

ENERGY AUDIT PROCEDURE

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0. PREMISE: ENERGY SAVING AND EFFICIENCY

The ever increasing burden and instability of energy costs faced by developed countries, in particular those that see oil as the main source of energy, has created a marked awareness in public opinion on the subject of energy saving and efficiency.

The signing of the Kyoto Protocol on climate change in 1997 has increased the importance of the environmental dimension and of sustainable development in EU energy policy.

The energy used in the residential and tertiary sectors, made up largely of buildings, represents over 40% of EU total energy consumption. As these sectors are expanding, their energy consumption and therefore carbon dioxide emissions are destined to increase.

The increase in energy efficiency at the end-use of energy, intended as a “virtual” resource to be made the most of, must be based on suitable regulatory support. Without this, it is almost impossible to hypothesize the innovation of an energy system properly oriented to overcome structural deficiencies that the socio-economic development of the system itself has made evident over time.

In the last ten years we have seen growing activity to identify new legislative instruments and new applicative methodologies designed to improve efficiency in the production and use of energy, in the development and spread of renewable resources and in the protection of the environment.

0.1. REGULATORY FRAMEWORK

0.1.1. EUROPEAN LEVEL

Directive 2002/91/CE on building energy performance

The European Union has intervened with the enactment of Directive 2002/91/CE relating to “Energy Performance of Buildings”, to be implemented by all EU States by 4th January 2006.

The aim of this directive was to keep energy consumption down, tackling the problem on a global scale where the overall energy requirements were the result of all the needs in the building including not only heating but also ventilation, production of sanitary water, air-conditioning and lighting.

The main regulations contained in the directive required Member States to:

- define a methodology at a national level to calculate the energy requirements of buildings;
- identify the minimum requirements regarding the energy needs of new buildings;
- set the minimum requirements regarding the energy needs of large, existing buildings undergoing refurbishment;



- introduce compulsory energy certification for new buildings;
- prescribe periodic inspections of boilers and air-conditioning systems in buildings, as well as an overall appraisal of heating system where boilers are more than 15 years old.

The calculation of energy requirements in buildings may be carried out with methodologies that differ from region to region, but shall be such that the following aspects are taken into consideration:

- insulation, exposure, climate;
- type of heating system, air-conditioning and artificial lighting (tertiary only);
- use of renewable sources of energy and the architectural characteristics of the building.

Directive 2006/32/CE on energy efficiency, end-use of energy and energy services

The aim of the directive is to improve the efficiency in the end use of energy under the costs/benefits profile of Member States by:

- a) providing the indicative objectives, the mechanisms, the incentives and the institutional, financial and legal framework necessary to eliminate the existing barriers and imperfections in the market that hamper an efficient end-use of energy;
- b) creating the conditions for the promotion and development of an energy service market and the provision of other measures of improving energy efficiency by end users.

The aim of the Directive is to reduce the average level of energy consumption of Member States by 9% within 9 years of implementation, measured in the 5 years prior to adoption of the policy.

This directive defines and promotes art. 12 energy analyses (energy diagnoses) as an essential instrument for identifying methods of improving energy efficiency.

Energy efficiency Action Plan (2006)

The ambitious Action Plan was presented to the European Commission on 20th October 2006 and passed by the European Council on 23rd November 2006.

The plan provides for a wide range of action and concrete measures in the field of energy saving, including the requirements of energy efficiency, improvement of the transformation of energy, modification of behaviour with regards to energy with the aim of encouraging users to reduce how much they consume, and finally the development of international partnerships.

In particular, from the established priorities, that of continuing the implementation of the directive on building and, on the basis of the experience gained in applying it, using the directive framework to fulfil the potential of further energy saving through building.

The Council has confirmed in this way the desire to collaborate with the Commission and with the European Parliament, as well as with industry and the citizens within the Community, in an attempt to achieve a potential EU energy saving of 20% by 2020. The Council has



underlined that a swift execution of the Action Plan could result in an annual saving of 100 million Euros by 2020, equivalent to 390 M TOE. The application of the individual actions in the plan could also substantially reduce EU CO2 emissions by 2012, in accordance with the Kyoto Agreement.

