of protecting the users' interest. Primary energy and the contributions of renewable sources are evaluated with the national references.

The final delivered energy need of the whole building considering the cooling and heating systems and the production of hot water, it´s a function of the plant of energy subsystems and the monthly balance of energy consumed by the subsystems. The Italian regulation makes a difference between regulated subsystem in upstream direction regulation and the emission subsystems. It must be conceded that the entering energy (Q_{in}) should be the same as the total sum of the exit energy (Q_{out}), the wasted energy (Q_l) taking into account the recovered energy ($Q_{l,rh}$) and the recovered auxiliary energy ($Q_{aux,rh}$):

$$Q_{in} = Q_{out} + Q_l - (Q_{l,rh} + Q_{aux,rh})$$

The overall energy performance of the building is expressed as:

$EP_{gl} = EP_i + EP_{acs} + EP_e + EP_v + EP_{ill}$ [kW.h/m^2.yr] where:

EP_i: energy performance index of winter heating;

EP_{acs}: of sanitary water heating;

EP_e: of summer cooling;

EP_v: of ventilation;

EP_{ill}: of artificial lighting.

For residential buildings the energy performance of artificial lightening and of summer cooling are not necessarily considered, then, the before expression is shortened.

This takes into account the demand of primary energy for winter and summer air conditioning, for the production of domestic hot water and for artificial lighting.

For existing buildings, the “method of calculation from survey on the building or standard” is used. This refers to the evaluation of energy performance starting from the input data obtained from measures carried out on site from the existing building.

The energy certification for buildings is defined with a report determining the energy performance of the property and suggesting the energy requalification interventions that are economically convenient, it includes a classification of the building according to the energy performance that must meet the legal limits.

Art. 6 – Certificates have a maximum validity of ten years, this is not affected by measures update or introduction of energy certification of additional services, and it must be updated with each renovation or intervention that modifies the performance energy of the building.[29]

- The degree D. interm 26/06/15 proposes:

Art. 3 – Constitutes the guideline for the certification of energy performance (APE) of buildings. This defines the adequate levels of quality and the dissemination and increasing comparability of energy performance.

Art. 4 – Essential elements for the certificate APE are: values related to the energy performance of the building; values in accordance with the current standards; performance class that allows the citizens to evaluate and compare energy

[29]https://www.anit.it/wp-content/uploads/2015/03/DM26giugno09.pdf

performance; suggestions and recommendations to the most significant and economically convenient interventions for the improvement of the energy performance.

Each APE is done by an authorized professional with the obligatory reports: global energy performance in terms of total primary energy or non-renewable; energy class determined through the global energy performance index; energy quality of the building for the purpose of containing energy consumption for heating and cooling; reference values; carbon dioxide emissions; energy exported; recommendations for improving energy performance.[30]

Climatic Characterization – UNI 10349 -2016

For the analysis of the energy performance in the dynamic hourly regime the technical standard UNI EN ISO 52016-1:2018 is used. This provides a method for assessing the hourly calculation of heating and cooling energy need; latent energy need of humidification and dehumidification; sensible energy need; and internal temperature. This standard provides some specifications for addressing the different thermal zones inside the building, given that calculations must be done for each thermal zone. This hourly analysis is going to be used as a base for a more complex system. [31]

The Edilclima software has a data base of hourly climate data for each Italian municipality having a detailed description of the external temperature, sun irradiation, relative humidity, vapor pressure and wind flow. All this information is taken by following the limit boundaries provided by the UNI 10349-2016.

To have an accurate energy assessment, the climatic information must be presented given that this has a big impact on the energy consumption regarding the thermal aspects. It´s not possible to know in detail all the climatic aspects affecting the building, this is why, with some characteristics of the property and with this standard, all the climatic information is given. This is important because the energy consumption destinated to the heating of areas will be directly affected to climatic characteristics. In hours where the sun is striking directly into a heated space, the heat will maintain

[30] https://www.mise.gov.it/images/stories/normativa/DM_Linee_guida_APE.pdf
[31] https://www.iso.org/obp/ui/#iso:std:iso:52016:-1:ed-1:v1:en

without the need of a much energy. Contrary, during the night or in shadow hours the space will require a greater energy consumption to maintain the room heated. Like this there are many different climatic aspects that have a big incidence on the energy consumption like the season of the year, winds, humidity, shadow hours … These conditions are regulated by the technical standard with indices and calculation methods where the input data needed are known characteristics of the building like the location, orientation, altitude, …

Knowing the climatic limit conditions for the building in study, it´s possible to interevent by changing the heating or cooling generators for ones of better energy level. This will improve the energy and thermal performance of the building, and the design of the new plant must follow the conditions set by this standard. Another possible intervention is to change the enclosures (doors and windows) considering different materials or accessories o it, and this will be designed considering the climatic conditions and following the limits proposed by the technical standard.

The national series consists of three parts:[32]

Part 1: Monthly evaluation of the thermal energy performance of a building; methods to divide the solar irradiance in direct and diffused fraction; and calculation of the solar irradiance on an inclined surface. UNI 10349-1 provides the necessary climatic data for the verification of energy and thermal performance of a buildings including the systems for summer and winter air conditioning.

Part 2: Project data. The technical report UNI / TR 10349-2 provides the necessary climatic data representative of the limit conditions for the design of the thermo energy performances of the buildings. Is used for sizing the systems for summer and winter air conditioning and to assess the risk of overheating.

Part 3: Cumulative temperature differences (degree days) and other synthetic indexes. UNI 10349-3 provides calculation methods and tables of synthetic indices that define the climatic characteristics of a territory. The calculation methodology determines both, in the cooling and heating season, the degree days, cumulative

[32] https://uni.com/index.php?option=com_content&view=article&id=4819%3Ariscaldamento-e-raffrescamento-degli-edifici-pubblicata-la-serie-nazionale-uni-10349&catid=170&Itemid=2612#

differences in mass humidity, solar radiation cumulated on a horizontal plane, and the synthetic index of a territory. The indices can also be used for a first rough check of the plants.

Insulation – CAM

On the other hand, the UNI EN ISO 12631 standard defines a method for the thermal performance and thermal transmission of continues façade. For this calculation is important to know the materials used in the external part of the building considering the insulation, and the opening materials which can be glass, plastic, or may have curtains or panels inducing to a more efficient thermal transmission.[33]

Once the energy study has been done, different interventions can be applied to the building considering this analysis with the aim of improving the energy level of the building as disposed in the Superbonus measures. One of the main interventions proposed by the Superbonus incentive, is the application of an insulation layer on the external surface of the building. However, this layer must verify certain criteria imposed by the Italian government.

Criteri Ambientali Minimi – Minimum environmental criteria. Environmental requirements aimed to identify the best design solution from an environmental point of view. The CAM norms are defined within the environmental sustainability frame of consumption and are adopted by Decree of the Minister of the Environment for the Protection of the Territory and the Sea. This obligation guarantees not only the reduction of negative environmental impacts, but also the promotion of sustainable "circular" production and consumption models.[34]

In the matter of building, there is a section for the design of new construction, renovation and maintenance of buildings approved by the Ministerial Decree 11/10/17. The description regarding the thermal and acoustic insulation is found in the segment 2.4.2.9. of the normative. The insulation materials are obliged to follow the upcoming criteria. Their production cannot use flame retardants or against with an

[33] http://store.uni.com/catalogo/uni-en-iso-12631-2018
[34] https://www.minambiente.it/pagina/i-criteri-ambientali-minimi

ozone reduction potential, as declared in the national regulations. If the final product contains at least one of the listed harmful components, they must be made from recycled or recovered material according to the minimum quantities indicated. [35]

Haven chosen as intervention for the energy requalification the installation of an insulation layer on the external surface of the building, the results are of great efficiency. This will reduce the thermal dispersion of walls mainly from a heated space to a non-heated space or to the exterior. Then, less energy will be required for tempering a room, lowering the energy consumption and improving the energy level of the building. This is one of the main interventions proposed by the Superbonus, so it has to be done to every building in course. And of course, this intervention must follow the criteria imposed by the nation. With the CAM norms the materials that can be used for the insulation construction are specified having as aim the production of a green protective layer.

Thermal Transmittance – UNI EN ISO 6946

This international standard provides a method of calculation of the thermal resistance and thermal transmittance of components used in the building construction, and set limits of the acceptable transmittance level of a material depending on its use. This does not include doors, windows, glass materials or other elements design to permit the heat transfer. The method can be applied to materials of thermically homogeneous layers, and there is an approximate method for those materials with thermally heterogeneous layers with some correction factors. In this last case, the individual resistance of each layer is computed and with this the total thermal resistance of the component can be deduced.[36] The thermal resistance of homogeneous layers is defined as:

$R = \frac{l}{\lambda}$ l: thickness of the layer; λ: design thermal conductivity of the material

To this value, a correction factor will be applied which depends on the ventilation of the air layer. For unheated spaces, the external wall may not be insulated given that

[35] https://www.minambiente.it/sites/default/files/archivio/allegati/GPP/allegato_tec_CAMedilizia.pdf

[36] https://qdoc.tips/iso-6946-pdf-free.html

the space itself is considered as a thermal resistance. If treating an air layer, depending on the characteristics of this layer, the thermal resistance will be provided by the technical standard.

After computing the thermal resistance of each element, the total resistance (R_T) of the building is calculated as the sum of the individual elements. Then the maximum relative error is computed as to verify that the thermal transmittance meets the required specifications:

$$e = \frac{R'_T - R''_T}{2R_T} * 100; \; R'_T: upper\ limit\ of\ total\ thermal\ resistnace; \;\; R''_T: lower\ limit$$

The analysis of the upper and lower limits considered the element divided into sections that are thermally homogeneous. The upper limit of a complete element assumes a one-dimensional heat flow with a perpendicular vector to the surface of the component, and is a relationship between the areas of each section (f_i) and the thermal resistance of each section (R_{Ti}). On the other hand, the lower limit parts from the hypothesis that those planes parallel to the element surface are isothermal. Then, this thermal resistance is computed as a sum of the internal surface resistance (R_{si}), the design thermal resistances of each layer (R_j) and the external surface resistance (R_{se}).

$$\frac{1}{R'_T} = \sum_i \frac{f_i}{R_{Ti}} \qquad\qquad R''_T = R_{si} + \sum_j R_j + R_{se}$$

Then, the thermal transmittance is calculated by the relationship: $U = \frac{1}{R_T}$

To this, the corresponding correction (ΔU) shall be applied considering the characteristics of the material, however, if the correction is smaller than 3%U, then this is not applied. This correction depends on the air gaps, the mechanical fasteners and the inverted roofs, and the final thermal transmittance is: $U_c = U + \Delta U$

Thermal bridge – UNI EN ISO 14683

International technical standard for the heat flow of thermal bridges in a building construction that defines the linear thermal transmittance and some simplified methods and boundaries limits. For these thermal bridges, the standard provides a method with tabulated values to determinate the heat flows and estimate the thermal transmittance of it.[37] The transmission heat transfer flow rate of a building envelope (Φ) is computed as: $\Phi = H_T\ (\theta_i - \theta_e) \quad \theta_i: internal\ temperature; \quad \theta_e: external\ temperature$

H_T: transmission heat coefficient and it depends on the direct heat transmission through the building envelope (H_D), the ground heat transmission (H_g), and the heat transmission through unconditioned spaces (H_U). This coefficient describes the heat flow rate through the building elements dividing two environmental temperatures.

Dealing with linear thermal transmittance means assuming that the thermal bridge has a uniform cross section along one orthogonal axe, then the point thermal bridge is a localized area influenced by a thermal transmittance. Here, the heat transmission depends on the area of the element (A_i), the thermal transmittance of the element (U_i), the length of the thermal bridge (l_k), the linear thermal transmittance (Ψ_k), and the point thermal transmittance (χ_j). The point thermal transmittance is usually neglective, then the following relationship can be shortened.

$$H_D = \sum_i A_i\ U_i + \sum_k l_k\ \Psi_k + \sum_j \chi_j$$

Superbonus 110%

The Superbonus is a subsidy provided by the Decreto Rilancio, article 119 form the decree law N.34 of 2020 “Misure urgenti in materia di salute e di sostegno al lavoro e all’economia”. This is active from 1 July 2020 to 30 June 2022 for specific interventions in the field of energy performance, anti-seismic interventions, installation of systems photovoltaic or infrastructure for charging electric vehicles in buildings. Those for energy requalification of buildings are called Super Ecobonus. [38]

This incentive measure aims to make homes a more efficient and safer place providing a mechanism where interventions are caried out at no cost for the citizen. The Superbonus is an instrument to rapidly activate the construction sector and respond to

[37] http://www.iuav.it/Ateneo1/docenti/architettu/docenti-st/Fabio-Pero/materiali-/corso-tecn/appli-03-14683-ISO_FDIS-ponti-termici.pdf

[38] https://www.agenziaentrate.gov.it/portale/superbonus-110%25

the important climatic and environmental challenges.[39] It also encourages the intervention of energy efficiency for instruments that with communication, robotics or other advanced technology methods benefits the mobility for people with disabilities or in an advanced age; the installation of electric vehicle charging stations; and photovoltaic solar systems. To accept the project the approval of the majority of proprietaries is needed. [40]

Ecobonus subsidy is granted when interventions are carried out that increase the level of energy performance of existing buildings. There are two groups of interventions that can be done in the renovation of a building:

- Main or driving interventions: reduction of energy requirements for heating; replacement of winter heating systems on the common parts or on property units; thermal improvement of the building; covering of the external structure with insulation materials; substitution of external doors and windows for ones of higher thermal efficiency; installation or replacement of window shutters;
- Additional or driven interventions: energy efficiency interventions; installation of solar panels for the production of hot water; panels installation of photovoltaic systems for the production of electric energy; replacement of water heating generator systems; elimination of architectural barriers.

In order to apply for the Ecobonus, at least one of the driving interventions must be caried out. Once this requirement has been met, the driven interventions can be implemented. The set of these interventions must involve a minimum improvement of at least two energy classes of the building. The company working on this project will receive a credit equal to 110% of the invoice value so they can have a 10% as monetary outlay. [41]

The Ecobonus provides economic incentive to specific interventions aimed at energy requalification carried out on common parts of residential condominium

[39] https://www.agenziaentrate.gov.it/portale/documents/20143/2665656/Risoluzione+n.+60+del+28+settembre+2020.pdf/078dfa15-2b90-b0d3-9c27-2c8026dbdfa4

[40] https://www.agenziaentrate.gov.it/portale/web/guest/schede/agevolazioni/detrazione-riqualificazione-energetica-55-2016/cosa-riqualificazione-55-2016

[41] https://www.governo.it/it/articolo/superbonus-110-case-pi-efficienti-e-sicure-costo-zero/15948

buildings or on individual real estate units within a condominium building. The deduction varies from 65% to 85% depending on the intervention and where the intervention is applied (real estate or common areas). [42]

This measure creates a cyclic market mechanism that offers benefits to all the involved: citizens can renovate their homes for free reducing the cost of bills; companies can increase their profits thanks to the higher volume of work; and the state can make homes more efficient and safer, and motivate employment increase.[43]

[42] https://www.mise.gov.it/index.php/it/incentivi/energia/superbonus-110
[43] https://temi.camera.it/leg18/post/pl18_app_detrazioni_fiscali_per_interventi_di_ristrutturazione_edilizia_e_di_efficienza_energetica.html

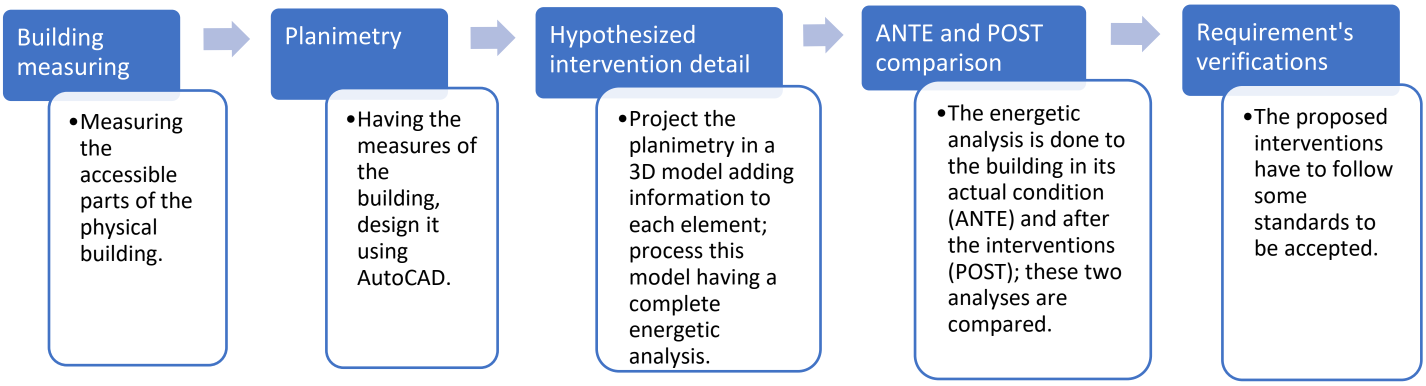
CHAPTER

3

Pre-Feasibility Study

The first stage of the project is the Pre-Feasibility study where the building is analysed in detail and the interventions to improve its energetic level are defined. This is a theorical phase which provides all information needed for continuing with the practical phase.

To have a better understanding of this first phase, a flow chart is shown with a step-by-step guide of the processes regarding the feasibility study.



Building Measuring

The first step is the measurement of the building. This is done manually; with a laser and a meter the building is measured both from the exterior and the interior, or using new technologies like a drone and a laser scanner which will measure in greater detail the exterior of the building, and if the space is the required, with the laser the interior can also be measured. The drone works with photogrammetry where the devise captures a big number of images of the top-view building from different angles, then these photos are overlapped forming a high quality and accurate 3D model of the building.[44] On the other hand, the laser works with a LIDAR system also reproducing a 3D representation of the building, where the laser reflects the object, in this case the building, and returns to the scanner devise as if the laser had "bounced" against the building. Like this, the system can generate a model of the building knowing the exact distance of each point of the structure from the device.[45] These two models can be blended perfectioning the model. This is done in some buildings because is a much expensive method which requires a certain knowledge for its use.

Due to privacy policies it's not possible to enter to each apartment, but the common areas and the back part are accessible. It´s important to measure every detail:

[44] https://wingtra.com/drone-photogrammetry-vs-lidar/
[45] https://www.motorpasion.com/tecnologia/que-es-un-lidar-y-como-funciona-el-sistema-de-medicion-y-deteccion-de-objetos-mediante-laser

doors both internal and external, in which sense the doors open, windows, stairs length, where the stair starts and where it ends, wall depths, hight of each floor, … All of these measures are recorded in centimetres [cm] with the already mentioned tools and are reported in a handmade scheme.