0.2. IMPORTANCE OF ENERGY AUDIT

The rational use of energy implies the study and analysis of all the interventions that bring a reduction and an optimization to energy use.

In order to correctly employ the various sources of energy an in-depth study of the current situation and of the actual energy needs of the system in question is necessary, beforehand. Then aspects for improvement or possible solutions that satisfy the requirements can be evaluated.

The phase of acknowledgment is therefore based on a preventative audit that must be accurately planned and delivered in order to arrive quickly at a clear, comprehensive picture of the energy problem under study.

The fields of application of energy audit can be:

- energy certification of the building;
- general energy screening useful for managing a building site;
- analytical and instrumental study of the energy characteristics of a building that is to be significantly restructured;
- the arrangement of technical specifications for a call for tender for energy performance contract.

0.3. METHOD ORIENTED TOWARDS TECHNICAL SPECIFICATIONS

This study will adopt the last of the various fields of application indicated above. This approach tries to combine sufficiently accurate information, regarding consumption and interventions, with the costs that Public Administrations can allocate to the preparation of tenders for energy services, with provisional planning of interventions to ameliorate the energy performance of its buildings.

The aim, therefore, is not so much to maximise the level of accuracy or the profit for the operator as it is to get as close as possible to the needs of the customer, which means:

- minimising time;
- reducing management costs;
- improving the quality of the buildings and its systems;
- reducing the cost of investments;
- monitoring contractors' operations.



0.4. AIM OF THE MANUAL

The aim of this manual is to provide a standardised procedure to make energy evaluation on buildings fast, practical and efficient following a customer oriented method.

The manual aims to be clear and precise, and to represent a reference that guides the operator step by step, whether it be an expert or a novice: in fact, once the phases of work are well defined a priori, one can save time without neglecting important elements.

0.5. STRUCTURE OF THE MANUAL

The structure of the manual reflects and follows the phases of execution in the methodology.

The initial phase is the survey of the actual state of the building, starting with the collection of all available information from: climatic tables, documentation, inspections and interviews.

All the information gathered is then organised in an information archive. In this way the customer is supplied with an organic and updatable database to remedy chaotic paper filing.

Once the material has been given organicity it is possible to proceed with the data processing which aims to calculate representative indexes about the state of the building.

Having the situation clear from the beginning, it is possible to take into consideration all feasible interventions for correcting possible lacks and for reducing consumption. It is important to calculate the following for every intervention: timing, investments, savings etc...

With respect to the various possibilities and having noted the economic, practical and management characteristics, the Administration will have a useful instrument for operating within the plan obviously following the needs and the priorities of the case.



SURVEY OF THE ACTUAL STATE

In this phase you will collect all information that will be possibly useful for the audit. The collection of information follows a logical order that begins with a general picture of the building and proceeds step by step towards a more detailed audit. First all the information currently available is collected then any gaps in the data are filled in by investigation and direct measuring.

1. COLLECTION OF DOCUMENTATION

Documentation is used to indicate all information left in paper or other format, relative to:

- *project information*: that is the characteristics of the construction of the building and of its technological systems,
- *energy information*: that is how the building has performed from the point of view of consumption up to the moment of the audit.

If this kind of material exists, it represents an important starting point for the auditor as it allows to save time during the phase of inspection.

1.1. PROJECT INFORMATION

(a) *Plans and prospects*

These documents can be found as:

- Graphic *.dwg* files
- Paper files.

If the building is private property, the owner must be asked. Otherwise the planner, or the Municipal technical office (in fact, in Italy a copy of the plans must be handed in to the municipal technical office).

If the building is public property it is necessary to ask the Municipal technical office or the planner.

Once the plans have been retrieved, after having made an effective comparison with the reality during the inspection, the following information is obtained:

- Orientation
- Lengths
- Heights
- Glazed surfaces

In case the information does not correspond, one should use the most recent measurements. In the absence of tables, but with the availability only of the plans, for a quick evaluation simply collect the data for height between floors and the dimension and number of windows.



It often happens, above all with older buildings, that the records have been lost. In this case it is necessary to get the information from direct on-the-field measurements. For this procedure see the next chapter.

Functional diagrams of plants

These documents can also be stored in the following ways:

- Graphic .*dwg* files,
- Paper files.