Figure 8. Laser scanner

Figure 9. Drone

Figure 10. Measurement elements

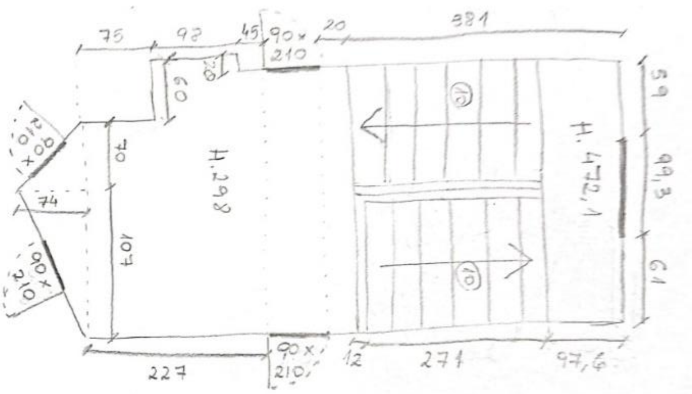


Figure 11. Scheme of the 1st floor [cm]

This project takes special attention to heated spaces, so these areas must be measured in great detail. Photos of the place are also required; this will be needed to have a better understanding of the scheme. The bell with the name of the proprietaries must be photographed to have an understanding of the amount of people leaving in the building. Photos of the structure showing the surroundings to contextualize the building. A photo of the front as straight as possible is needed so that this can be then rectified with a program to take the measures that were not able to be done manually.

Figure 12. a) Cell-phone image b) Rectified image

This rectifying process is done with the tool RDF_didattica.exe, program that works with distances in meters [m]. First some vertical and horizonal lines have to be marked by the user as shown in the table “Individua rette parallele” that produce the rectifications parameters in “Tabella dei parametri”. Then, the area to be rectified is selected in “Area di ricampionamento”, usually the total image. These steps are presented in Figure 4. Last, an object of the photo is selected uploading the real dimensions and selecting these measurements in the image, shown in “Definizione rapport x/y”. This last process is also visible in Figure 5. Having all this information the program strengths the image, and measurements from the image can be done where the program returns an approximate value of the real life considering the parameters inserted before. This measurement is shown in Figure 6.

Figure 13. RDF guide lines

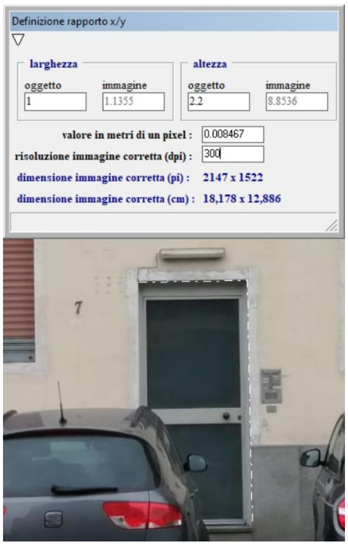


Figure 14. RDF definition of example-object

Figure 15. Real distance over rectified image

Some parts of the building are not accessible to measure manually nether to photograph as to use this las method. In these cases the structure can be analyse using Google Maps, Google Earth, or any similar tool that allows to observe the external structure of the building. In Figure 7 a Google Maps image of the building is used to complete the measures. Using AutoCAD, the sides of the building in image where measured, and knowing the real distance of one of the sides, the other real distance is easily computed.

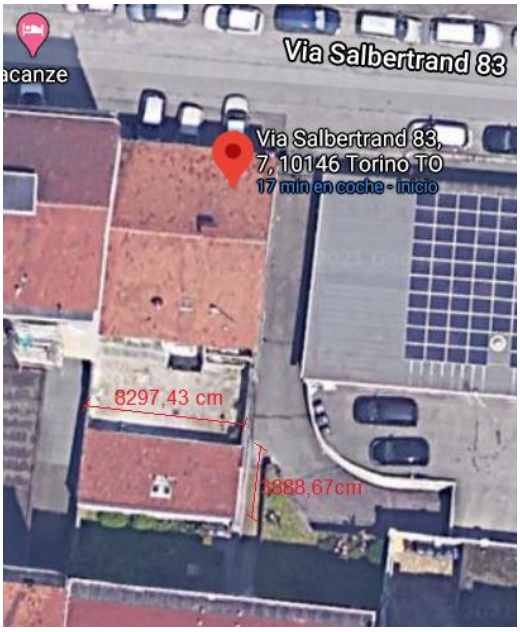


Figure 16. Google Maps view

This are all the measurements methods used during this process which were described from the most accurate to the less one. This process has to be documented, a folder is made where building information and the schemes are filed. The building information considers the property address, data of the building administrator, date of the survey, number of apartments, number of floors, number of common stairs, …

Planimetry

The information taken from the previous step is used to make a first basic plan of the building using AutoCAD. At the beginning only the floor plans are drown coting the basic distances, hights of each floor and basic elements (doors, windows, scales, …). Even dough the measurements of the internal apartments are not available, knowing the common areas and the front of the building these spaces are approximately designed.

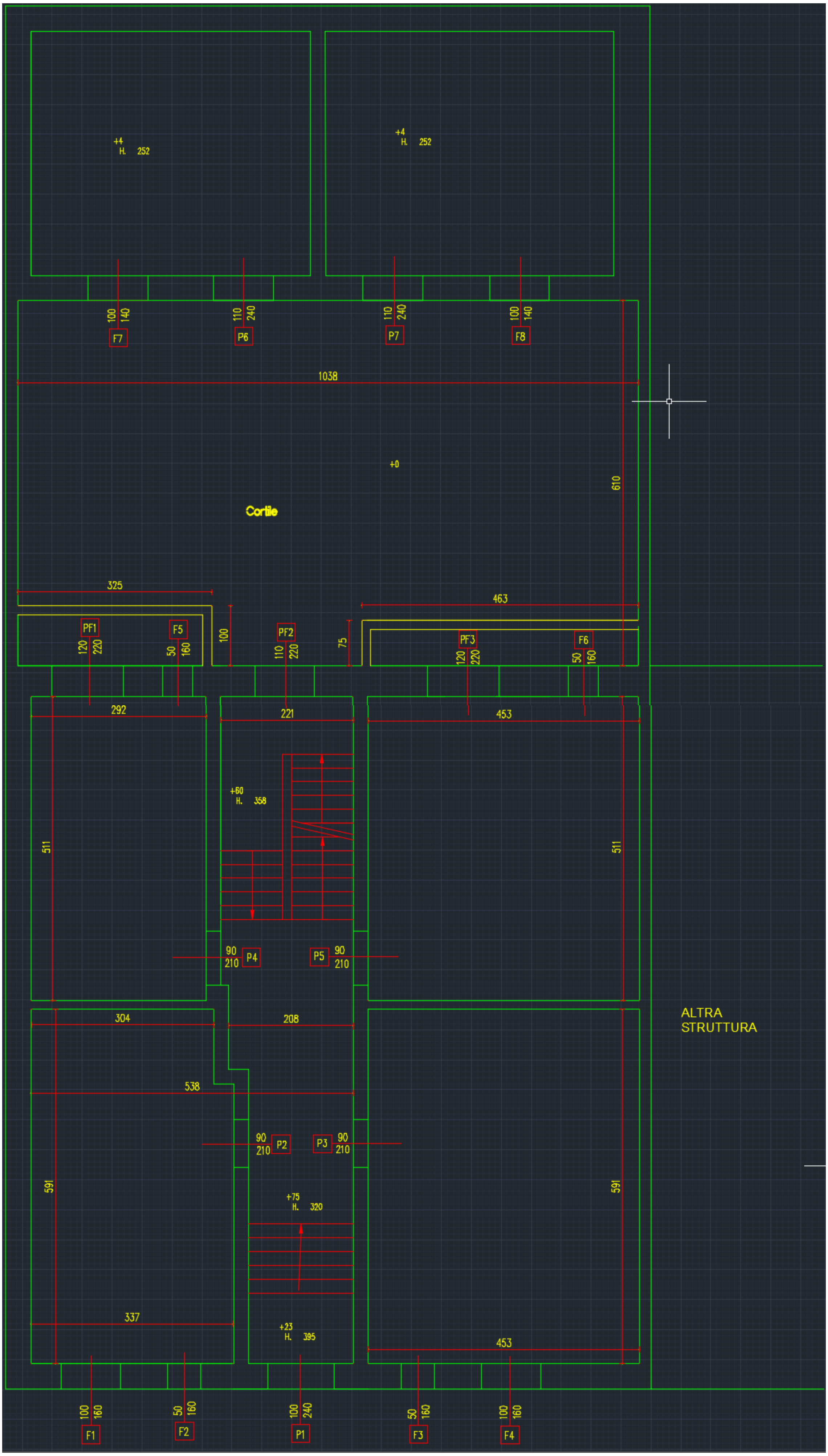


Figure 17. Ground floor plant

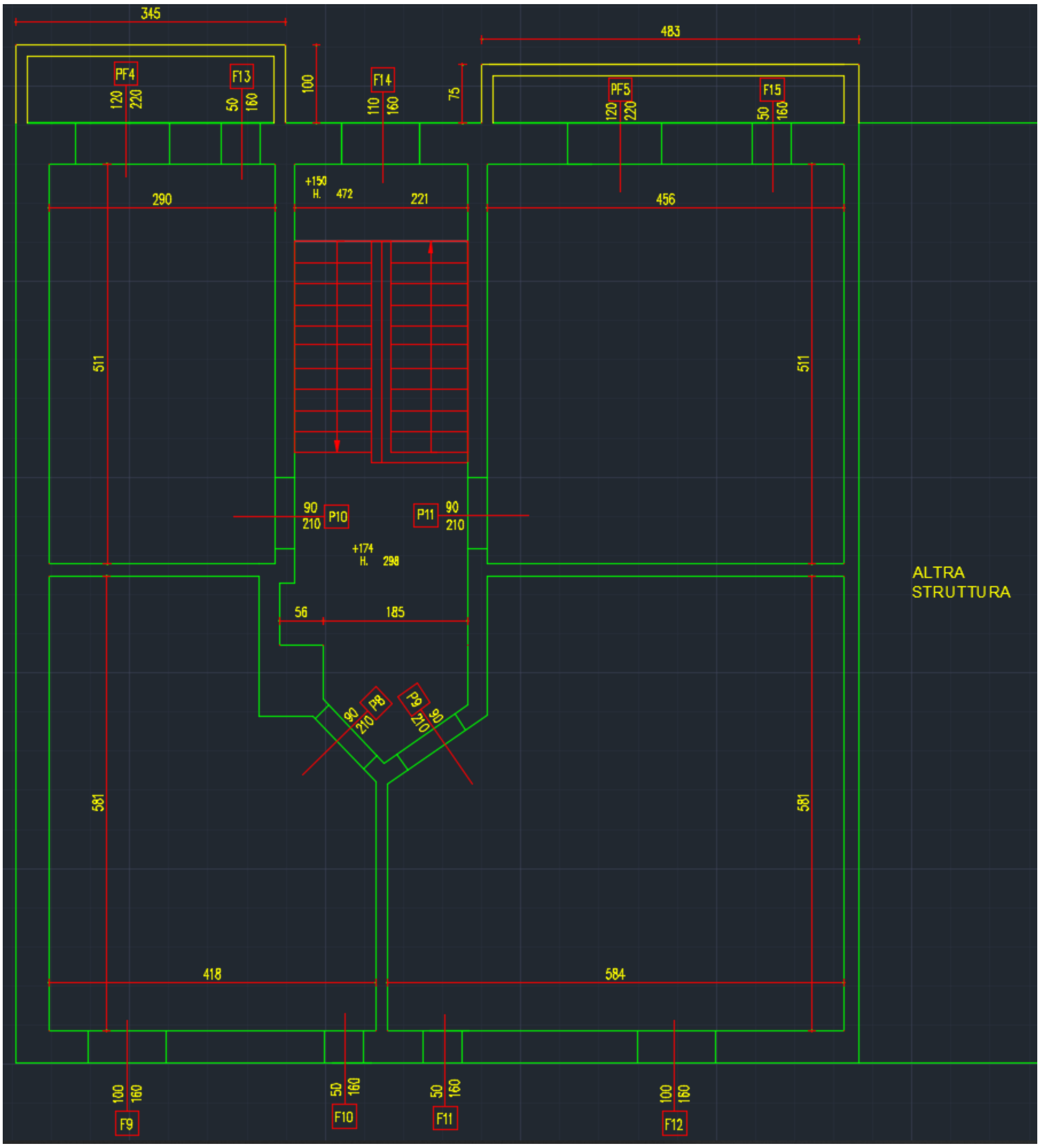


Figure 18. 1st floor plant

These are the prelaminar planes of the building based on the information previously collected. It´s observable that not all the measurements were included in this first plane (ex. opening of doors) or at least they were not coated (ex. walls depth) and in this first stage it´s not necessary to produce some cuts or draw the front of the building. However, it is appreciable the coat of each space, the numbering and dimensions of doors and windows (F: finestra = window; P: porta = door; PF: porta finestra = window door), balconies, and neighbour structures.

The dimensions that were not possible to measure were deduce. Internal walls depth 25cm; inter-apartment walls depth 15cm; external wall with neighbour structure (right wall) 20cm; external wall without neighbour structure (left wall) of the same size as front external wall.

Thermal Input Data

Before doing the energy analysis of the building, some thermal characteristics of it have to be defined. Knowing the behaviour of separate elements of the original building, the replacement of better versions is analysed. The elements of interest in this section are windows which will be replaced for more thermal resistant once, generators that will also be replaced for more energy efficient once, insulations and wall properties to know how and where to reinforce the external structure aiming to have a more energy efficient building. These elements will be one by one analysed to have a complete understanding on which interventions to apply.

- Window

As explained before, the thermal transmittance U is the average flow heat that passes through a square meter of area of an element dividing two spaces with different temperature and it's measured in W/m^{2}K. In the construction of a building, all the elements of it must have a low U value if the objective is to improve the energy performance.

In the particular case of windows, the calculation of Uw is an average value between the transmittance of the frame (Uf) and of the glass (Ug), and to consider the interaction between these two, the linear thermal transmittance (Ψ) is included in the relationship:

$$U_w = \frac{A_g\, U_g + A_f\, U_f + I_g\, \Psi}{A_g + A_f}$$

$$/\ A_g: glass\ area; A_f: frame\ area; I_g: glass\ perimeter$$

All these are values given by the fabricant, so it's easy to compute the total thermal transmittance of a window. By the Ministerial Decree 26/01/21, the Italian legislation determinates for the climatic area, the thermal transmittance maximum limit value of openings.

Zone	Gradi/giorno	U_{lim} [W/m²K]
A	< 600	3,7
B	600 – 900	2,4
C	900 – 1.400	2,1
D	1.400 – 2.100	2,0
E	2.100 – 3.000	1,8
F	> 3.000	1,6

Figure 20. Italian map of climatic zones

It’s observable how the U limit will be lower in the coldest areas. The Climatic Area of Turin is Zone E, then a transmittance of U=1,8 for windows should be respected in the construction of buildings. If the transmittance of windows is not going to be computed, this value can be used for the analysis of energy performance, assuming that the fabricant also considers this limit value.[46]

- Generators

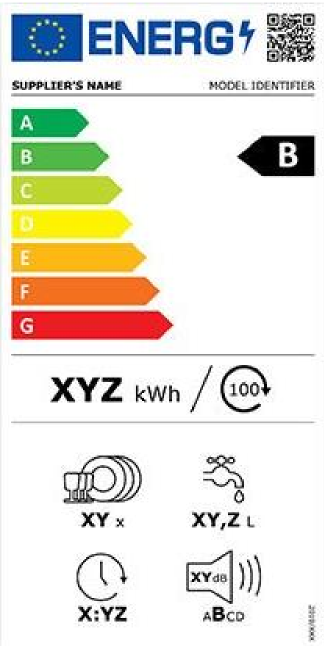


Figure 21. Energy label

Space heaters, water heaters and air conditioners, regardless of their type or fuel consumptions, have an energy label that identifies in a scale from A (efficient) to G (no-efficient) the energy performance of the unit. This is an important aspect to consider when replacing the unit, knowing that the aim of this project is to improve the energy performance.

Another aspect to take into account is the type of generator that is going to be installed, there are some options more friendly to the environment that others, as they were described in before sections, and the energy

[46] https://www.nurith.it/en/vantaggi/thermal-transmittance

source should also be noted. There are options to generate sustainable energy as a complement to fuel, this will have a better impact on the environment, an economical benefit and an improvement in the energy level of the building.

Last, the size of the generator has to be calculated to cover the needs of the building, without oversizing it because this will be unproductive and a waste of money. For this there are some tables that can help identify the type of generator needed for different residences, usually provided by the fabricant.[47]

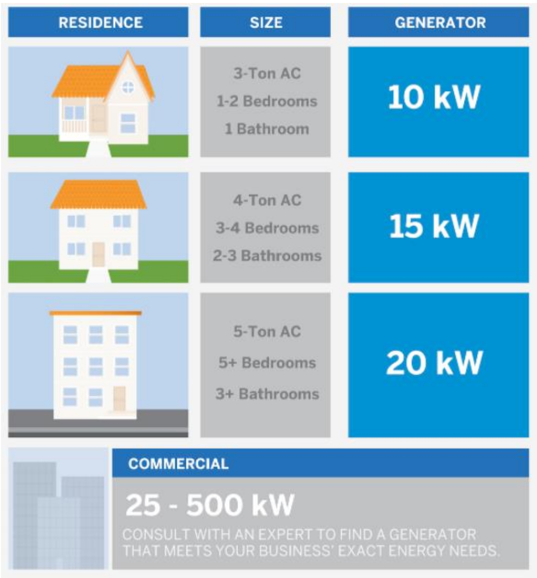


Figure 22. Demonstrative example of a generator size identification

This can also be computed knowing the total space that is going to be conditionate, the thermal transmittance of these spaces, and the openings presented in each room. The following computation of the power demanded to the generator is provided by the SIA 384 standard[48]:

$$\Phi_{gen,out,new} = \frac{m_{an} \, . GCV}{t_{an}} \frac{\eta_{an,old}}{\eta_{an,new}} \frac{1 + \eta_{an,new}}{2}$$

$\Phi_{gen,out,new}$: power of substitute thermal producer [kW];

m_{an}: annual average consumes of fuel [kg/m^3];

GCV: calorifc value [kWh/kg];

[47] https://www.constellation.com/guides/appliances/energy-efficient-generators.html#sizing
[48] 2781-Determinazione della potenza del generatore termico

t_{an}: operation at full load during a year [hr];

$\eta_{an,old}$: existing annual efficiency of calorific value;

$\eta_{an,new}$: new annual efficiency of calorific value with the substitute generator;

This calculation is for the replacement of a similar generator, in case of changing the type of generator, this power production is used as a reference, but it won't be of high precision. An example of the values used for a gas generator is presented in the next table:

2.6 RISCALDAMENTI A GAS

Potere calorico GCV del gas	
Gas naturale	10,4 kWh/m³ [1]
[1] *Il valore indicato è riferito a 0.98 bar, 15 °C (altopiano), per un metro cubo d'esercizio, come lo si può leggere dal contatore del gas.*	
Grado di rendimento η_{an}	
Caldaia nuova (a condensazione)	85 % a 95 %
Caldaia vecchia (non a condensazione)	80 % a 85 %

Figure 23. Gas generator values

- Insulations

The installation of external insulant to the walls is one of the interventions that will be done to all the buildings in renovation. To analyze which material should be use for the insulant, different aspects are compared.

Blanket insulations which are provided in rolls, are commonly used for this purpose, this is a soft and flexible material, easy to manipulate. They have to be cut in the desired shape before installing them, and its comfortable for insulation irregular surfaces. This can be made of fiberglass, rock wool mineral, natural fibers or plastic fibers, each having different thermal properties.

Foam board insulation is another format which presents a more rigid structure which is not possible to bend. This can be applied in walls, floors, ceilings and low roofs. This is a flammable material so it has to be covered with a gypsum board or any other similar fire-resistant material. This has a very high insulation value in a compact space which is an important characteristic. This is usually made of polystyrene, and is the material chosen for this project. [49]

Underneath, a table with the density (ρ) of each material and the thermal conductivity (λ). This is an important relationship when searching for a material that in a thin layer provides a good thermal insulation. The thermal conductivity measures for a room insulated by a specific material, the watts of heat flow through a meter of material until the protected space heat decreases a unit of kelvin.

Insulation material	ρ (kg/m^3)	λ (W/m K)
Glass wool panels (PLV)	20	0.043
Glass fibre mat (FFV)	11	0.053
Rock wool panels (PLR)	40	0.042
Rock fibre mat (FLR)	50	0.044
Extruded polystyrene (XPS)	33	0.038
Expanded polystyrene (EPS)	15	0.045
Expanded polyurethane (PUR)	30	0.038

Figure 24. Table of insulant characteristics

The R value is another important measure that must be considered, this is representative of the resistance to heat flow and is computed as the thickness of the insulant material needed to reach a desired heat flow.

The material chosen for the insulant panels in these renovations was the expanded polystyrene (EPS), which from the table it can be observed the good relationship between density and thermal conductivity, and compared to the rest of the materials is one of the best in this aspect. This characteristic is attributed to the many air pockets trapped in between the foam, and due to the small dimensions of this pores this is also a moisture resistant material. EPS has a high compressive strength, tolerating high levels of compression and making the material more durable. Different from other materials, this doesn’t release fibers when installing it, so it´s a safe product that doesn’t need special protection for its manipulation. Another aspect to consider is the economical one, a comparison between the prices of the different materials should be done before deciding which is the better option. The cost of its installation is very low because of the little equipment it requires. A negative characteristic of this material is its difficulty to recycle, so the polystyrene waste has a negative environmental

[49] https://www.servicechampions.net/blog/blanket-insulation-vs-board-insulation/

connotation and its production is also contaminant because it emits pollutants which are harmful for the atmosphere. [50]

- Thermal properties of Walls

To know where to apply the insulant reinforcement, a thermal analysis of the building envelope has to be done. The ability to maintain a thermal comfort in the indoor environments will be regulated by the materials and geometry constructing the envelope. A wall is conformed of different layers of materials which have different thickness and thermal conductivity. Under the hypothesis that the heat flows through the wall is one dimensional, the following equation explains the transient heat conduction[51]:

$$\lambda \frac{\partial^2 T}{\partial x^2}\bigg|_j = \rho\, C_p \frac{\partial T}{\partial t}\bigg|_j$$

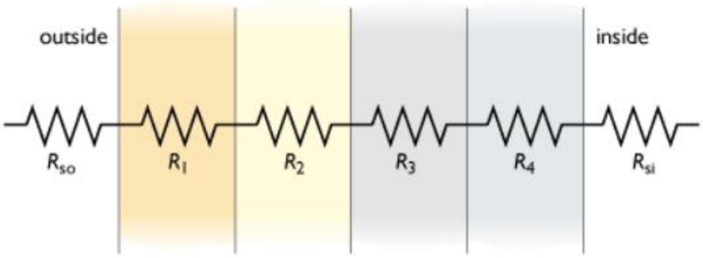
λ: thermal conductivity; ρ: density; C_p: specific heat capacity at constant pressure; T: temperature; x: space; t: time; j: layer number

Material	λ (W/m K)	ρ (kg/m³)	C_p (J/kg K)
Cement plastering	0.721	1762	840
Brick wall	0.811	1820	880
EPS insulation	0.035	24	1340
Cellular concrete	0.188	704	1050
Dense concrete	1.740	2410	880

Figure 25. Thermal characteristic of wall materials

This is a complex equation to understand the behavior of a multi-layered wall. However, having the thermal resistance of each layer, the total thermal resistance can be computed as the sum of them. And having the total R value, the U value is computed as the inverse of R.

[50] https://pricewiseinsulation.com.au/blog/is-polystyrene-a-good-insulator/
[51] http://www.ibpsa.org/proceedings/BSA2013/16.pdf



$$R_T = R_{out} + \sum R_i + R_{ins}; \quad U_T = \frac{1}{R_T}$$

In the following table an example is provided:

LAYER	l [mm]	λ [W/m.K]	R [m² K/W]
Outside surface			0,04
Cement	15	0,54	0,03
Brick	115	0,77	0,15
Mineral wool	40	0,035	1,14
Aeriated concrete block	40	0,11	0,64
Dense plaster	15	0,57	0,02
Inside surface			0,13
R_T			2,15
U_T [W/m²K]			0,47

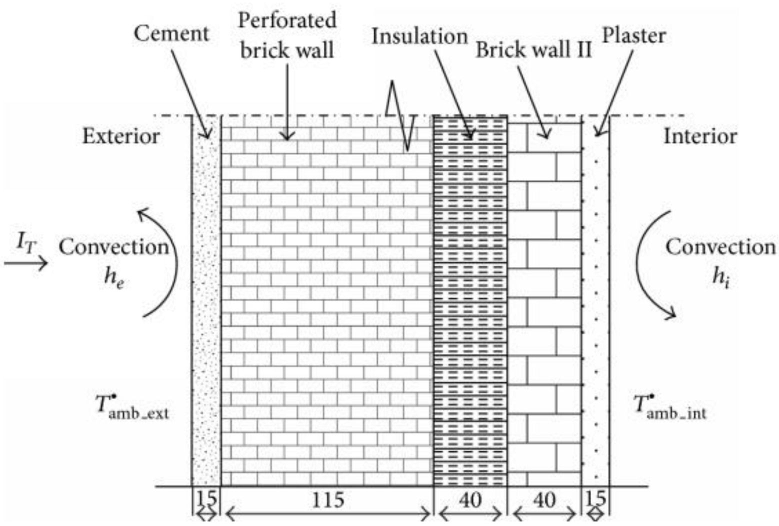


Figure 26. Multi-layer wall diagram

If the before chosen insulant is incorporated:

LAYER	l [mm]	λ [W/m.K]	R [m^2 K/W]
R_{old}			2,14
Insulation	40	0,038	1,05
R_T			3, 19
U_T [W/m^2K]			0,31

Is easy to appreciate the high increment of thermal resistance when the insulant is added.

Hypothesized Intervention Detail

In this phase it´s important to define the facilitating interventions between the ones proposed by the decree regarding the Superbonus 110, the chosen interventions must ensure the improvement of at least two energy levels of the building.

To certify the energy class of the building, an APE (Attestato Prestazione Energetica) of the total building is required. This is a document describing the energy characteristics of a building, it´s a control instrument that synthesizes the energy performance in a scale from A4 to G.[52] For this the certificate of energy performance of the hole building is computed for both, the building in the original state (ANTE) and the estimated building after the intervention (POST). This analysis is done by projecting the interventions and estimating with a software the efficiency of the ante and post building.

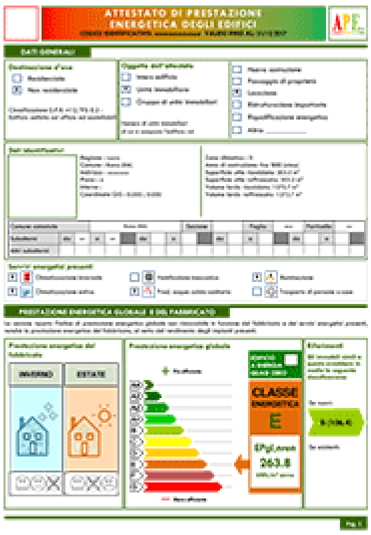


Figure 27. Example APE certification

There are different software’s for this process, in this particular project Edilclima was used. A 3D model of the building must be done using as a base the AutoCAD planimetries already designed, assigning to each constructive element the energy properties of the material and defining the heated areas. Having this information, the

[52] https://www.certificato-energetico.it/certificazione-energetica.html

APE can be computed. For the POST analysis the energy model must be done considering the energy interventions, this will we done starting from the ANTE model using its general data and adding the descriptions of the interventions which are: inserting the thermal isolates that improve the transmittance factor, making accessories up-grades in frames and windows, and substituting the heating systems adopting a more efficient one, between others. Last a comparative document of the ANTE and POST project is done. If in this comparation the energy level is improved at least two levels, the intervention is accepted, so it can be carried out. [53]

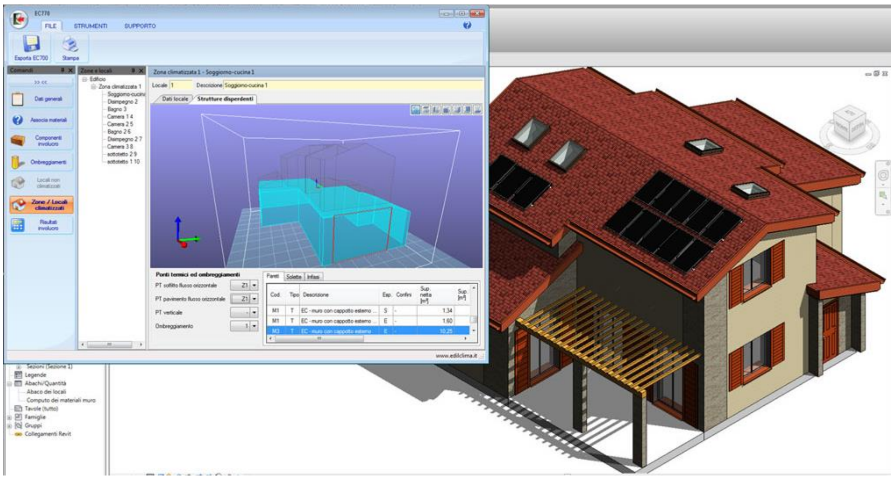


Figure 28. 3D model using Edilclima

Using Ediclima EC700 the procedural that is followed is:

1. Project information:

Insert input data such as the certifier name; building location; building category using the decree DPR 412/93; between other building characteristics.

This information is important, first, to identify the building, given that many structures can be analysed at the same time. Second, to define the climatic conditions that the norm identifies with the location and other characteristics. In the subsequent step, by determining the norm that is going to be followed and, in this step, by inserting general information of the building, many technical aspects are automatically defined. Here the importance of uploading this basic information of the building. For example, the location of the building will define the climatic zone, the category of the building will

[53] https://bim.acca.it/ecobonus-110-studio-di-fattibilita/

determine which kind of ventilation is needed, the orientation will establish to how many hours of shadow and light it will be exposed, … This is necessary to analyse how the climatic properties affect the building thermal transmission, thus how this will influence the thermal energy demand.

2. Climatic information:

Following the standard UNI 10349 – 2016 the program sets the limit values that must be considered.

The technical standard in use is identified, depending on the country or continent a different standard may be followed. Having defined the technical standard to be followed, limit conditions are imposed that must be verified by the building. Then, the energy analysis will be done under this frame, taking always in consideration the limit values. And after the ANTE analysis, the interventions to be done will be accepted only if they verify the standard.

3. Normative regime:

Use of the decree D. interm 26/06/15 and UNI/TS 11300

All the standards and regulations that are going to frame the process of energy evaluation must be noticed. As described in Chapter 3, these norms provide an accurate method of calculation for the energy analysis. From these, the most important points related to this project are the ones regarding renewable energy (UNI/TS 11300-4), the calculation of primary energy considering how much of this derives from renewable sources (UNI/TS 11300-5), and the APE report of the energy evaluation to standardized the study of every building (D. interm 26/06/15). There is an obvious tendency towards green energies and the norms are trying to make an incentive in this direction. This is why the interventions proposed must follow this tendency, and the APE study will help decide which interventions are more economically and ecologically convenient.

4. Default information:

Data about the internal and external temperature limits; type of internal ventilation; electric energy; … All this information is given as default by the program following the before assigned norms.

Limits are defined following the normative code, in this way, these conditions are imposed, so the analysis and possible intervention solutions will verify the norm. Many characteristics are not possible to measure with the tools provided for this project, so this is also useful to have an estimation of values instead of having the exact measurement. Using the limit value sometimes provides an overestimation which is necessary to leave a safety margin because when designing, all the possible influences are theatrically analysed but in the practice these aspects are in constant variation.

For example, the internal and external temperature cannot be known because it´s difficult to measure in precision and because it depends on many other factors, it not a constant. Then, by using the limit temperature values, the thermal energy demand is overestimated, but at least is a static result. When analysing which interventions to apply regarding the thermal aspects, this temperature limits will also be considered. It´s necessary to keep the same method of analysis during the complete process. A possible intervention is to change the heating generators, and this will be design considering the limit conditions described on this section that matches the limit values required for the installation of these generators. Then, the complete process follows a correlation and verifies the norm.

5. Define wall and floors:

Its components, location and how they connect spaces that are or are not heated. In the description of walls and floors the internal components of these must be assigned, each layer's material and dimension, if the wall is dividing two heated spaces or not, and other important information. It's also possible to create separation walls with no information for spaces that are not of interest like a wall between two non-heated locals. In the case of windows and doors, the material is defined, the location of this, and if there is a blackout curtain. Balconies are only described by the slab thickness, there is no detail on the material of these.

This is very important for the energy analysis, each of these elements have a thermal dissipation index which depends on their materials. Then, the temperature in a room will be kept as desired for an amount of time, this will depend on the elements that enclosure the room and its materials; on the neighbour room, if it´s also a heated space or not; and on the heating systems that are being used. So, by knowing in detail the structure and connection of walls and floors, it's possible to compute the dissipation index of the building and analyse for each room what's the energy demand required to keep the desired temperature inside the space.

From this step it´s also possible to suggest different interventions. Knowing the areas that need more dissipation support, thermal insulations can be recommended. Detecting the spaces exposed to high thermal variation (rooms next to the exterior of the building), the installation of heating systems can be proposed or changing the system for a more efficient one. These interventions have to be done considering the aim of the project that is to improve the energy level of the building.

6. Modelling:

The DWG from the planimetry step is loaded to the program, and the elements with information defined in point 5 are assigned to the planimetry as are the hight and lift of each local. Only the heated locals are important, the rest of the planimetry can be left without information.

Having the 3D model with elements attached to information, the analysis is more complete. Not only the materials and location of the elements are specified, but also the volume of this materials, and how they are disposed. This has a big impact on the energy study. Of course, bigger spaces will require of extra heating in winter, and more protection from the thermal dissipation. Like this, more aspects are identified and the interventions suggested can be more accurate.

7. Thermal bridges:

Defined when there is discontinuity in the structure, change of material or structural elements. For example, attic – wall intersection; wall – window intersection; pillars – wall intersection; division between locals of different temperature; … The type of thermal bridge and the location of it is specified. This is only defined in the post analysis because it considers the isolation which is part of the thermal intervention done to the building.

This is important to notice because losses of heat can occur in these points. The thermal bridges must be considered in the energy analysis given that they increase the energy demand required to keep a room with constant temperature. The isolation that will be added in the intervention is necessary to prevent these losses or diminish them, like this, lowering the energy demand and improving the energy level of the building. Other interventions can also be done regarding this situation. Changing windows and doors if they have a poor termination with the wall is a possible solution to decrease the consequences of a thermal bridge.

8. Characteristic of each local:

With the planimetry the locals are divided, to this some information must be attached such as the area; hight; internal temperature; ventilation; …

In this project only the heated spaces are studied so it's important to inform which locals are heated to know which ones to analyse. It´s also necessary to know climatic and volumetric information of each local as to recognize which room will be colder, what type of ventilation they need depending on their position, the surroundings of a room to understand how the temperature flow will be, … Having a deep understanding of the spaces, the interaction of these with neighbour rooms, and the climatic influences affecting the space, it's possible to do an accurate analysis of the energy consumption to maintain a constant temperature in the room with clean air and providing comfort for the occupant.

9. Dispersion area:

Define the area of windows, doors, walls, and floors; temperature of each face; and how much this element dissipates [W/ m^2 K]. A floor between two locals equally heated will have no dissipation. Meanwhile, a wall between a heated local and the exterior will have a lot of dissipation.

This is a more detail analysis of the elements where, again, the importance of the relation between two locals is highlighted. The structure's dissipation control depends on the materials of each element. In this project, working with old buildings, in general the elements of the structure have a high dissipation index, this is why an isolation membrane is set on the surface to have a better control over the losses. Despite the dissipation tolerance of the material, the temperature will flow toward the cooler room. Then, if a heated room is next to the outside of the building, this will lose its desired condition much faster as a consequence of the high temperature difference.

With this information, deductions on which locals need more thermal control are done. This means that more energy is going to be consumed for those locals that demand a greater assistance. Analysing this, not only the energy study can be perfectioned, but also the recommendations on which interventions to do and where to apply them.

10. Typology of the plant:

Description of the equipment used for heating; cooling; ventilation; heating of sanitary water; … In the case of renewable energy plants define if its thermic solar or photovoltaic. For these elements inform the type of terminal, the emission efficiency; water temperature and circulation; and characteristics of the generators. In this step the environmental standards must be followed.

The generators are the source of gas or electricity in the building, so it´s of great interest to know the energy consumption of them. In the buildings studied many old generators are found with low energy level. This has a big impact on the energy analysis of the building, and it will lower the energy class of it. Knowing this aspect, the intervention that can be proposed is changing the generators for ones with less energy consumption needed for the same performance. Of course, the economic aspect has to be also evaluated, and if the space is comfortable for doing this installation.

In the post analysis, where renewable energy plants may be introduced, the analysis is more interesting because alternative energy is considered, and this will clearly have a positive impact on the energy level of the building. Installing solar panels provides heat and hot water while photovoltaic panels produce energy, both from renewable sources.

11. APE certificate:

The software can start processing the information giving, as a result it returns a report with the thermal and energy information of the building, this report is the APE certificate.

This document is the one declared by the D. interm 26/06/15 for the Italian territory which is based on the terms provided by the UNI/TS 11300 standard. In this report all the before mentioned aspects are analysed together to have a complete review of the building. An integrated study is done considering the climatic information of the general building; the norms that must be verified; structural capacity to maintain the internal conditions in a constant comfort state; organization of the spaces; delicate points that worsen the thermal energy situation; and heating and cooling systems.

Having this complete analysis, the possible interventions to improve the energy level of the building are deduced. Once the interventions are chosen, an APE of the post building can be done estimating the final situation of the building. In this way, both, the ANTE and POST energy level are known, so this can be compared and the interventions studied in better profundity.

ANTE and POST Comparison

An example of a building that was studied is shared. In the following figures it´s exposed the consume of energy and gas of the building in the ANTE and POST state. This information derives from the APE analysis using the Ediclima software as explained before.