It is necessary to collect *Functional* diagrams of:

- Central boiler house
- Satellite stations (if present)
- System for sanitary hot water production (if independent from the central heating system)
- Electric system (not essential).

If the building is owned by a private, the owner must be asked. Otherwise the planner, or the Municipal technical office may possess a copy of the diagrams.

Sometimes collecting documents regarding public buildings can be difficult. First it may be necessary to ask the municipal technical office, or the planner, the plant manager of the maintenance staff. If the plant is run correctly, its documentation should be kept inside the thermal plant, in a specific closed container (according to Italian regulations). The plant documentation contains the log book, diagrams and user's manual.

In case one is not able to recover this information, it is necessary to obtain it by direct inspection. If the person responsible does not have the necessary experience, it would be advisable to consult a planner for heating systems capable of reconstructing the plant on paper.

(b) Certification

Strictly speaking, certificates for the thermal system are not connected to the energy audit, but they are however required documents for thermal plants and important for aspects of safety: they must therefore be collected and verified. In the event that they are not present or that they have expired, it will be necessary to explain this to the owner and to provide for their renewal or issue during the course of the work to be carried out.



ENERGY INFORMATION

Energy information includes anything that relates to the consumptions of the systems, at least for the last three years, in order to give an idea of the real performance of the building.

(a) Past consumption and bills

Past heat (gas, district heat...) and electrical consumptions include the total annual consumptions from previous years. This kind of information is required when one wants to build a performance benchmark for the building.

Monthly consumptions of the past three years (usually available from the bills) is enough to have a sufficiently detailed picture.

- If the building is private property, the availability of the bills will depend on the owner's thoroughness. In the event that bills have not been kept, the owner will need to ask for consumption data directly from the energy distribution company.
- If the building is public property, the bills should be available from the Treasurer's office. Unfortunately searching for the bills may be considered a task too onerous for the staff, as they are recovered through documents of expenditure, organised by date. If it is not possible to recover the bills through the staff, it will be necessary also in this case to ask the local energy distributor.

If the management of the systems has been entrusted through an energy service contract the information should be obtained directly from the company, which will normally have accurate accounts. On rare occasions it may be claimed that the information is reserved, inasmuch as the invoice is only for kilocalories consumed, determined by the heat meters. Such a claim is usually not supported by the law, but stated out of fear of revealing the savings obtained.

Consumption costs can be obtained from bills, or obtained from the distributor: costs are useful when preparing an investment plan or calculating pay back time. If available, energy consumption figures measured from heat meters are also useful, both the overall heat consumption and partial/local readings.

(b) The Energy supply contract

The energy supply contract is a very useful piece of information: it is possible, after a careful analysis, to modify the contract towards more advantageous conditions for the consumer and therefore to contribute positively to a reduction in costs.

Important elements to be verified are:

- yearly costs for the running of the system (including third party liability)
- yearly standard maintenance costs
- overtime maintenance costs carried out over the last three years.



2. INSPECTION

The inspection is the most delicate part of energy audit: the quality of the final evaluation depends on the quality of the measurements and observations during inspection.

The inspection consists of the on-site collection of building and plants data:

- Checking printed plans against the real conditions
- Spotting missing information from documentation
- Obtaining a realistic idea of the situation

In order to optimize time during inspection it is important to follow a pre-determined, logical order starting from general to details: an initial analysis of the outer shell of the building will give a general idea of the situation, then gradually the audit will move in to details.

(a)

Upon arrival on site, first thing will be to make an overall idea of the general structure of the building. The auditor will easily get an idea of the age of the building and of the general state of its maintenance (good condition, flaking walls, no maintenance at all, etc...). Defining the date of construction will help deducing structural and construction features.

(b)

It is necessary to establish the orientation of the building as this allows to calculate how much each of its surface is exposed to the sun (see EN regulation n. 836).

With the help of a compass and using North and the main surface as points of reference, note the orientation of all vertical walls. In order to fix these elements it is advisable to make a draft of the building plan and to mark the points of reference useful for orientation.

Furthermore on the same plan it is useful to highlight elements adjacent to the building which could affect exposure to the sun such as trees and other buildings.