Prestazioni energetiche degli impianti e stima dei consumi di energia

	FONTI ENERGETICHE UTILIZZATE	Quantità annua consumata in uso standard (specificare unità di misura)
x	Energia elettrica da rete	30240 kWh
x	Gas naturale	17266 m³

Figure 29. APE study – ANTE

Prestazioni energetiche degli impianti e stima dei consumi di energia

	FONTI ENERGETICHE UTILIZZATE	Quantità annua consumata in uso standard (specificare unità di misura)
x	Energia elettrica da rete	67366 kWh
x	Gas naturale	2621 m³

Figure 30. APE study – POST

Using the corresponding transformations, it´s possible to know how much CO_2 these quantities of energy and gas represent:[54]

$$1m^3 gas \rightarrow 1{,}9kgCO_2; \quad 1MWh\ gas\ fired\ powered\ plant \rightarrow 185kgCO_2$$

Then the following calculation is done with an excel table:

gas:	1,9	kgCO2/m3
electricity:	0,185	kgCO2/kWh
apartment N°	17	

Building:

	ANTE		POST	
	gas	electricity	gas	electricity
APE	17266	30240	2621	67366
kgCO2	32805,4	5594,4	4979,9	12462,71
%	85	15	29	71
kgCO2	38399,8		17442,61	
Difference of more than		**2**	**times**	
Individual saving of		**1232,78**	**kgCO2/yr**	

Figure 31. CO2 emission analysis

Where the amount of CO_2 is computed having the indexes for each energy source, then the percentage of CO_2 for each source is computed knowing that the sum of gas and electricity emissions represent the 100%. In the ideal case where every apartment consumes the same number of services, the total emissions of CO_2 can be divided by the number of apartments. In this example the building has 17 apartments. Then the difference of CO_2 emitted in the ANTE and POST analysis per apartment is computed. Like this, a personalized estimation of CO_2 reduction can be given to the occupants.

[54]https://www.innovasjonnorge.no/globalassets/eea-grants/romania/ro-energy/energy-audit-call-for-proposals/er_6-conversion-guidelines-ghg_energy-audit_v0.2-14.03.2019.pdf

Figure 32. Route Torino - Lecce

The difference of the CO_2 emissions is an important value that should be noticed to the building occupants and proprietaries to analyse if they want to do the intervention. The measure of unit $kgCO_2$ it may be difficult to understand for people that are not merged in the topic given that this is not a measure used in the day to day. This is why the search of a more tangible comparison was an interesting challenge. By dividing the values of the total CO_2 emission for the ANTE and the POST analysis it´s easy to show the difference between these two, as marked at the bottom of figure 15. However, a more demonstrative interpretation was made. If a regular car consumes $404 \frac{gCO_2}{mile} = \frac{0{,}404}{1{,}609} \frac{kgCO_2}{km} = 0{,}251 \frac{kgCO_2}{km}$, and the route in car from Turin (Nord Italia) to Lecce (Sud Italia) is of 1148km then this trip emits a total of $0{,}251 \frac{kgCO_2}{km} \cdot 1148\text{km} = 288{,}15\ kgCO_2$. So, in the ANTE analysis the building emits an amount of CO_2 equal to 133 trips, while the POST building is equal to almost 60 trips. The same interpretation can be done to the individual reduction of CO_2 having that each apartment is reducing the same number of emissions as 4 trips.

It's also important to specify how much these values represent in money as to inform the residents on the amount of money they will be saving after the interventions. In the following table the cost of a kWh electricity is specified for domestic residences.

Consumo annuo	4,5 kW
1000 kWh	€ 0,31
1.500 kWh	€ 0,25
2.100 kWh	€ 0,23
2.700 kWh	€ 0,22
3.300 kWh	€ 0,21
3.900 kWh	€ 0,21
4.500 kWh	€ 0,20
5.000 kWh	€ 0,20

Figure 33. Cost of kWh for domestic residence[55]

From figure 13 and 14 the consume of all the building is provided, knowing that this particular building has 17 apartments the consume of the total building is divided in the amount of apartments as to define the cost of a kWh using the table of figure 17.

On the other hand, the cost of a standard m^3 (smc) of gas depends on the region of residence and the average annual consumption. The price established by the Energy, Gas and Water System Authority for smc gas is between 0,85 and 1,20€. Taking the average value, the cost of gas will be considered to be 1€/m^3. [56]Multiplying this index by the amount of gas consumed presented in the APE reports the cost of gas is computed. Last, the cost of both services is summed having the total tariff for the whole building per year. Following the same example than before, the calculations were made with excel:

[55]https://taglialabolletta.it/quanto-costa-un-kwh/
[56]https://www.facile.it/energia-luce-gas/tag/costo-metro-cubo-gas.html

gas:	1,9	kgCO2/m3
electricity:	0,185	kgCO2/kWh
apartment N°	17	

kWh	€/kWh
1000	0,069
1500	0,056
2100	0,051
2700	0,049
3300	0,047
3900	0,047
4500	0,044
5000	0,044

Building:

	ANTE		POST	
	gas	electricity	gas	electricity
APE	**17266**	**30240**	**2621**	**67366**
kgCO2	32805,4	5594,4	4979,9	12462,71
%	85	15	29	71
kgCO2	38399,8		17442,61	
Difference of more than		**2**	**times**	
Individual saving of		**1232,78**	**kgCO2/yr**	
kWh/apartment		1779		3963
€/kWh		0,056		0,047
€/m3	0,154		0,154	
total €	4352,40		3569,84	
individual €	256,02		209,99	
Total saving of		**782,57**	**€/yr**	
Individual saving of		**46,03**	**€/yr**	

Figure 34. CO2 and economic analysis

If every apartment consumes the same in services (ideal case) it´s possible to divide the total cost in the amount of apartments as to present a more individualized situation to the building occupants. As a result, for this example, each apartment is saving 46€/yr and 1232,78 kgCO2/yr.

This information is presented to the occupants of the building in study, and knowing this they should decide whether they want to start the intervention or not. To approve the renovation, a majority of proprietaries must accept the project.

In Appendix B, an example report of what is shown to the building occupants its presented.

Requirement’s Verifications

As to know which interventions to apply, different criterions are used. Of course, all of the criterions must verify the requirement of the norms, and some of them will be the specifications of the norms. The decision of the interventions to consider for a building does not derive from an exact calculation but is a consideration of different aspects. There are also many limitations, this is why the aim is not to improve as much as possible the energy level of the building, but to always follow the normative and the Superbonus 110% specifications while improving some energy levels.

First, the building must be observed and some necessary modifications will be easily noticed. For example, if a building has windows with old materials or thin glasses, the changing of windows is an intervention that is need to be done. However, if a building has a very old electrical generator that consumes a lot of energy, but the space doesn't allow to replace it for a newer one because a new one requires more space or because there is no space for the installation, then this intervention will not be done. Like this, with some intuition and professional experience, the principal interventions are noticed.

Then, the Superbonus specifies that the interventions must lead to an improvement of two energy levels. So, the objective will be to do the necessary interventions to improve only two energy levels, no more, no less. This is because a bigger improvement would require more financial support for carrying out the interventions, and the bonus destinates a specific amount of money per intervention. This economical limitation must be considered as well as the necessary improvement of two energy levels set by the normative, when considering which interventions and on which amount are going to be done.

Another specification of the Superbonus is that a majority of occupants have to accept the project for this to be done, this means that the interventions have to be accepted by the occupants or proprietaries of the building. Then, after studying which renovations or installations are more suited for the building, these have to be discussed with the residents to decide which interventions are going to be carried out and which are not. The occupant will also decide if he wants an intervention to be done in the inside of his private apartment, besides the work that will be done to the common areas of the building.

The decree also describes some main or driving interventions which must be done, so this will be the first to consider. After analysing the energy impact of these, the additional or driven interventions are studied. Following this criterion, the minimum necessary interventions that should be first contemplated are: the energy consumption for heating; replacement heating systems; external isolation of the structure; substitution of external doors and windows; and installation of window shutters.

Last but not least, the interventions chosen for a building must follow the normative for building renovation in the Italian territory. This are the standards and regulations expressed in Chapter 3. This verification must be done, it’s not possible to proceed with the project if an intervention is not in norm.

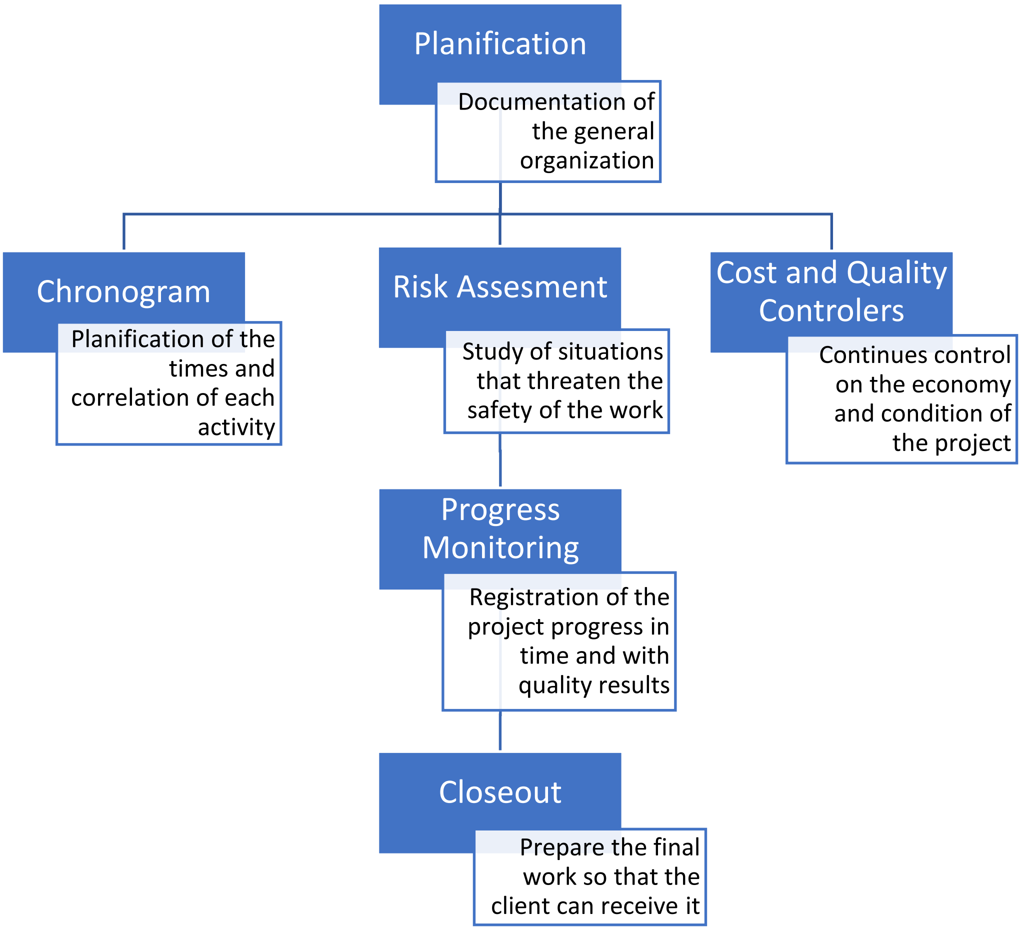
CHAPTER

4

Work on Site

Second stage is the work on site, the project is now on its practice phase where the interventions previously analysed are being done to the building. A description of this process is detailed.

The Project Manager will provide an organize structure for achieving an optimal work. This must follow very closely every step of the building renovation including those aspects outside the work on site, as are the documentations, relationship with subcontractors, between others. This is a very detailed organization where every activity forms part of an integrated project. Different from the Pre-Feasibility study, in this section there is not a chronological order for the aspects to analyse, but many "steps" of the process have to be done at the same time, and will be developed simultaneously. This requires a very organized and capable group of work given to the complexity of the project. Following, a diagram with the main structure of this stage: [57]



Planification

In this first stage it´s important to maintain a close relationship with clients as to achieve the customer satisfaction which is one of the main objectives. The contract will

[57] https://www.infobuild.it/approfondimenti/cosa-fa-project-manager-mondo-costruzioni/

define the main structure considering the timing of the complete operation, the site measures and safety norms that must be followed. In this specific case, a flexible contract is defined by the Italian government which provides the bonus encouragement, and using this as a base, for each specific situation the contract will be adjusted to the agreement defined between the contractor and the client.[58]

In this face, the subcontractors have to be contacted.

Organisation of the activities to be carried out for the complete procedural and planification of a work division assigning different responsibilities to the correspondent professional. As a group, decide which techniques of construction and strategies are more suitable for the project.

Interventions

- Replacement of heating systems

The first step for replacing a heating system is to consider all the new technologies and be informed about it. With the correct research, it’s possible to find furnaces with 98% of efficiency. Another important aspect to consider is the space that is going to be heated, if this space has good thermal resistance windows, if the walls are protected with an insulant structure, and other factors that help measure the demand of the space. To have the optimal system, a correct analysis of the space in use has to be done as not to make an over dimension of the generators. This will ensure an energy saving and an economical advantage. It should also be analyzed which spaces have more use as to install the heating system in the correct position. There are some rooms that may not need a heating system, but can be heated by the one on the next room. This means a good design and planification of the intervention.[59]

[58] https://piemontese.aicqna.it/files/2016/06/Federico-Rizzo-Il-Project-Manager-nel-Settore-Costruzioni.pdf

[59] https://www.netrinc.com/blog/top-5-mistakes-to-avoid-in-replacing-a-heating-system/

Following, a description of the installation of a combined boiler and water heater. It has to be considered that this is one of the many possible options, some others will be next explained.

First the generator unit is located in a proper and comfortable space, it should be easy to access if maintenance or reparations should be done, and it must be easy to connect the generator to the other spaces of the house. Then, the location is one important thing to consider. Ones the unit is positioned, some holes have to be done as to ventilate with the exterior, one hole for the flue gas to go from the unit to the exterior and another for air to come from the exterior to the unit as to be burned, this last is the combustion air. Two PVC pipes are connected to the unit to go from the generator to the exterior, and these are the two channels that were explained before. The intake and the exhaust are not covered at the end of the PVC that is exposed to the exterior, as to permit a proper ventilation, but a screen is collocated as to avoid birds or bugs entering to it. The ventilation must be above the snow line so this is not blocked; the exhaust has to be at least 30cm under openings, and between the intake and the exhaust there has to be at least 30cm spearing them, so that the flue gas expelled does not enter again as combustion air.

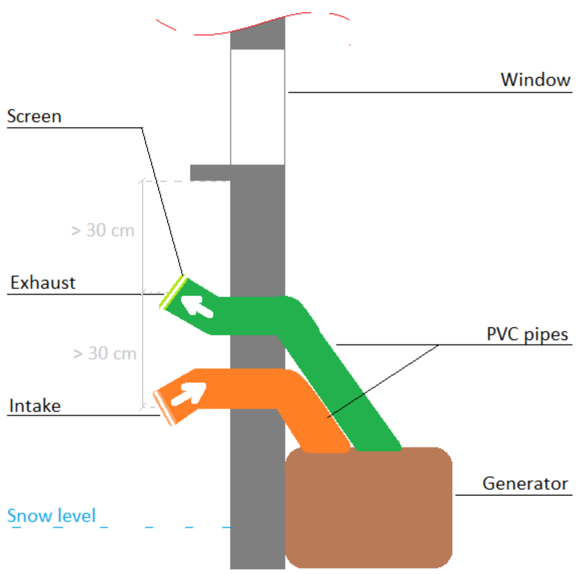


Figure 35. Generator installation diagram

Then the piping process gets started. There are hot and cold pipes which are connected to the whole house, supply and return pipes to the heating system connected to the convectors, a circulator pump that will induce the heat flow, and the gas connection to the combined boiler (water heating and central heating boiler combined in a unit). The supply pipe is in charge of providing water to the house. The return pipe is where the condensate water, product of a heater or radiation, is deflected back to the boiler. Accessory to measure pressure must be ensure and values to permeate the flow of water are also installed. Steel pipes are put together by welding the joint. A modulating gas valve can also be installed, this will regulate the load needed of firing power with an outdoor temperature sensor measuring the temperature average and setting the necessary power of fire considering this factor. Like this, the boiler is not always working at is maximum power, being more efficient and saving energy. The condensate water that is left over, that goes in the return pipes, goes to a limestone neutralizer to take the acid of the water and with a condensate pump this water is pumped over the sink to be used.[60]

Another solution to changing the generator units can be to change the radiators of each room that work with gas, to electric radiators, which are more energy efficient and have an easier maintenance. The installation of electric radiators is very easy, it depends on the model that has been bought but they are all similar, and they have uncomplicated instruction for the proper installation.

Before starting the installation of the electric heating system, the gas radiator (which is the most common radiator use in Italian buildings) has to be removed. For this the central heating system has to be turned off and before starting to manipulate the radiator, the system must be let to cool to avoid injuries. Once the system is cold, the radiator has to be turn off. This has two valves, the lock shield and the thermostatic valve. The thermostatic is easy to turn off, for this the head valve has to be rotated up to the 0 position, if the thermostatic doesn't have a head, this can be an accessory that has to be connected to the top part of the thermostatic. For the lock shield valve, the plastic cap is taken by manually pulling it up, sometimes this is screwed, in that case it has to be first unscrewed to be able to take the cup off. Then, using locker pilers the

[60] https://www.youtube.com/watch?v=BuxvKbIIYLU&ab_channel=ThisOldHouse

valve is turned off by turning it clockwise. Like this the radiator is isolated from the heating system, the is possible to continue with the drainage. A small bucket or something similar is collocated under the radiator to contain the water that is going to be drained. With locker pilers the pipe of the thermostatic valve is loosen up being careful not to damage the pipe, and the water is drained, when the water stops its flow, the blade point is opened with a special key so air can enter into the radiator so the remaining water is pulled off the system. When the water has been completely taken out of the system, the blade point is adjusted again and the knot of the lock shield valve is released so the radiator can be lifted to one side. In this process some more water may be drained. Once the radiator is completely detached from the pipes, this can be removed from the wall by easily pulling it off the rails from the wall.[61]

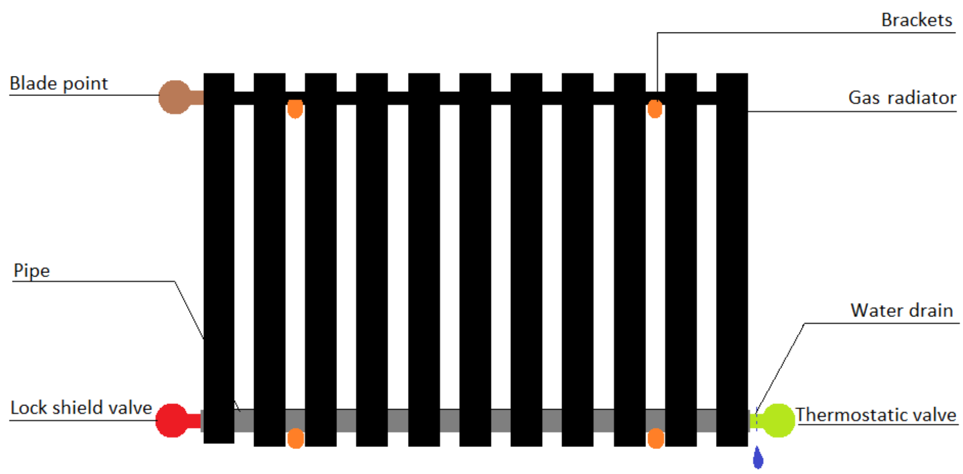


Figure 36. Gas radiator diagram

Having the previous radiator removed, the new radiator can be now installed. The first step is to hang the radiator on its decided place. With four brackets, one for each corner, which have a plastic protection at the end, the radiator will be hold to the wall. The brackets are screwed to the wall and they will fit between the radiator columns.

Then the heating elements, which must be sized for each radiator, are collocated, there is a termer and in the modern ones there can be a Bluetooth as to regulate the heater from the phone or any other intelligent device. These heating

[61] https://www.youtube.com/watch?v=x0wMpq2LUSY&ab_channel=AllenHart

elements are inserted at the bottom of the radiator, inside a cylinder section embedded in the radiator. Last the cable of the radiator will be connected to an electric entrance. [62]

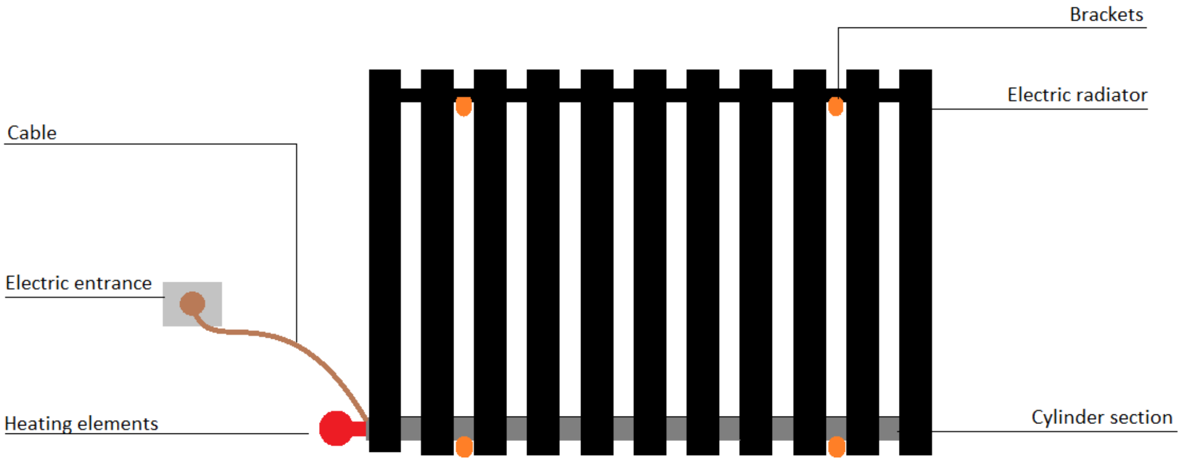


Figure 37. Electrical radiator diagram

- Solar panels installation

It's important to first analyze the adequate conditions for a solar panel installation considering the sun exposure, the obstacles to the sun light that should tend to cero, and the correct space for the installation. The number of arrays to install are calculated depending on the occupant's consumption.

First extensions are installed in the roof. These elements have a lag bolt that goes through the roof until the main roof beam which provides stability, and a point end with a length of 15cm over the roof. On top of this, an aluminum rial is attached by using screws. Over conduit wiring is done for each array, the conducts follow the line of the rial, once these connections are done, the panels will be wired to this. An alternative to this step is to have multiple panels wired up in series with each other as to generate more current, and they will feed a central inverter which is located next to the circuit. The negative aspect of connecting the panels in series is that if only one panel is malfunctioning, then the whole circuit will be interrupted. To avoid this, another option

[62]https://www.youtube.com/watch?v=1VnvL9ALfAQ&t=151s&ab_channel=TheRestorationCouple

is to wire the panels in parallel and to install micro inverters under each panel. This last option is the one chosen in this case. The inverters will convert DC current (power collected by the panels) to AC current (current that the house will use). For the installation of this, the DC circuit coming from the panel has to be connected on the entrance of the micro inverter and the AC output will be connected to the circuit that was before settle. Last the panel is installed, attaching it to the rials with screws, and conceiting the panel to the DC input of the micro inverter.

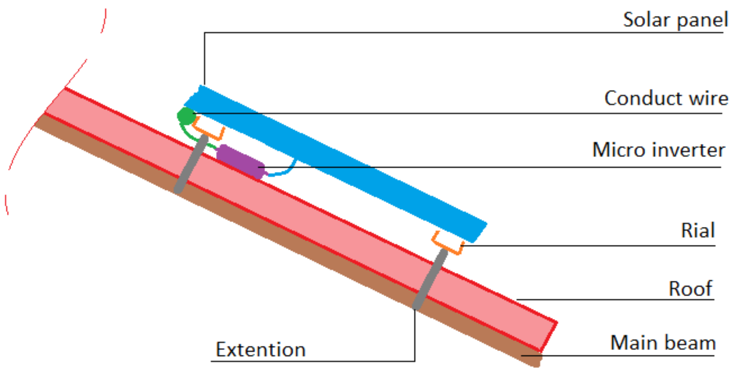


Figure 38 . Transversal view of solar panel

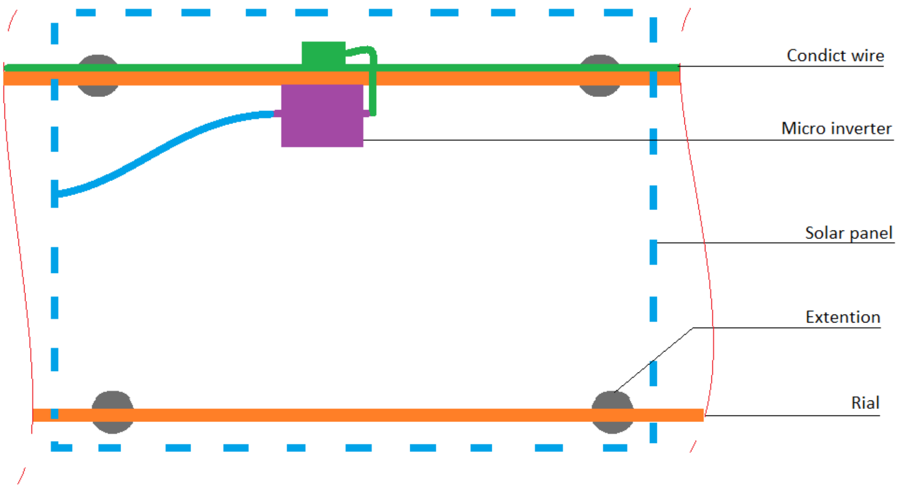


Figure 39. Top view of solar panel

Once the panel is installed, the wiring is finished from the basement. The solar power from the roof goes down to the basement through the conduit where an electric meter will measure the solar production of energy. The wire continues through the meter up to an electrical panel of the house where the last connections will be done. In this connection there are three wires, the ground connected necessary to neutralized the circuit used for security reasons, and the other two wires that will be connected to a breaker and it will be used as back feeding power to the house.[63]

- External isolation of the structure

The correct installation of a system of insulation requires first an accurate control of the support wall which will be used as a base, analyzing its verticality and planarity. A baseboard is collocated at the bottom part of the wall at 1 or 2cm from the floor as to guarantee the correct protection of the bottom part of the insulation and to create a perfectly stable base for the system. After cutting the edges of the baseboard as to follow the wall shape and length, this is placed in the wall with screws considering a perfect horizontality.

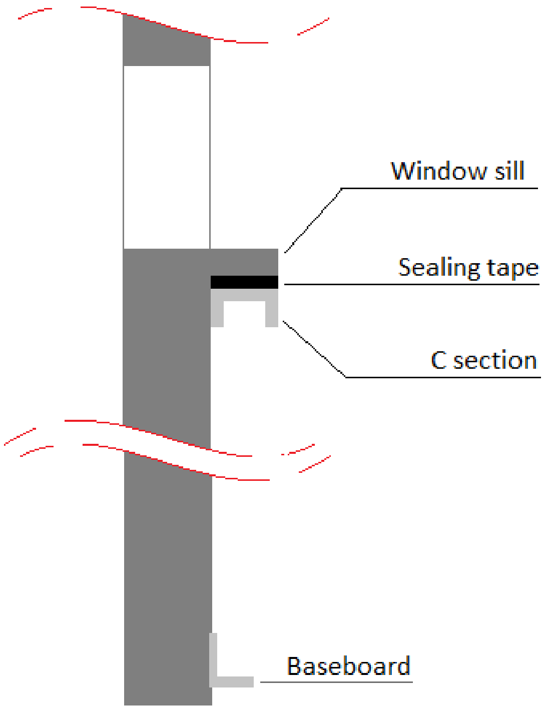


Figure 40. Window sill and baseboard

If there are window sills that can´t be taken away, this has to be prolongated as to provide the necessary space for the insulant. This is done with a light steel C section that is cut considering the length of the window still, and is collocated under this. In

[63] https://www.youtube.com/watch?v=subiaaXBoDI&ab_channel=ThisOldHouse

between the window and the C section, a self-expanding sealing tape is collocated to ensure a perfect sealing. This tape will enlarge its volume 7 times its initial width within an hour, like this, the passage of air or water is completely denied between these two elements. Once the tape is collocated, the C section is installed with screws underneath it.

Before starting with the installation of the insulant panels, this must be cut considering the necessary measures to cover, the spaces for windows and doors, and some decorative features that must be considered in the shape of the panels. This is done with a precise cutter of hot wire. An adhesive mortar is prepared for the correct installation of the insulant panels. This mix is spread over the face of the panel that is going to be collocated against the wall, like this an adequate installation is ensured blocking any possible movement between this area and the wall, but allowing the dilatation of materials due to temperature.

The panels used for insulation are of sintered expanded polystyrene with a density of 20 kg/m^3. This is correctly positioned in a horizontal direction starting from the baseboard, where the mortar should have no effect on the width of the total installation. At the edge of the wall, the panels will be collocated some few centimeters exceeding the wall length in an alternated order, as to produce a perfect fit with the panels of the other face of the wall.

Figure 41. Sintered expanded polystyrene

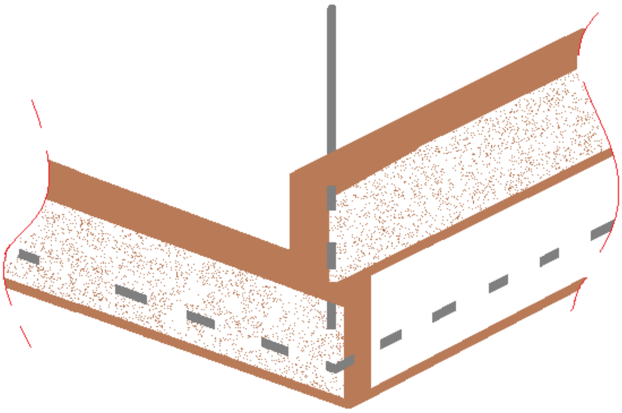


Figure 42. Polystyrene colocation

In openings, the insulant panels are cut in an L shape as to avoid joints in points with accumulation of superficial tension. If, due to an error in the installation, there is a leakage in between the panels, this will be corrected by covering the space with thin special insulating slice.

After 24hs of rest, when the mortar has been correctly hardened, the panels can be screwed. The screws must have a length equal to the anchorage defined by the technical standards plus the width of the panels. The screws are collocated in the central parts of the panels and other strategical points, and the polystyrene is cut around the screw while inserting it in the material, as to ensure a good attachment and blocking it at the perfect profundity. This small circle cuts in the panels around each screw, is seal by a polystyrene circle covering the exact dimensions, permitting the perfect planarity and eliminating the possible punctual thermal bridges.

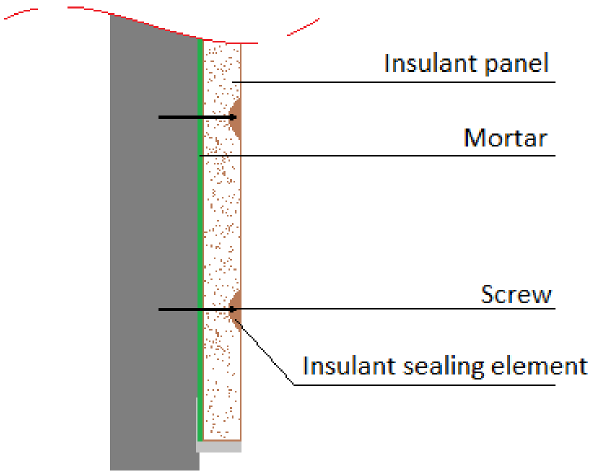


Figure 43. Transversal view of insulant installation

The colocation of panels in the window frame must include the adequate accessories to provide a perfect sealing. A mesh is positioned between the frame and the insulant which secures a perfect joint with no movement between these parts, avoiding cracks and avoiding the entrance of air or water. The mash has an adhesive side which is collocated in the window frame as to have a perfect sealing with the opening, then the panel is collocated, and the mash is adhered to the panel with mortar. This insulant panels will have a reduced width and a grater insulant power, a panel of expanded polystyrene with graphite as additive is used which has a better thermal conductivity.[64]

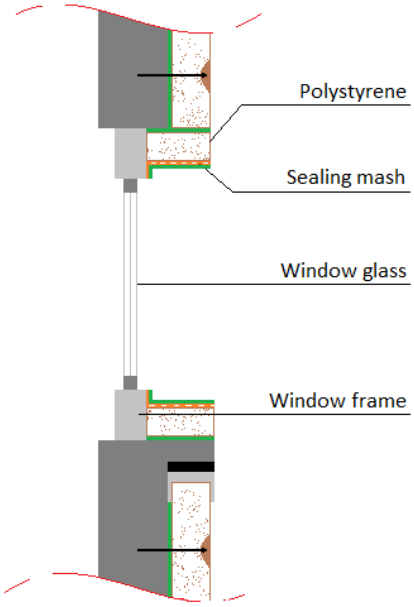


Figure 44. Transversal view of insulant installation in window

Before starting with the reinforced armor layer, some accessories must be applied, as mash of reinforcement and profiles to avoid cracks and support the loadings. The cylinder profiles of aluminum cross the polystyrene making a hole in it, and reaching the wall in the specific point of loading, then adjust with screws. Then, for the support of light loads, a hole of depth 1cm is done in the polystyrene that is then covered with a plastic shield.

Now, the structure is reinforced. First, cracks at 45° around the windows are avoided by covering the panels on every side of the window with a plastic mash that is adhered using mortar. The same process is done to the whole frame, the plastic mash is collocated starting from the insulant panel of the window frame and it covers all the panels surrounding the window. The same process is done in the angular between two walls, the edges are covered with this mash. Then, the whole wall of insulant is covered with mortar, and an armor mash is assembled, superposing any other element before

[64] https://www.infobuild.it/approfondimenti/facciate-ventilate-soluzione-molti-vantaggi/#:~:text=Una%20facciata%20ventilata%2C%20prevede%20un,viene%20aggiunto%20uno%20strato%20isolante

installed. After 24hs of rest, a new hand of mortar is applied to the structure as to have a perfect adhesion of the mash.

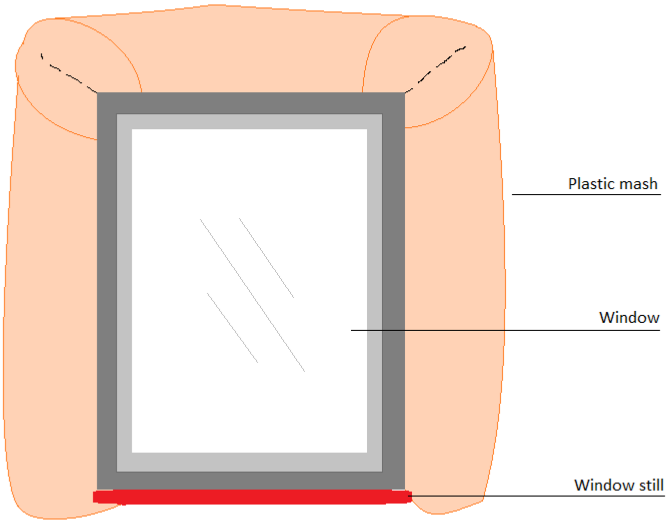


Figure 45. Front view of insulant installation in window

Some decorative elements are inserted at the top and bottom of the walls depending on the design of the façade. After around 6 days, when the mortar is totally hardened, the façade can be painted, like this, the w all will absolve better the colors. [65]

Controllers

The work on site must be constantly controlled as to ensure a correct procedural, as to be efficient and accomplish the work on the schedule time, and to control there is no waste of money.

Doing a chronogram is necessary first to organise and program the work, and second to verify that this is being correctly followed. A chronogram is a procedural guide for the management of all the activities to optimise the time consumption of each activity and the lapse of the whole operation. This must follow the contractual timing, and using it as a reference, the construction logistics must be analysed. The chronogram is used to organize the activities and during the renovation process, to verify the correct advance of the project.

[65] https://www.youtube.com/watch?v=jraVh2g22OY&ab_channel=leoluongo

A chronogram of the interventions before explained is done. It must be considered that not all the interventions are dependent, meaning that they could be done in parallel, but due to the lack of workers, they won't be done at the same time. In continuation, an example chronogram is shown:

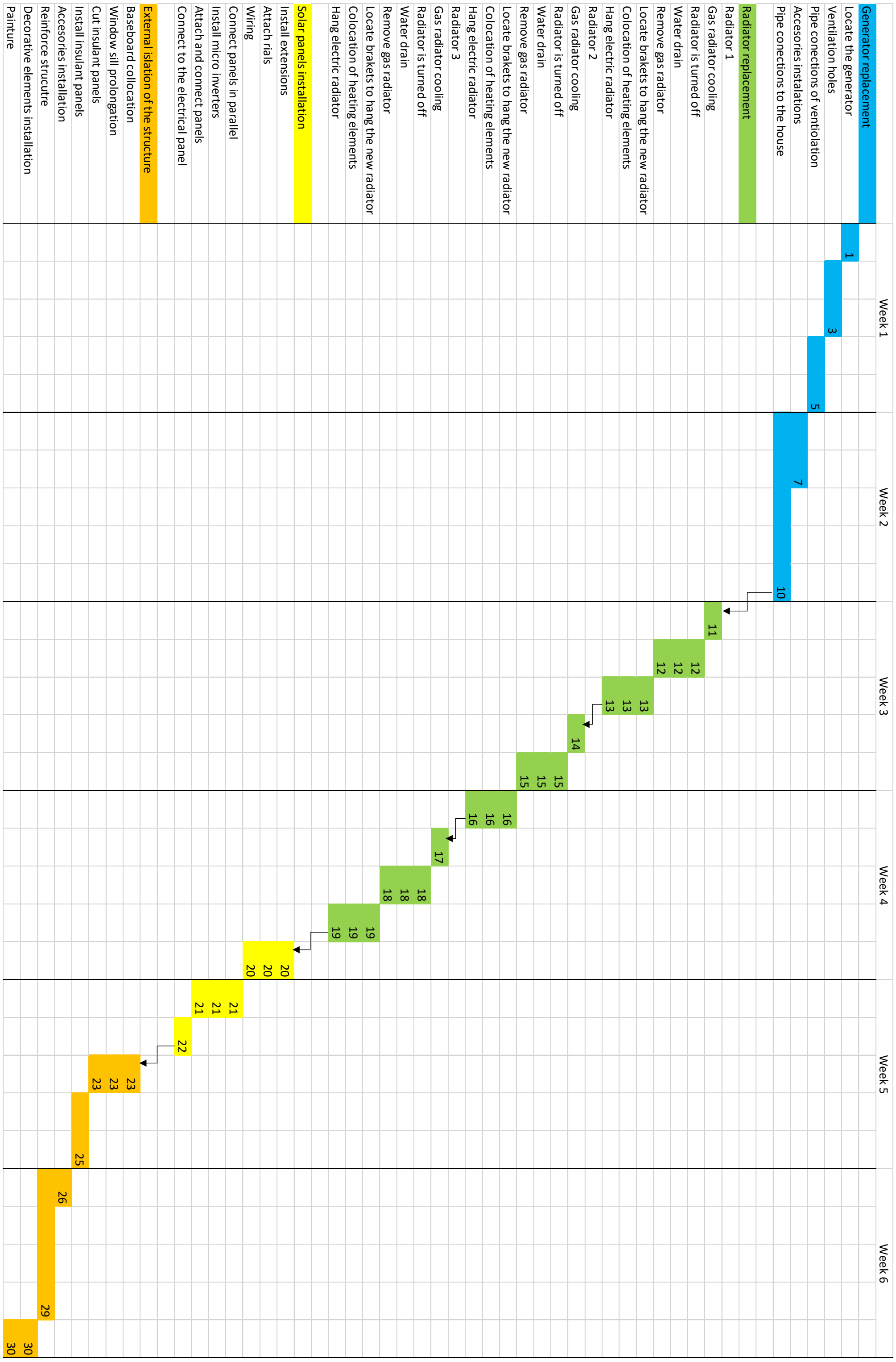


Figure 46. Chronogram of the interventions

As observed, the interventions are identified in different colours. The bars indicate the amount of time that each process takes and it's quantified in days. At the end of a bar, the number of days of the whole operation until the current process is indicated. To complete the interventions proposed in this work, a total amount of 30 working days is required.