(c)

The building may be made up of many units, for functional or aesthetic reasons or as a result of subsequent renovations: this can lead to complications when calculating surface areas and volumes during the audit, especially if all the units use the same boiler. Therefore it may be useful to make a plan of the layout of the elements and proceed unit by unit when measuring, to later consider all parts together during the calculation phase. However, construction units which use different boilers must be considered as distinct buildings.

(d)

Now that a general idea about the structure has been obtained, it is possible to proceed with measurements of the outer shell. This phase becomes indispensable when the architectural building plans are not available, otherwise (once it has been checked that the plans reflect the reality), the plans may be used.



Given the magnitude of the measurements to be made, it is advisable to use a portable, laser distance meter to ensure a margin of error as small as possible (it usually gives a margin of error in mm).

The measurements to be taken on the outside are as follows:

Total height of the building

Length of the walls

With regard to the total height, it is necessary to position the distance meter on the ground and point it towards a prominent point at the top of the building.

With regard to the length of the external walls, it is necessary to position the distance meter horizontally and point it towards a projection on the other side of the wall. If there is no projection present, it is useful to have someone place a smooth surface for the laser at the last corner of the wall.

(e)

In addition to the total surface area of the building it is necessary to know the dimensions of the windows and doors. These elements are important for the energy balance of the building as, opening onto the outside and having higher thermal conduction coefficients than the walls, they are a large source of dispersion.

From the outside it is easy first of all to make a general calculation dividing the doors and windows by:

type (same dimensions)

surface

floor.

The measurements can be made from the outside for the most accessible elements (for example those on the ground floor). For those on the upper floors or for less accessible doors and windows, the measurements should be made during the inspection from the inside of the building.

Having previously catalogued the doors and windows by type, it is sufficient to measure one sample for each type of door or window which has the same dimensions.

(f)

Having gathered all the available information from this first survey, it is possible to proceed to the next, more specific phase.

When entering the building one can easily spot the following features:

type, layout and use of the premises: offices, school rooms, laboratories, bathrooms, halls, etc... which should be taken into consideration with regard to energy needs

number and use of the floors: the number and use of the floors can often be intuited from the outside, however it is always advisable to confirm the presence of basements, mezzanines, attics, etc... which are discernable from the inside only.



(g)

Requiring a logical order with which to proceed, the next step is to work floor by floor, analysing first of all the characteristics of the shell and then the systems.

In order to study a “floor type”, it is necessary to begin with the hall and then to proceed room by room. It is necessary to note the following information for each room.

Dimensions

Measuring the dimensions of the rooms is important in order to be able to make a final calculation of the volume of the building actually heated.

The height of the floor and the length of individual internal walls can be measured using the laser distance meter.

Characteristics of the shell:

In order to have an exact idea about the construction characteristics of the shell, it would be necessary to take core samples of the walls. This procedure involves taking samples of the entire thickness of the wall so that it is possible to see directly the thickness and type of materials used in the construction.

In most cases, this type of procedure is not feasible for economic, time and practical reasons. In an audit such as the one proposed here, we should use less precise methods that are, however, also less intrusive and less time-consuming.

- *wall thickness:*

moving towards the window or an internal door, it is possible to measure the thickness of the outer and inner walls. For this particular information it is only necessary to take a few measurements, given that the thicknesses should be maintained throughout the rest of the building.

- *presence of insulation:*

ruling out the possibility of taking core samples, the presence of insulation will have to be “guessed”: broadly speaking we can suppose that buildings constructed after 1991 will have insulation. For buildings from before this date, if no one on site is capable of giving relevant information, it will be necessary to find out or ask the opinion of an expert, for example a thermal technician or a builder.

- *presence of suspended ceilings:*

suspended ceiling elements are visible to the eye. They are important for the energy balance in the building due to their insulating properties. Therefore it is necessary to know the thickness and the material from which they have been constructed.



- *type of floor:*

floor coverings are also very important for the energy balance. The vast range of materials used (as a result of aesthetic, practical and economic choices) gives rise to a similarly vast range of thermal conductivity. It is necessary to establish whether the floor is in direct contact with the ground or if there is a space underneath that is not heated.

Windows

If the total number of windows has been counted from outside, it is still nevertheless necessary to establish the presence of windows not visible from the outside or that face onto internal courtyards.

Having already catalogued them by dimension, all that remains is to measure one sample for every type and from every sample to note the following:

- *type of glass*

There are many typologies of glass that may be encountered and therefore also many conductivity coefficients associated with each. For example:

- o single glazing
- o double glazing
- o triple glazing
- o anti-theft glass
- o energy saving glass (low emission)
- o reflective glass
- o other glass with advanced thermal characteristics

- *frame type*

The first thing to establish is the material used to construct the frames. The following are common:

- o wood
- o aluminium
- o steel
- o PVC

Then it is necessary to establish air tightness. In the event that there are no certificates (still rare in the Italian production of windows and doors) it is possible to confirm the use of single or double trimmings, the straightness of the doorstep, the presence of distortions, cracks, draughts, ...

- *dimensions*

In measuring the doors and windows it is necessary to note and distinguish between the following:

- o actual dimensions of glass surfaces
- o total dimensions of frames (to differentiate between total surface area and glass surface area).



- *screening (internal/external)*

These have the aim of protecting the people inside the building from direct sunlight, but at the same time must guarantee a high level of natural visibility. It is necessary to note the types of screening as their influence represents a reduction in natural sunlight that depends on the type of protection from:

- o internal or external Venetian blinds
- o white curtains
- o coloured curtains
- o horizontal or vertical external sun shadngs

Air vents

It is necessary to note the presence of air vents which are often positioned near the ceiling. This type of system allows for a mechanical recycling of air inside the building regulating temperature and relative humidity, filtering the air and guaranteeing the relative comfort of the air present in common areas.

Knowing exactly in which rooms the system is used allows calculation of the total volume, related consumption and potential savings. We will deal with more detail later on.

If present, the vents should be located (for example on the doors of the rooms where they connect to general vents in the hall, or in the bathrooms and kitchens).

Heat supply systems

The function of the heating bodies is to introduce thermal energy produced by the heating generator into the environment and to transmit it through the distribution network, exchanging heat with the environment by convection and irradiation.

It is necessary to note the following information:

- *Type*

The types that may be found are:

- radiators: composed of equal vertical elements (typically in cast iron, in sheet-steel or in aluminium alloy), they come assembled and inside flows a heat-carrying liquid that is usually water. They are connected to the feed pipes and return pipes by means of suitable interception valves.

The cast iron radiators are characterised by an almost unlimited lifespan and by an elevated thermal inertia. This last characteristic makes them particularly suited to applications where it is not necessary to reach operating conditions on ignition of the system (for example residencies where the system is continually in operation).

Steel radiators are subject to damage by corrosion which limits their lifespan.

Aluminium radiators (which have been used since relatively recently), present strong resistance to corrosion and high thermal results with minimum obstruction and low thermal inertia.

For aesthetic reasons, radiators are often covered up by furniture or positioned in available recesses: this causes, in general, a considerable reduction in power supply.



- radiant plates: unlike radiators, they are not made up of modular elements, but of one unique block, in general made of steel or sometimes in cast iron. In comparison with radiators they are characterised by minimum obstruction and a low quantity of water, radiant surfaces being equal. Thanks to the ease of maintenance they are suited to use in schools, gyms, hospitals, and in all environments that require maximum cleanliness with minimum obstruction.
 - radiant panels: these are heating bodies, with elevated surfaces of exchange, made up of many surfaces in the attic, on the floor, or, more rarely, on the lateral walls and suitably heated by winding tubes where the heat-carrying liquid is circulated. The use of these panels is common in very high buildings (industrial warehouses, gyms...), but is now also very common in residences.
 - convectors: here the exchange comes essentially through natural convection. They are made of thermal exchange batteries constituting fin tubes where the heat-carrying liquid flows, in general arranged in metal consoles or in suitable recesses in walls suited to a front closing panel. They require an elevated running temperature and are not suited to working with condensation heaters.
 - fan-coils: these are mainly considered convectors working under forced convection. They are very useful in the case of summer-winter air- conditioning.
 - unit heater: these are heating bodies suited to heating large environments where an elevated level of comfort is not required (industrial warehouses, gyms, swimming-pools...). They are characterised by low thermal inertia, minimum obstruction and elevated noise. They require heat-carrying fluid at a high temperature.
- *quantity*
the heat supply units in every room and of every type must be counted (for example the number of elements of the radiators) in order to make a final calculation of the total quantity of heat emission. Defining this, even though it is a long and boring process, can be useful in the absence of information relating to the thermal needs of the building.
- *Presence of thermostatic valves*
if radiators are present, it is important to establish the presence of thermostatic valves. They regulate the flow of hot water automatically depending on the temperature selected and set on a suitable graded knob. The valve closes slowly as the ambient temperature, measured by a sensor, moves towards the desired temperature, allowing the “deviation” of the remaining hot water to other radiators that are still open. The energy saving from the use of thermostatic valves can be up to 20%. Precisely for this reason, apart from a few exceptions, they have become compulsory in the construction of new buildings and for renovations.