This is done at the beginning of the construction, and later, during the construction another one can be done in real time as to have a record of the real time that each process took. In reality, some holydays that where not considered extended the process, due to lack of organization and delay in receiving some materials in the contraction site, the process also got extended, some works where done faster than what expected, and some processes were added, but in general, the complete work was longer that what was planned. The renovations were completed in a total of 41 days (8 weeks), this is the 137% of the schedule planned.

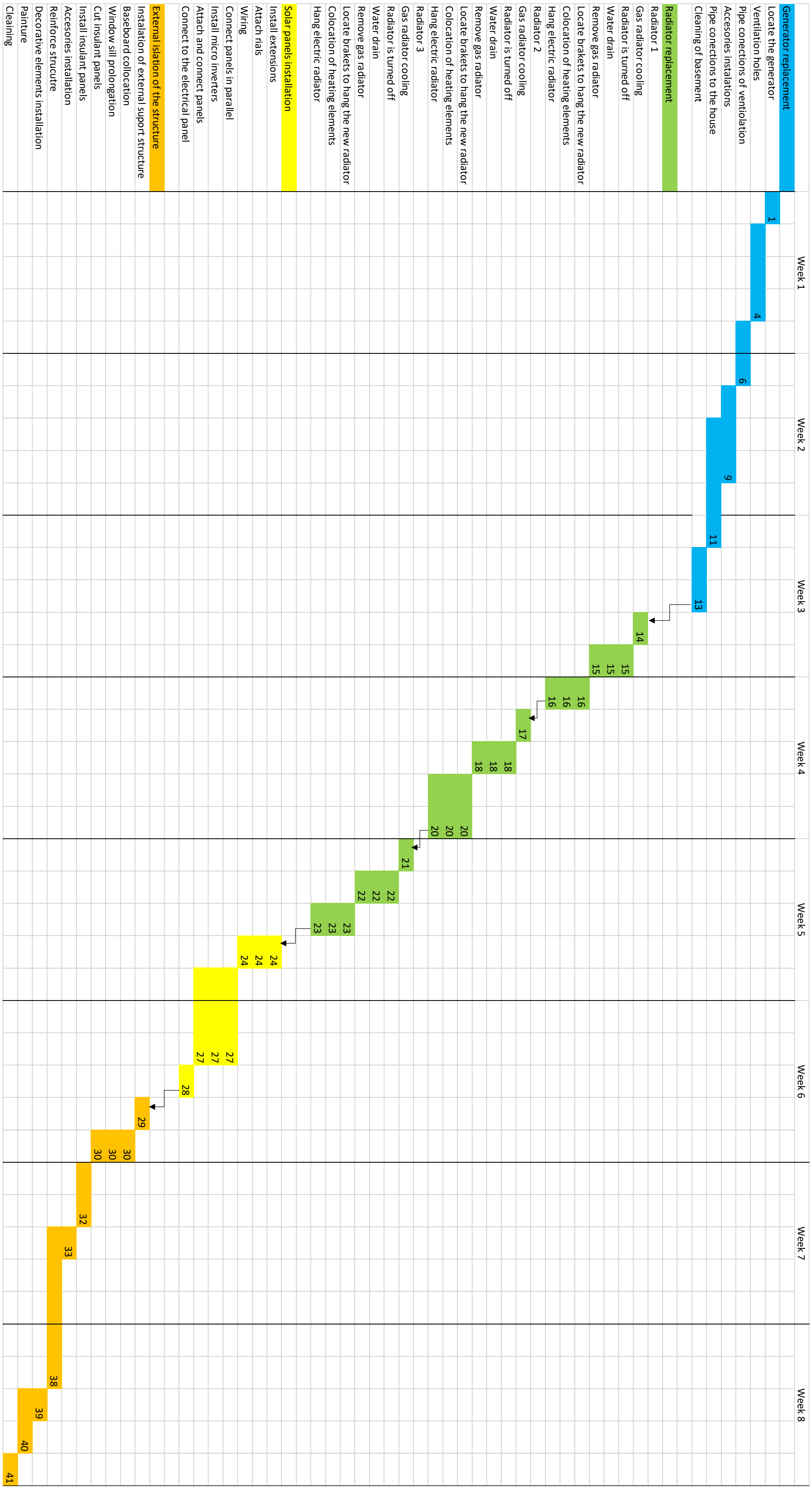


Figure 47. Real time chronogram

The management and direction of the construction is documented as to analyse the advances and if the objectives are reached in an effective way. This requires continuous visits to the construction site for supervision with monthly reports on the progress and the schedules can be updates if necessary.

These construction documents refer to any possible documentation related to the construction project as contracts, drawings, permits, controls, … All the plans of the building will be saved in this section, both the original plans and the new ones where the renovations appear, and this can be updated if necessary. Certificates of the state approving the work, contract forms with the conditions and specification, and any new reform that is done during the process. For the daily monitoring, a schedule of progress can be done and constantly verified, schedule for the contractors, daily reports of the construction, report of the materials location, between others.

The progress reports are done by the person in charge if the on-site work, and it has a description of the work done until the moment, a comparation with the scheduled originally planned, and an evaluation of the quality of the process. An example of a progress report:

PROGRESS DAILY REPORT

Renovation building: Salbertrand 83
Report presented by: Bianca Pérez Fernández

Work started: 02/08/2021
Work completed until the date: 02/09/2021

TASK	SUB - TASK	% WORK COMPLETED	DATE SUBMETED
Generator replacement	Locate the generator	100	02-ago
	Ventilation holes	100	05-ago
	Pipe conections of ventiolation	100	09-ago
	Accesories instalations	100	12-ago
	Pipe conections to the house	100	16-ago
	Cleaning of basement	100	18-ago
Radiator replacement	Gas radiator cooling	100	30-ago
	Radiator is turned off	100	31-ago
	Water drain	100	31-ago
	Remove gas radiator	100	31-ago
	Locate brakets to hang the new radiator	100	01-sep
	Colocation of heating elements	100	01-sep
	Hang electric radiator	100	01-sep
Solar panels installation	Install extensions	100	02-sep
	Attach rials	100	02-sep
	Wiring	50	02-sep
	Connect panels in parallel	0	
	Install micro inverters	0	
	Attach and connect panels	0	
	Connect to the electrical panel	0	
External islation of the structure	Instalation of external suport structure	0	
	Baseboard collocation	0	
	Window sill prolongation	0	
	Cut insulant panels	0	
	Install insulant panels	0	
	Accesories installation	0	
	Reinforce strucutre	0	
	Decorative elements installation	0	
	Painture	0	
	Cleaining	0	

Figure 48. Progress report

Safety systems are evaluated during the planification face to prevent and reduce accidents at work, and control measures will be taken during the complete process to reduce any possible risk. A hazard management assessment should be conducted prioritizing the health and safety of employees.

Clear instructions are given to the employees to avoid any risk, a proper training of dangerous activities is done and constant supervision is provided. Using these tools, the risk is minimised, having a safe workspace. Other techniques to avoid risky situations are to substitute dangerous substances for more friendly ones; use of evident security warnings; use of remotely – operated machines; provide to the personal the necessary protective equipment; and make workers be aware of the risks by informing them of it and of the preventive solution.

To analyse the possible risks some standards must be use as reference as the legislative requirements, health and safety guidance, recommendation of professional bodies, government standards, between others. Previously determinate those activities which involve a significant risk level as to know which activities to assess, and define special techniques to use in high-risk activities.

Doing a historical analysis, the risks are detected for this type of construction:[66]

- Slips: many serious injuries are leaded by slipping from a levelled surface;
- Working at hight: 25% of fatalities are a result of falls from over 2 meters;
- Machinery manipulation: access to dangerous paces while the machine is at motion must be prevented by incorporating protective devices;
- Vehicles: the risk of driving a vehicle for the driver as for a third person is always present
- Electricity: presented as electrical systems, electrical equipment and connectors, when approaching any of these, the necessary safety protocols must be followed;
- Dust: in important concentrations, and sometimes carrying other dangerous powders, this can be very risky to the health. The smaller are the particles, the more dangerous the dust is. The risk is when particles are inhaled but, due to their size, they are trapped in the lung tissue and can´t be exhaled, on the other hand, very small dust can be absorbed by the skin reaching the blood flow. Some dusts are toxic, some flammable or just irritant, but all of them can be harmful in different exposures. In the constructions it is most likely to find irritant dust which has to be in a very large concentration to be absorbed by the body[67];

[66] https://app.croneri.co.uk/topics/risk-assessment-construction/indepth
[67] https://ec.europa.eu/taxation_customs/dds2/SAMANCTA/EN/Safety/Dust_EN.htm

- Noise: the noise of an activity should not be at exceed the levels where a normal conversation can´t be carried out. Noise is measured in decibels (dB), a normal conversation is around 60dB, noise higher than 70db for a prolongated time causes damage effects, and noise above 120dB causes an immediate harm to the human ear[68];
- Vibration: the vibrating of the body is an important danger alarm, this will produce a progressive harm to the body, at the beginning the person will manifest some pain and after a prolongated exposure this will transform into an injury. Vibrations can induce injuries in tendons, muscles and bones[69]. The tools to be used in a construction site should have from manufacture a description of the vibration level and the points per hour assigned to the tool. This last has to be multiplied by the number of hours of daily use, and this number should not exceed the 400 points per day which is the exposure limit value (ELV)[70];
- Extreme temperature: unhealthy work environments require specific preventive equipment for workers. The normal temperature of the body is around 37°C, if this temperature goes up to 32° - 40°C muscle cramps or exhaustion symptoms may appear, at temperatures between 40°C – 54°C heat exhaustion and fainting, and higher than 54°C sunstroke or insolation can occur. On the other hand, if the body temperature goes under 37°C shivering and increase in the heart rate may be experienced, for temperatures between 33° - 30°C shallow breathing, inability to walk and partial unconsciousness, under 30°C poor breathing, no reflexes and the possibility to fall into a coma or die[71];
- Fire: the work place must be prepared for a possible fire incident.

Cost and Quality Controllers

Verification of the budget on a frequently basis taking into account both the direct and indirect costs of the intervention. Those costs related to the construction

[68] https://www.cdc.gov/nceh/hearing_loss/what_noises_cause_hearing_loss.html#:~:text=A%20whisper%20is%20about%2030,immediate%20harm%20to%20your%20ears.

[69] https://www.ccohs.ca/oshanswers/phys_agents/vibration/vibration_effects.html

[70] https://www.hse.gov.uk/vibration/hav/advicetoemployers/assessrisks.htm#exposure

[71] https://www.healthline.com/health/extreme-temperature-safety#extreme-cold-temperatures

contract are "direct costs" and are related to materials, labour and subcontractor costs. On the other hand, the so called "indirect costs" are those not specified in the construction contract as home office costs, small tools, maintenance costs, taxes, insurance, between others. [72]

Before the work on site is stated, an estimation of all the costs has to be done as to present to the state, to the occupants of the building, and to have a previous analysis on which supplier is better and the amount of money that is going to be needed for each operation. This is an easy task but it demands a lot of time, it consist on contacting different suppliers, asking for the prices of materials or equipment, calling contractors to know the cost of their services, laboratories if test have to be done, … Every little part of every process has to be considered, different options compared and like this a complete cost analysis of all the renovation is done. This is an estimation because even dough all the costs have been taken from accurate information, explaining to the supplier the exact characteristics of the product or service needed, this price has not been confirmed and it may variate when the product or service is actually bought.

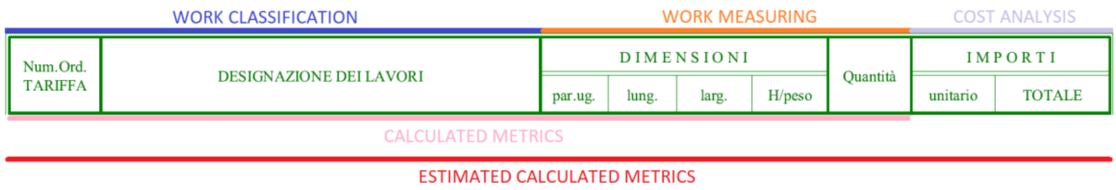


Figure 49. Columns of an estimated calculated metrics

The document before explained is called "Calculated Metrics", actually the calculated metrics is the determination of the quantities of material needed in each process, and the estimated calculated metrics is the valorisation of the quantities and finally the cost of the complete work. The calculated metrics is a detailed measure of the works needed along each process. Each measure can be described in: equal parts (par.ug.), width (lung.), length (larg.), height/weight (H/peso), besides there is the quantity. For the estimated calculated metrics, the unitary price of each work is detailed and this is multiplied by the quantity as to have the partial cost of each work. Last the sum of all the partial costs is the final total amount of the construction. Before these

[72] https://www.lutz.us/direct-vs-indirect-costs-construction-industry/

characteristics are detailed, a description of the work being analysed is done by numerating this in order of application and by textually describing the process.[73]

pag. 10

Num.Ord. TARIFFA	DESIGNAZIONE DEI LAVORI	DIMENSIONI				Quantità	IMPORTI	
		par.ug.	lung.	larg.	H/peso		unitario	TOTALE
	R I P O R T O							268'245,56
53 NP.B15135B	Sistema di facciata ventilata continua **REALIZZAZIONE DI FACCIATA VENTILATA**							
	LATO STRADA VIA GIULIETTI *(larg.=11,500+0,5+0,5)			12,500	10,500	131,25		
	SFRIDI *(par.ug.=0,5*131,25)	65,63				65,63		
	FORI INFISSI PARI 1 ML A MQ							
	LATO STRADA VIA GIULIETTI							
	F2 1.5*1.5 *(lung.=1,5+1,5+1,5+1,5)	4,00	6,00			24,00		
	PF1 1*2.4 *(lung.=1*2,4)	4,00	2,40			9,60		
	PORTONCINO DI INGRESSO *(lung.=1,5+1,5+3+3)		9,00			9,00		
	SOMMANO m2					239,48	327,21	78'360,25
54 B35108e	Discendenti montati in opera compreso pezzi speciali ed ogni altro onere e magistero per dare l'opera finita a regola d'arte con esclusione dei soli collari di sostegno: Ø fino a 100 mm: in acciaio inox da 8/10							
		2,00		12,500		25,00		
	SOMMANO m					25,00	22,15	553,75
55 B35110b	Collari per sostegno di discendenti, montate in opera compreso fissaggio al supporto ed ogni altro onere e magistero per dare l'opera finita a regola d'arte: in rame o acciaio inox							
		2,00		12,000		24,00		
	SOMMANO cad					24,00	5,33	127,92
	INVOLUCRO OPACO CAPPOTTO EPS (SbCat 9)							
56 DA2.5.04.03 8.b	ESECUZIONE DI TRACCE Tracce nella muratura, eseguite a mano, compresa la chiusura delle tracce e l'avvicinamento del materiale di risulta al luogo di deposito provvisorio, in attesa del trasporto allo scarico: per tracce in muratura di mattoni pieni: della sezione 101 ÷ 225 cmq							
	PASSAGGI IMPIANTISTICI DORSALI ELETTRICHE		50,00			50,00		
	SOMMANO m					50,00	26,88	1'344,00
57 DA2.5.04.03 9.b	ESECUZIONE DI TRACCE Tracce nella muratura, eseguite a mano, compresa la chiusura delle tracce e l'avvicinamento del materiale di risulta al luogo di deposito provvisorio, in attesa del trasporto allo scarico: per tracce in muratura di mattoni forati: della sezione 101 ÷ 225 cmq							
	PASSAGGI IMPIANTISTICI DORSALI ELETTRICHE		50,00			50,00		
	SOMMANO m					50,00	20,10	1'005,00
58 02.P02.A32. 010	Piccozzatura di intonaci su pareti e soffitti per favorire l'aderenza di nuovo intonaco							
	PERIMETRO DI FACCIATA *(lung.=0,5+0,5+11,5+11,5)		24,00		10,500	252,00		
	SOMMANO m²					252,00	3,63	914,76
	A R I P O R T A R E					75,60		350'551,24

COMMITTENTE: Condominio VIA GIULIETTI 1

Figure 50. One page of an estimated calculated metrics

[73] https://biblus.acca.it/focus/computo-metrico-estimativo/

The cost analysis is done to manual labour, materials, renting of equipment, expenses and the profit of the company. The manual labour is analysed by the cost of hour which is registered in a table depending on the type of labour regulated by each province. The cost of materials is defined by the price of it, the transportation to the work site, the unloading of it and the waste of the material. In the cost of equipment or vehicle renting the analysis considers the materials that this will consume as lubricants or gasoline, the maintenance of it and the insurance needed. The expenses are part of the indirect cost and its around the 15% of the total costs, this includes the administration of the whole work, the engineering work, verifications, security, between others. Last, the profit for the company will be of the 10% of the total cost, this is defined by the state in the Superbonus 110% where the government compromises to provide the 110% of the costs for the building renovation.[74]

Before the final project reaches the client, this has to pass certain quality controls. Verifications and if necessary, reparations must be done. These inspections are done by people that were not involved in the activity. During this assistance, some specified requirements are evaluated regarding the quality of the process and of the final product. Managing the technical and administrative procedures, errors are prevented, these are assessed following the regulations and standards. [75]

There are different tools to achieve a correct quality control. The checklist is a very common one, it´s an easy visualization of which processes pass the quality control and which don't. Once the quality detector has not pass, a fishbone diagram can be use to locate the problem and analyse what is the defect root, here sub causes provoked by different aspects will be analysed, the areas of analysis may be machine, people, method, ... The control chart is a registration on time of a process as to analyse in which period of time a problem or irregularity occur, when the limit conditions where exceeded, some unstable periods, and the average behaviour of the processes. This is useful to control for example if workers are respecting the security regulations, or if solar

[74] https://biblus.acca.it/focus/analisi-prezzi/
[75] https://www.designingbuildings.co.uk/wiki/Quality_control_for_construction_works

panels are producing the desired amount of energy. Stratification is an interesting tool to separate some factors and find a localized pattern, so to control a process, the work of the different machines may be followed separately as to later identify which one is having an irregular behaviour. The pareto chart identifies different aspects of a process that have defects and analyses them first separately and then as a whole giving a visual interpretation of the lack of quality. This are some examples of the possible control tools that are used for a frequent quality inspection, they are used combined to achieve a better understanding of the process quality and problem identification.