- *Operating method*

Apart from the technical characteristics of heating bodies, it is advisable to establish the method of operation and regulation. Typical methods are as follows:

- continuous
- manual control
- thermostatic valve control
- control by area or environment
- centralised control
- timer control

This is important insofar as inappropriate use of the equipment results in a not negligible waste not to mention a deterioration in the overall comfort of the environment.

- *Distribution method*

The distribution of the fluid to the heating bodies can be achieved in various ways:

- by risers, that connect all the radiators placed vertically on various floors of the building in sequence
- by distribution collectors, to which all the radiators on a floor or in an area are connected
- by modul system, where a group of radiators is connected together in series, in general in a small area.

The type of distribution influences the possibility of control: with risers it is impossible to control area by area, therefore it is necessary to resort to thermostatic valves and to calculate the heat through allocation of the radiators, with the collector system it is possible to set up control and recording by area. With modul systems temperature control can cause problems due to the diversity of temperature between radiators in series, therefore it is necessary to check the flow.

Lighting

One of the most important factors as regards the overall comfort of the environment and electrical consumption is lighting. In this case a good compromise is needed between consumption and supply. With the advent of new types of efficient lamps and of domotics solutions, it can be worthwhile entering into this sector in order to have consistent advantages.

In order to evaluate the possibility of improvement it is advisable to carry out a census of the lighting systems in every room and note the following:

- *types and power of individual lamps*

The most common types of lamps for internal use are:

- incandescent lamps (typically from 15 to 150 W)
- alogen lamps (typically from 50 to 150 W)
- neon lamps (typically from 20 to 80 W)
- compact fluorescent lamps (from 7 to 50 W)



while for external use:

- high pressure sodium vapour lamps
- low pressure sodium vapour lamps
- mercury vapour lamps
- metal halide lamps

- *Quantity*

The number of every type of lamp will be required for the final evaluation of total consumption.

- Domotics elements

Domotics can help rationalizing existing system.

Therefore it is necessary to note the presence or possible application.

The simplest and most common interventions are as follows:

- movement indicators: they switch lights on and off only if there are people in the room
- adequate natural light indicators: they switch lights on and off depending on sufficient light from the windows
- systems for reducing light flow (dimmers): they regulate the flow of individual lamps depending on the natural light in the room
- switching on of lamps in sequence: this gives priority to the lamps furthest from the windows, depending on the natural light in the room.
- Temperature control of the heating bodies: they command a thermostatic valve by means of an sensor and a timer programme stored in the central computer.

Other electrical equipment

Depending on the purpose of the use of the building, various types of electrical equipment can be found: computers, printers, fridges, boilers, etc...

For each type of equipment it is useful to note the following:

- *quantity*
- *power and consumption*
- *age*: this last aspect is often very important as the growing awareness of users with respect to wasting energy has forced producers to focus on energy saving as an advantage of their products. For computers there is the "Energy Star".

Apart from the type, it is also important to be aware of the way in which electrical equipment is used:

- continually
- only in certain periods
- occasionally
- etc...

And, in the event that they are not in continual use, it is advisable to establish whether they are connected to multiple sockets with ON/OFF switches and luminous indicators, that



allow energy consumption to be avoided, even if minimal, through connection to the “stand-by” setting.

We have seen how to tackle the floor type of a building.
Particular situations may be encountered regarding basements and attics.

Basement

If the basement is habitable and heated, it should be treated using the procedure described above as any other floor.

It often happens however, that basements are not heated, but used nevertheless. In this case only the electrical equipment should be noted during the audit so we do not set the problem of evaluating thermal dispersion.

Attics

The same situation applies to attics as we have seen for basements.

The only difference is that attics may contain direct access to the roof (for example skylights). Taking this possibility into account it is advisable to note the characteristics of the covering:

- inclination,
- orientation,
- available space not in the shade (chimney pots, aerials, masts),
to evaluate the possibility or otherwise of setting up solar systems.

In the attic the possibility of the following should be evaluated:

- laying insulation material on the surface (absence of obstructive material, accessibility, necessity of providing pathways for access to the roof or other locations)
- housing the control equipment for a photovoltaic system or plant and the positioning of a thermal solar system, including the dimensions of the access pathways
- the possibility of laying tubes or cables to the power boards in the lower floors (photovoltaic) or to the thermal plant (for solar hot water).



2. INSPECTION

2.1. SYSTEMS: technological plants

Having concluded the investigation of the shell of the building, it is possible to proceed with the more technical stage: the inspection of the systems in the building.

In this phase the following will be dealt with separately:

- thermal system
- sanitary hot water system
- forced ventilation system
- summer cooling system
- electrical system

2.1.1. THERMAL SYSTEM

A “thermal system” may be defined as “a technological system intended for air conditioning of environments with or without production of hot water for hygienic use or for centralised production for the same purpose, including systems of production, distribution and use of the heat as well as parts for regulation and control; individual heating systems are therefore included in the thermal systems, whereas the following are not considered thermal systems: heaters, fireplaces, individual radiators, detached water heaters”.

The following are present in a thermal system:

- a thermal energy production system, which has the function of heating the heat-carrying fluid;
- the heat-carrying fluid distribution tubes, which have the function of transferring the thermal energy produced by the production system to the heating bodies;
- heating bodies (radiators, fan-coils, etc...), which have the function of introducing the aforementioned thermal energy into the environments to be heated, exchanging heat with the environment in part by convection and in part by irradiation;
- a control system, which has the function of maintaining the temperature of the environment at the desired value, with respect to legal requirements.

There are various types of thermal systems. In order of increasing power, the thermal system may be:

- autonomous: supplies an individual family unit
- centralised: supplies one or more buildings that are part of a complex of flats
- district heating: supplies one user (civil and/or industrial) that frequently makes use of cogenerative systems of thermal and electric energy.

2.1.1.1. TYPES OF FUEL

The types of fuel used in heat production are as follows:

- Solid fuels:



- Biomass
- Liquid fuels
 - Diesel fuel
 - Fuel oil
- Gaseous fuels
 - Methane
 - LPG

2.1.1.2. CENTRALISED THERMAL SYSTEMS (power \geq 35kW)

2.1.1.2.1. General

The so-called centralised thermal system is an system that produces heat for heating environments and possibly, but not necessarily, for producing sanitary hot water for use in a building or a group of buildings, in general that are part of a complex of flats.

The power of the system may vary, with respect to the size, from a few tens of kW to some thousands of kW for large complexes.

Essentially, a centralised heating system consists of the following components:

- one or more heat generators placed in a block of flats
- a distribution network of heat-carrying fluid, made up of a series of tubes of varying diameters, that connect the thermal centre with the heating elements (in recent systems the circulation of the heat-carrying fluid is guaranteed, by circulation pumps, while in very old systems the circulation was a natural type).
- the heating bodies
- the regulation and centralised control systems, usually found in the same location as the heat generator, or remote controlled from the control station with most buildings.
- one or more expansion tanks.