Quality Control				
ITEM	DETAILS	YES	NO	N/A
1	Generator replacement			
1.a	Corect space for colocationg the unit	X		
1.b	Proper cuting of wall	X		
1. c	Proper pipe conection	X		
1. d	Corecr instalation of accesories	X		
1. e	Verification of a proper flow	X		

Figure 51. Checklist example

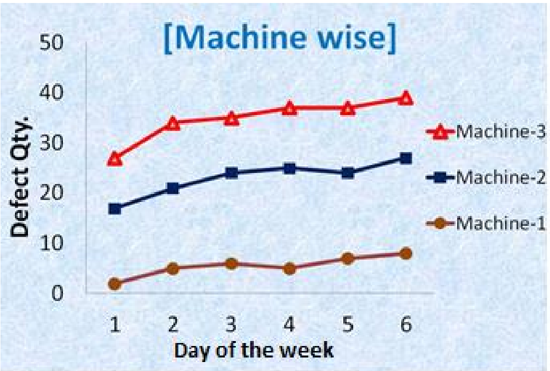


Figure 52. Stratification example

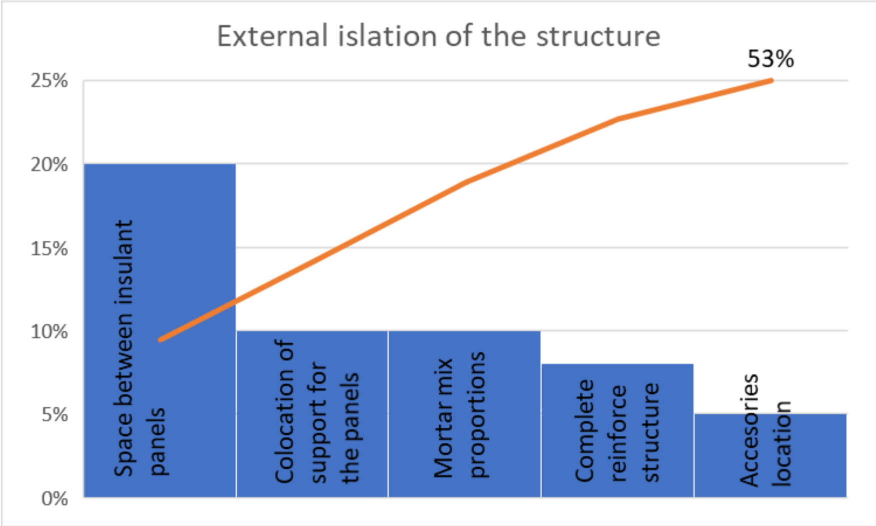


Figure 53. Pareto example

As explained before, these inspections are done by an external part, however, some internal controls can also be done to ensure a correct process and have a faster alert in case of failure. The already explained tools can also be of this use, a daily or weekly checking routine is important to maintain the conditions inside the norm.[76]

Closeout

Last but not least, the closeout of the intervention is an activity that must be taken into account in the management of the project once the construction is over. Before deriving the final project to the client, the following process must be done. A verification that the building has all the agreed renovations is to be done and documented ensuring a complete work that matches the quality requirements. The site of work has to be cleaned up before presenting it to the client, equipment's are to be returned and if any temporary construction was made this has to be removed. A good closeout requires this tidy presentation accompanied by the necessary documentation where the whole process and the financial description were archived in great detail.[77]

The closeout of a project it includes different aspects that are managed. A very important one is the punch list. Having all the renovations done, every part of the

[76] https://bizfluent.com/how-7640484-develop-quality-control-plan.html
[77] https://gillilandcm.com/2019/03/26/what-is-construction-project-closeout-management/

building is controlled to analyse if there is any change or correction to make. For example, if a sector of the façade was not painted, or a pipe connection has a leakage. This are final touches that the architect or engineer controlling the work have to notice before handing in the building. Like this, the manager does a punch list with all the corrections that need to be done to the building, and following this, the changes must be done one by one. In this phase, the contractual conditions must be considered and these should be considered in the time and budget originally planned.

Having the renovation totally completed, the necessary inspections have to be done by the corresponding authority. In the inspections, the building plans are review, as well as certificates and construction premotions, that there has been no interruption of the evacuation plans, … All the documentation is presented, with plans of the building, and certificates. If any problem is identified in this phase, a fast solution should be easily provided, this is why the support team should be prepared for any inconvenience.

Once the corrections and inspections have been done, when no more work on site is needed, the clean-up process is started. This has to be totally completed before ensuring the handover of the building. All the external structure that was created to repair the façade has to be taken away, in the generator replacement the old unity has to be removed and thrown, if openings where replaced the old windows and doors have to be removed, any waste product of the renovations has to be taken away, the equipment that was rented returned to its place. There are many things to consider in this phase, is important to have a correct clean up for a proper deliver.

All the documentation that was registered during the renovation process is now collected. This includes the documentation of the original building, with all the plans and the building characteristics, and the new documentation generated with this renovation having the contract, subcontractors’ contracts, regulations that where followed, new planimetry, inspections, progress reports, chronograms, financial documentation, calculated metrics, … All of the steps described during this paper where properly documented, this documentation generated during the whole process is now collected and prepared to deliver with the building. This is very important if future legal misunderstandings appear, to verify that every part of the work was done correctly.

Last comes the training. Once the building has been handed to the occupants, these have to be trained on how to use the new elements. If new windows or radiators where installed, their use must be explained, if the generator has been replaced or solar panels installed, the maintenance of them have to be explained, … Even though in the archived documentation the use of these elements is explained, it’s important to train the occupants or the building managers on the use of all the new equipment to ensure a proper operation of the building, and to provide a comfortable use of the building occupants.

CHAPTER

5 Conclusions

Conclusions of the project having the real results. At the end of the complete process the economic, social and engineering aspects can be analysed as a whole.

An energy requalification is part of a bigger project where the individual benefit becomes the collective benefit for the community, and in a major scale for our planet. Projecting an energy requalification means to invest in the individual awareness to show them the benefit that this will produce to each building occupant. This are times with big possibilities of change where a project to reduce the energy demand of a building can have an important impact. It´s remarkable the presence of the government in this important ecological mater, which describes the tendency of society to acknowledge this problem. The climatic impact is the final objective of this sustainable intervention. This is a project that begins with the individual returning to itself a positive impact. [78]

The requalification of a building is an important change that improves the environment of the habitant and as a result, improves the environment of the collective. At the beginning, people may be unsure of taking the decisions to affect their intimacy provoking big changes to the personal space. When the individual understands the positive impact of this energy transformation, it will be on their power to start this regenerative cycle. This is why, as professionals, an important step of the project is to have a good communication with the client and to transmit the information in terms of their understanding.

This project generates an active economic cycle with actions including the positive incidence on the environment and the awareness of people. This new economy that is produced is helpful for the individual, for the community and for the environment. [79] Not only will the individual be economically and ecologically retributed, but the project also generates more work creating a micro economy, people become more aware of the environmental impact that things of our daily use have and change their view to an eco-friendlier one with the hopes of recuperating the earth's health.

The whole script describes a complete management of a construction work, starting from a theorical idea to the final physical product and having a detailed analysis of every small step. This is the laborious work that a group of engineers must follow to have a successful result, and is very interesting to have this report that is a description

[78] https://www.consilium.europa.eu/it/policies/climate-change/
[79] https://issuu.com/fpstudiotorino/docs/edificio_rigenerativo_sapevi_che__

of that effort. A project as complex as this one is to be studied from different perspectives at the same time, this includes the economical, ecological, legal, and social aspects, between others. There are so many the influences that shape this project and, by working on it, an unbiased attitude must be adopted if a clean and professional process is expected.

Every step described in this document is of great importance and cannot be sub-estimated. It´s the function of the engineer to guide the project by analysing, documenting, and verifying each of these steps.

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APPENDIX

A

Definitions and Terminologies

Definition of some technical terms that are going to be used in the present report. Space assigned for the better understanding of some concepts and of the complete project.

Accounting system: technical system that allows the measurement of thermal or cooling energy supplied to the individual real estate unit served by a centralized heating system.

Air-conditioned environment: closed environment heated or cooled at a controlled temperature.

Air-conditioned gross volume: volume concerned for the operation of the energy systems, considered for the determination of the energy performance index.

Air temperature of an environment: air temperature measured in the manner prescribed at technical standard UNI 8364-1.

Air-conditioning (winter or summer): set of functions designed to ensure the wellbeing of the occupants by controlling the internal environment (temperature, humidity and purity of air).

Architecturally integrated: solar thermal or photovoltaic system that uses developed components integrate and replace architectural elements.

Average seasonal overall performance of the heating system: ratio between the thermal energy needed for winter heating and primary energy (including energy of auxiliar devices) calculated with reference to the annual period of operation.

Average seasonal production yield: ratio between the useful thermal energy generated and fed into the distribution network and the primary energy calculated with reference to the annual operating period.

Boiler: generator consisting on the complex burner-hearth design allowing the transmission of heat produced during combustion to a fluid.

Building: system that consist on a structure delimiting a define volume with an internal design that divides this volume providing each space of energy systems permanently installed serving a standard operation in relation to the intended use.

Building energetic boundary: boundary that includes all relevant areas of the building or the energy systems connected to it, both inside and outside the structure, where energy is consumed or produced.

Building energy services: services aimed to ensure comfort conditions in the building:

- H winter heating: supply of thermal energy to maintain a predeterminate temperature considering humidity;
- W domestic hot water: supply for sanitary use of hot water at a prefixed temperature;
- V ventilation: air exchange in indoor environments;
- C summer air conditioning: compensation of the contribution of sensible thermal energy and latent to keep inside the room conditions of dry bulb temperature and relative humidity suitable for the wellbeing conditions;
- L artificial illumination: supply of artificial light when natural light is insufficient;
- T transport: of people and things. Lifts, sidewalks and escalators.

Building technical system: technological system dedicated to an energy service to perform one or more function connected to the energy services of the building. A technical system can be divided into several subsystems.

Building undergoing major renovation: an existing building that is in maintenance, renovations or conservative reorganization on more than 25% of the total surface. These major restructuring interventions are divided into:

- First level renovations: intervention with an incidence greater than the 50% of the total gross surface of the building including the renovation in heating systems and air conditioning service;
- Second level renovations: intervention with an incidence greater than the 25% of the total gross surface of the building including the renovation in heating systems and air conditioning service.

Climatic data: with reference to the building location, this data may include the degree-days (GG Gradi Giorno), the monthly average of the outdoor air temperature (θ_e), the monthly solar irradiation on the horizontal plane ($I_{sol,h}$), and the total monthly solar irradiation for each orientation (I_{sol}).

Climatic zone: subdivision of the national territory according to the degree days (DD) of the localities, regardless of geographic location. These areas are marked from the letter A (DD < 600) to the F (DD > 3000).

Cogeneration unit: unit compressing all the devices to achieve the simultaneous production of thermal and electrical energy.

Cogeneration micro - unit: cogeneration unit with rated electrical power below 50kW.

Cogeneration small unit: cogeneration unit with lower installed generation capacity to 1MW.

Combustion efficiency or conventional thermal efficiency of a heat generator: ratio between the conventional heat power and the heat power of the hearth.

Condominium: building with at least two real estate units where the proprietaries of each unit are co-owners of the common parts.

Conventional thermal power of a heat generator: thermal power of the hearth decreased by the power lost due trough the chimney by the continuous operation.

Cooling season: period of the year during which there is a significant demand of energy for cooling the rooms.

Covered area (Sq): projection on the horizontal plane of the planovolumetric shape of a building.

Degree Days of a location (DD): parameter representative of the local climatic conditions used to estimate the energy demand to keep the inside environment at a desired temperature.

Demand of annual primary energy for artificial illumination: amount of primary energy required over the course of a year for the artificial illumination of all rooms.

Demand of annual primary energy for the production of domestic hot water: amount of primary energy required over the course of a year for the production of domestic hot water consumed in the building.

Demand of annual primary energy for winter/summer air-conditioning: amount of primary energy required over the course of a year to maintain the design temperature in continuous activation regime.

Demand of global annual primary energy: quantity of primary energy related to all services considered in the energy performance calculated over a time interval of one year.

Demand of thermal energy for the air conditioning in winter/summer: amount of heat needed to supply or remove from an environment to maintain the desired temperature conditions during a given period of time.

Demand of thermal energy for the production of domestic hot water: amount of energy needed to heat the domestic water for a given period of time using conventional data referring to volume and temperature of entrance and disperse.

Efficient use system (SEU): system in which an electricity product plant with power not exceeding 10 MW is directly connected to the consumption system of a single costumer.

Energy diagnostic: technical report that identifies and quantifies energy saving opportunities under the cost-benefit profile of the intervention by defining the reduction in energy costs, the related return time and the possible building class improvements in the energy certification. The report must explain the choices that are going to be made and the motivation of these.

Energy from renewable sources: energy from renewable non-fossil sources.

- Wind energy;
- Solar energy;
- Aerothermal energy: heat accumulated in the environment air;
- Geothermal energy: heat stored under the earth’s crust;
- Hydrothermal and oceanic energy: heat stored in surface water;
- Hydraulic energy;
- Biomass: biodegradable fraction of products, waste and residues of biological origin;

- Landfill gas;
- Residual gas from purification and biogas process.

Energy plant: technological system permanently inserted in a building to ensure the supply of an energy service.

Energy performance of a building: annual amount of energy actually consumed or expected to be required to satisfy the building standards (winter and summer air conditioning, heating of domestic water, ventilation, illumination, lifts and escalators). This is expressed by one or more descriptors that take into account the building's insulation level, the technical and installation characteristics of the system, climatic aspects in relation to the location, indoor climate requirement, exposure to the sun, influence of adjacent structures, existence of systems of energy transformation, …

Energy produced in situ: energy produced, captured or withdrawn within the boundary system.

Energy project of the building or energy design: procedure that integrates the design of the building from the primary design to the executive drawings including the selection of the most suitable solution for the rational use of energy, reduction of environmental impact, verification of energy requirements, execution of calculations, and preparation of reports.

Energy qualification certificate: (AQE Attestato di Qualificazione Energetica) Document prepared and certified by a licensed professional where the demand of primary energy is reported, the class to which the building belongs in relationship to the regional energetic classification, and the maximum admissible values set by the legislation in force for the specific case.

Energy redevelopment: existing building undergoes an energy redevelopment of maintenance, renovation or conservative rehabilitation resulting in an energy performance variation changing the energetic level of the building. These interventions involve less than 25% of the total gross surface.

Energy vector: substance, energy or phenomenon provided from the outside of the system boundary, meeting the energy needs of the building.

European technical standard: standards available for public use adopted by the European Committee for Standardization (CEN: Comitato Europeo de Normazione), the European Committee for Electrotechnical Standarization (CENELEC Comitato Europeo di Normalizzazione Elettrotecnica), or the European Institute for Standards Telecommunication.

Exported energy: quantity of energy relative to a given directional vector, generated within the boundary system and used outside this boundary.

Filter systems: self-adhesive polymeric films applicable on glass on the internal or external side capable of modifying one or more of the following characteristics of the glazed surface: transmission of solar energy; ultraviolet transmission; infrared transmission; visible light transmission.

Global energy performance index (EPgl): amount of primary energy actually consumed or expected to be necessary to meet a standard use of the building for all energy services considered. It's referred to the unit of useful energy surface in [kW.h/m^2.year]. This index may be descriptive of primary energy from non-renewable sources, renewable sources or the sum of both.

Gross dispersion surface: external surface [m^2] which delimits towards non-air-conditioned environments the gross air-conditioned volume of the building.

Heat generator: device that allows to transfer one of the following heat forms to the heat-vector fluid or directly to air-conditioning or domestic water system:

- Heat produced by combustion;
- Heat obtained from any other form of energy (electrical, mechanical, chemical, natural derivation, …);
- Heat contained in a low temperature source and requalified at a higher temperature;
- Heat contained in a high temperature source and transferred to the heat-vector fluid.

Heat pump: device or system that realizes an inverse thermodynamic cycle, transfers heat from the natural environment (low heat source temperature) to the room at a controlled temperature. In the case of reversible heat pumps, it can also transfer heat from buildings to the natural environment.

Heating season: period of the year during which there is a significant demand of energy for heating the rooms.

Heat-vector fluid: fluid through which thermal energy is transported inside the building or exported to the outside.

Maximum values of the ambient temperature: maximum values of the temperature of different environments of a real estate unit, during the period in which the winter air conditioning system is in operation.

Method for calculation verification: basic data processing system defined with the methodology for assessing the energy performance that aims to facilitate the calculation activity doing a quality control of the results.

Methodology for determining the energy performance: set of technical based procedures that fallow a standardized criterion aimed to determine the energy performance of a building. Starting from an appropriate data base collected through an energy diagnostic the energy qualification or performance is certificated.

Nearly zero energy building (NZEB): building with very high energy performance calculated in accordance to the almost zero energy required to be covered by energy from renewable sources.

Nominal values of power efficiency of thermal plants: those declared and guaranteed by the manufacturer for continuous operation.

Optimal level in function of cost: level of energy performance that involves the lowest cost during the estimated economic life cycle. The lowest cost is determined taking into account the investment related to energy, maintenance and operation. The cost optimal level lies within the scale of performance in which the analysis is to be made.

Partial energy performance index EP: expresses the amount of primary energy actually consumed or expected to be needed to satisfy a single energy service of the building [kW.h/m2.year]:

- EP_H: for winter heating;
- EP_W: for production of domestic hot water;
- EP_V: for ventilation;
- EP_C: for summer air conditioning;
- EP_L: for artificial illumination;
- EP_T: for services regarding transportation (lift systems, sidewalks and escalators).

Periodic thermal transmittance YIE [W/m^2.K]: parameter that evaluates the capacity of an opaque wall and attenuate the periodic component of the heat flow that passes through in 24hs, defined and determined by the UNO EN ISO 13786:2008.

Primary energy: energy that has not undergone any conversion process.

Ratio (S/V): ratio between the gross dispersing surface S and the conditioned volume V.

Reference building: a model with identical terms of geometry, orientation, location, use classification, and surrounding situation for a building subjected to design verification, diagnostics, or other energy evaluations, with predeterminate thermal characteristics and energy parameters.

Reflectance: ratio between the intensity of the solar radiation globally reflected and radiation incident on a surface.

Renovation of a thermal plant: set of works that involve modification of the production systems, the distribution and emission of heat, and the transformation of a centralized heating system into individual heating systems.

Replacement of a heat generator: removing an old generator and installing a new one with a thermal power not exceeding the 10% of the power of the replaced generator, intending to supply thermal energy to the same users.

Residential and similar real estate units: floor or apartment of a building designed or modified to be used separately.

SCOP conventional: seasonal average coefficient of heat pumps performance for winter heating determined in reference conditions according to EN 14825. Must be declared by the manufacturer with reference to the mentioned standard, the climate conditions (C: cold; A: medium; W: hot) and operation conditions (load factor A – B – C D).

SCOP of operation: seasonal average coefficient of heat pumps performance for air conditioning estimated in actual conditions of use according to the normalized method referred to in the relevant UNI TS 11300 specification.

SEER conventional: seasonal average coefficient of refrigeration machines performance for summer air conditioning according to EN 14825. Must be declared by the manufacturer with reference to the mentioned standard, the climate conditions (C: cold; A: medium; W: hot) and the operation conditions (load factor A – B – C – D).

SEER of operation: seasonal average coefficient of refrigeration machines performance for summer air conditioning estimated in actual conditions of use according to the standard method referred to in UNI TS 11300 specification.

Thermal bridge: thermal insulation discontinuity that can occur in correspondence with the change of structural element (floors, vertical walls, …).

Thermal energy: heat for heating or cooling in civil or industrial use.

Thermal power of the hearth of a heat generator: product of the lower calorific value of fuel used and the flow rate of fuel burned.

Thermal transmittance: heat flux passing through a wall surface in [m^2] per the difference between internal and external room temperature in degree [K].

Thermal zone: part of the air-conditioned environment maintained at uniform temperature trough heating, cooling and ventilation systems.

Thermoregulation system: technical system that allows the user to adjust the temperature desired within the limits established by the legislation, for each real estate unit.

Total or gross volume: volume of the solid figure above ground defined by its planovolumetric shape.

Useful energy area: net walkable area of the volumes affected by air-conditioning where the high is not less than 1.50m. This surface is the reference denominator of all energy performance indices of all services.

Useful surface: net floor area of a building.

Useful thermal efficiency of heat generator: ratio between the useful thermal power and the power of hearth.

Useful thermal power of a heat generator: amount of heat transferred per unit of time to the heat-vector fluid.[80]

[80] https://legislazionetecnica.it/bcksistemone/files/regulations/pdf/XERDBGR20L2015967_P01.pdf

APPENDIX

B

ANTE – POST Comparison Example

After the Pre-Feasibility study, a simplified report of the energetic analysis is provided to the occupants of the building. An example of this report is presented in this section.

This appendix makes reference to chapter 3, section “ANTE and POST comparison”.

An example of the report presented to the occupants and proprietaries of a building is introduced. This presentation is a model which can be reproduced for many other buildings. The main objective is to explain in a clear and simple way the energetic impact of the building in the current condition and in the future condition after a possible renovation. Like this, showing the importance of this project from an energetic and economical point of view.

Prima e dopo la riqualificazione energetica, che impatto ha casa mia ?

Valutazioni economiche e ambientali sugli

CHE IMPATTO HA IL MIO EDIFICIO?

Una riqualificazione energetica può far parte di un progetto più grande, dove i benefici individuali si trasformano in benefici per tutti.

La riqualificazione di un edificio è sempre una trasformazione significativa, che migliora il contesto di chi abita e, nello stesso tempo, l'ambiente di tutti.

Ci siamo chiesti quali sarebbero realmente I vantaggi e l'impatto economico che deriverebbero dai lavori su questo edificio.

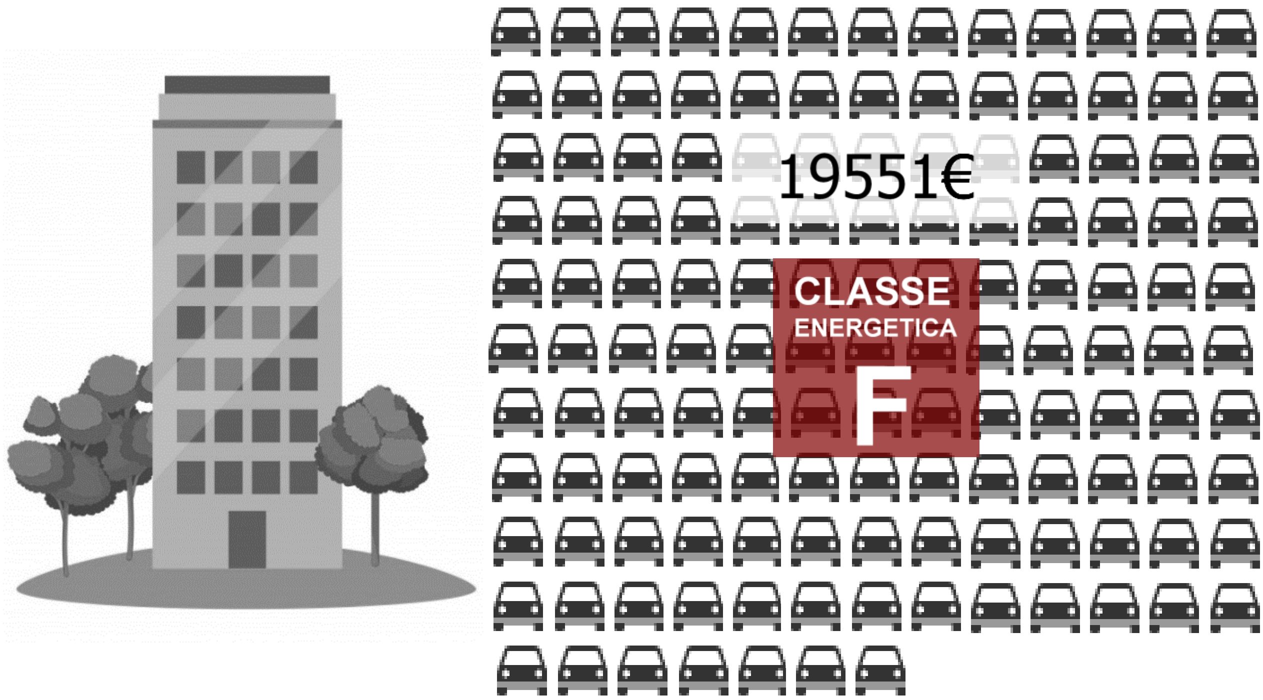
Nella pagina successiva c'è un'analisi comparativa tra i consumi prima e dopo l'intervento di riqualificazione energetica. Per rendere l'idea, abbiamo trasformato i numeri dei consumi in **viaggi in auto**. Immaginiamo un'automobile che va da Torino a Lecce: il numero di viaggi rappresenta l'impatto sul clima ma rappresenta, allo stesso tempo, il dispendio economico per riscaldare il nostro edificio. Osservando la situazione Ante intervento si può facilmente notare che una riqualificazione energetica incide sotto l'aspetto economico ed ecologico delle persone che abitano.

L'edificio di Via Pilo 7 a Torino è composto da 17 unità abitative. Edificato sul finire degli anni trenta, è uno stabile compatto di sei piani fuori terra oltre un sottotetto non abitabile.

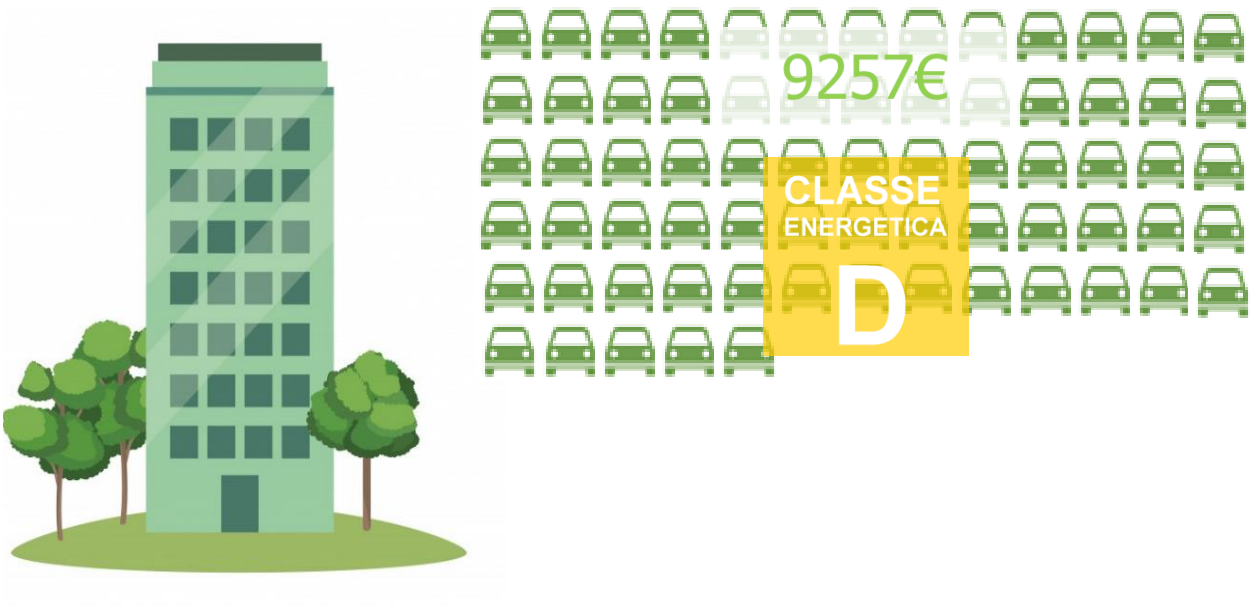
L'intervento di riqualificazione energetica consiste, principalmente, nel sostituire l'impianto di generazione esistente con altro più performante, coibentare con cappotti, integrare alla rete elettrica pannelli fotovoltaici.

Via Rosolino Pilo 7, 10143 TO

ANTE INTERVENTO viaggeremmo 137 volte da TORINO a LECCE



POST INTERVENTO viaggermo 69 volte da TORINO a LECCE



Edificio: Via Rosolino Pilo 7

	ANTE		POST	
	gas	elettricità	gas	elettricità
Consumo annuo	17856,00	30276,00	7670,00	28333,00
kgCO2	33926,40	5601,06	14573,00	5241,61
Totale kgCO2	39527,46		19814,61	
Risparmio totale di	**19713 kgCO2/yr**			
Risparmio individuale di	**1159,58 kgCO2/yr**			

	ANTE		POST	
	gas	elettricità	gas	elettricità
kWh/appartamento		1780,94		1666,65
€/kWh		0,06		0,06
€/m3	1,00		1,00	
Totale €	19551,46		9256,65	
Risparmio totale di	**10294,81 €/yr**			
Risparmio individuale di	**605,58 €/yr**			

Gas naturale:	1,9	kgCO2/m3
Energia elettrica:	0,185	kgCO2/kWh
Numero di unità immobiliari:	17	

Costo dell'energia	
kWh	€/kWh
1000	0,069
1500	0,056
2100	0,051
2700	0,049
3300	0,047
3900	0,047
4500	0,044
5000	0,044

Come abbiamo elaborato i dati

L'impatto sul clima di un'automobile o di un edificio viene espresso, normalmente in $kgCO_2$

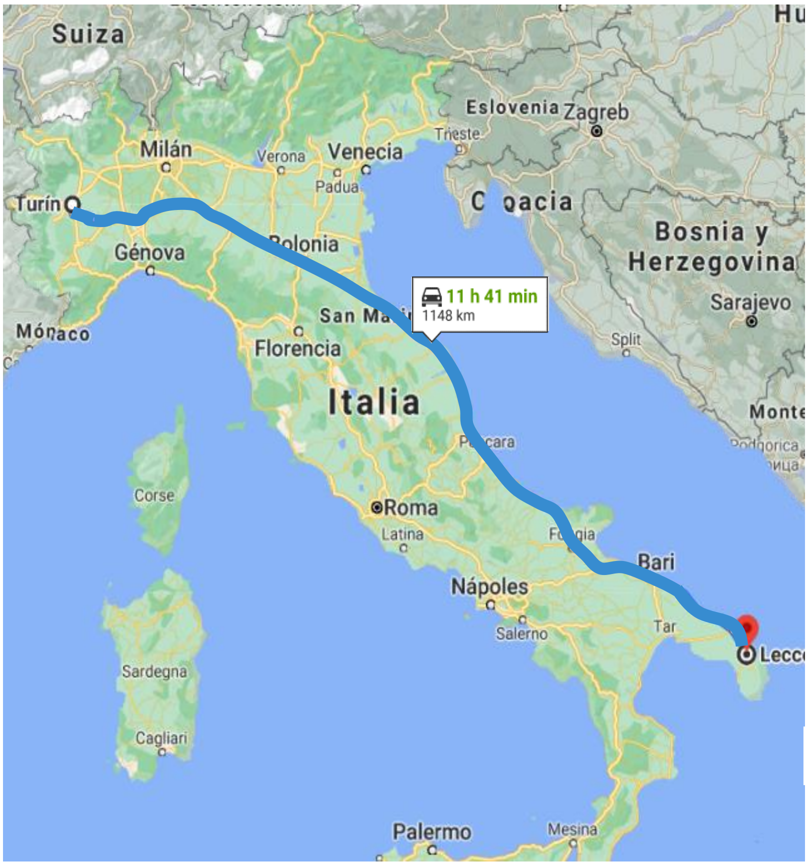
La misura dell'unità $kgCO_2$ può essere difficile da capire per la maggior parte delle persone, perché non è una misura utilizzata nella quotidianità.

Ecco perché abbiamo cercato un confronto più tangibile. E' stata una sfida interessante, per rappresentare meglio il concetto di impatto, sia sul clima che sulla nostra personale economia.

Per questo motivo è stata sviluppata un'interpretazione dimostrativa utilizzando il parallelismo con il viaggio in automobile. Questo è il calcolo:

Se un'auto normale consuma $404 \frac{\mathrm{gCO_2}}{\mathrm{miglio}} = \frac{0{,}404}{1{,}609} \frac{\mathrm{kgCO_2}}{\mathrm{km}} = 0{,}251 \frac{\mathrm{kgCO_2}}{\mathrm{km}}$, e il percorso in auto da Torino (Nord Italia) a Lecce (Sud Italia) è di 1148km, il viaggio emette un totale di $0{,}251 \frac{\mathrm{kgCO_2}}{\mathrm{km}} \cdot 1148\mathrm{km} = 288{,}15\ \mathrm{kgCO_2}$.

Con queste informazioni, il totale kg CO_2 calcolato nella Tabella di Presentazione alla linea 8 è divisa per 288,15 kg CO_2 per ricavare il numero di viaggi Torino – Lecce, che rappresenta le emissioni di questo edificio in particolare. Questo calcolo è svolto per l'analisi ANTE e POST, ed è rappresentato graficamente nello schema della prima pagina.



Riga					
1		Edificio:			
2					
3					
4		ANTE		POST	
5		gas	elettricità	gas	elettricità
6	Consumo annuo	xxx	xxx	xxx	xxx
7	kgCO2	---	---	---	---
8	Totale kgCO2	---		---	
9	**Risparmio totale di**		**---**	**kgCO2/yr**	
10	**Risparmio individuale di**		**---**	**kgCO2/yr**	
11					
12					
13		ANTE		POST	
14		gas	elettricità	gas	elettricità
15	kWh/appartamento		---		---
16	€/kWh		---		---
17	€/m3	1,00		1,00	
18	Totale €	---		---	
19	**Risparmio totale di**		**---**	**€/yr**	
20	**Risparmio individuale di**		**---**	**€/yr**	

Riga		
28	Gas naturale:	1,9 kgCO2/m3
29	Energia elettrica:	0,185 kgCO2/kWh
30	Numero di unità immobiliari:	xxx

Riga	Corto dell'energia	
27	Corto dell'energia	
28	kWh	€/kWh
29	1000	0,069
30	1500	0,056
31	2100	0,051
32	2700	0,049
33	3300	0,047
34	3900	0,047
35	4500	0,044
36	5000	0,044

Linea 6) Tramite l'APE (attestato di prestazione energetica dell'edificio) si ricava la quantità annua consumata di energia elettrica da rete e gas naturale. Raccogliamo i dati dell'edificio sia prima che dopo la riqualificazione energetica. Questa è l'informazione INPUT che si vede nella Tabella di Presentazione in colore nero nella linea denominata APE. IL resto dei valori sono di colore grigio perché non sono valori INPUT.

Linea 28 – 29) I coefficienti di trasformazione dal vettore energetico alla CO_2 è il seguente:

$$1\mathrm{m}^3 \mathrm{gas} \rightarrow 1{,}9 \mathrm{kgCO}_2; \quad 1\mathrm{MWh\ centrale\ elettrica\ a\ gas} \rightarrow 185 \mathrm{kgCO}_2$$

Questi valori sono indicati in grigio perché non sono valori di INPUT, ovvero coefficienti standard che rimangono gli stessi per qualsiasi edificio.

Linea 7) La quantità di kg CO_2 rappresentata da ogni servizio viene calcolata moltiplicando i coefficienti di trasformazione con i valori APE.

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*Questa informazione è basata su stime e non considera tutti gli aspetti che possono influenzare le condizioni energetiche dell'edificio.

Linea 8) L'emissione totale è la somma delle emissioni di gas e delle emissioni di elettriche rappresentate nella riga 7.

Linea 9) Per avere un primo confronto tra l'edificio nella situazione ANTE e POST riqualificazione, i valori dalla linea 8 vengono sosttratti. In questo modo è possibile notare che l'edificio POST avrà una differenza di quantità di kg CO_2 rispetto all'edificio ANTE.

Linea 30) Il numero di appartamenti nell'edificio è inserito come valore INPUT, per questo motivo il formato è di colore nero.

Linea 10) Per calcolare la riduzione delle emissioni di ogni appartamento, si sottraggono i valori POST (meno) ANTE, poi si divide il risultato per il numero di appartamenti indicato nella linea 30.

Linea 15) Il valore APE dell'energia elettrica (linea 6) viene diviso per il numero di appartamenti (linea 30) per individuare i kWh di energia elettrica consumati per appartamento, considerando che consumano tutti lo stesso importo. Il calcolo viene quindi eseguito in linea teorica.

Linea 27) Stabilisce il costo di un kWh di elettricità in base alla quantità totale di elettricità consumata per un appartamento.

Linea 16) Conoscendo il consumo di energia elettrica per appartamento (linea 15), il prezzo di un kWh si ricava tramite il dato nella linea 27.

Linea 17) Il prezzo di un metro cubo standard di gas è stato indicato 1€. E' un prezzo standard, in cui sono incluse accise, trasporto e altri costi. E' molto simile a quanto effettivamente ognuno di noi paga "in bolletta"

Linea 18) Per conoscere il costo totale dei servizi energetici dell'intero edificio, il costo di ogni servizio (linea 16 per l'energia elettrica e linea 17 per il gas) viene moltiplicato per il consumo totale di ogni servizio dato dall'analisi APE (linea 6); successivamente vengono sommati: $\text{costo gas} * \text{APE gas} + \text{costo elettricità} * \text{APE elettricità}$

Linea 19) La sottrazione del costo totale POST e ANTE (linea 18) serve per calcolare il risparmio economico totale.

Linea 20) La sottrazione del costo POST e ANTE (linea 19) , ma diviso per il numero di unità immobiliari (linea 30) serve per calcolare il risparmio economico individuale.

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*Questa informazione è basata su stime e non considera tutti gli aspetti che possono influenzare le condizioni energetiche dell'edificio.

Bianca Perez Fernandez, Politecnico di Torino e Università di Belgrano – Argentina si occupa, per questo studio professionale, dell'organizzazione del metodo di lavoro per progettare riqualificazioni energetiche e, nel contempo, di trovare il miglior modo possibile per trasferire agli utenti i dati sull' impatto ambientale e il risparmio energetico.

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