Two other components, not normally found in old systems, are:

- local temperature regulators (for example thermostatic valves on individual radiators), that in almost all cases are obligatory
- heat gauges for individual units

With reference to the distribution and circulation system, the centralized system may be in general:

- *risers*
the system is characterised by many risers, in general placed in correspondence to the outside walls of the building, to which the heating bodies are connected. The radiators in the same place, therefore, are connected to different risers.
- *horizontal distribution*:



consists of the current distribution system more common for new systems. There are three fundamental types:

- 1) systems with collection distribution with delivery and retrieval for each heating body
- 2) systems with monotube distribution and with heating bodies in series
- 3) radiant panel systems

2.1.1.2.2. Boiler house Inspection

The boiler house contains: a heat generator or generators, and other equipment necessary for the thermal system. In detail the following are present in the boiler house:

- one or more heat generators with relevant burners and safety devices
- tubes for adduction of fuel and the relevant components
- a network of tubes, thermally isolated, for the distribution of heat-carrying fluid to the users
- motor-driven pumps for the circulation of the fluid
- equipment for thermoregulation, safety and control.

Furthermore, the following equipment may also be present in the boiler house or in other locations:

- expansion tanks
- heat exchangers
- service oil tanks (for fuel oil systems with a main tank over the limits of suction from the burning pump)
- fire prevention system
- water softening system for replenishment of the thermal system.

The boiler house must remain locked to avoid intrusions, damage or tampering; for this reason it is necessary keep the keys:

- in the case of a private building, with the owner or the person in charge
- in the case of a public building, with the caretaker or the person in charge, or with the Municipal technical office.

(a) Regulations about characteristics of the boiler house

Entering into the boiler house, the first thing to do is to check the characteristics of the premises.

The premises must meet the requirements for fire prevention, site, dimensions, access, construction and structural characteristics. The boiler house is also subject to safety regulations that refer to the systems and the equipment present, the running and management of the plant itself.

Omissis: characteristics of the national regulations



Having checked all of these characteristics, it is necessary to note every anomaly. All interventions necessary to bring the boiler house up to standard should be inserted into the specifications.

(b) Overall state of the premises

Apart from the characteristics stated in the regulations, it is advisable to verify also the overall state of the practicality and maintenance of the premises, for example:

- technical space for movement
 - distance between equipment
 - presence of abandoned material
 - presence of dangerous objects
 - state of the walls
 - seepage
- etc...

(c) Retrieval of documentation

(d) Plant registration document

(e) Characteristics of the generators

The heat generators, commonly known as boilers, are the equipment that transfers thermal energy produced by combustion into a heat-carrying fluid.

The types of generators that can be found are classified as follows:

- type of fuel
 - solid fuel
 - liquid fuel
 - gas fuel
- heat-carrying fluid
 - hot water
 - superheated water
 - vapour
 - diathermic oil
 - hot air
- construction material
 - cast iron
 - steel
- pressure in the firebox
 - with a depression furnace (also known as atmospheric or aspirated air type)
 - with a pressurised furnace (also known as pressurised or blown air)



- steam temperature on exit (condensation or otherwise)
 - high performance
 - condensation
 - flowing temperature

The generators are characterised by the following power values:

- *thermal power of the burner*: defined as the product of the lower calorific value of the fuel used by the amount of fuel burned;
- *effective thermal power*: defined as the quantity of heat transferred to the unit over time by the heat-carrying liquid, corresponding to the thermal power of the furnace lost by the thermal power exchanged through the shell of the generator to the outside environment, by the thermal power lost through the chimney or for other causes;
- *conventional thermal power*: defined as the thermal power of the burner less the thermal power lost through the chimney. It is therefore the same as the effective thermal power increased by the thermal power dispersed through the heat generator shell;

and from the following performance values:

- *combustion performance*: synonym of conventional performance, intended as the relationship between conventional thermal power and the thermal power of the furnace;
- *effective thermal performance*: intended as the relationship between the effective thermal power and the thermal power of the burner.

The combustion performance has a higher value than the effective thermal performance (as it takes into account only loss through the chimney) and is equivalent to the relation:

Combustion performance = effective thermal performance + loss through the shell.

For normal power (or performance) values are intended those values declared and guaranteed by the manufacturers according to the regulations of continual operation and displayed on the license and in the instruction manual.

The information to be displayed on the heat generator license or in the plant documentation, if available, is as follows:

- make and model: recorded on the identification license
- date of system
- boiler power: indicated on the identification license in terms of modulation by field (only one value for traditional boilers)
- nominal power: indicated on the identification license in terms of modulation by field (only on value for traditional boilers)
- electrical power absorbed by the generator
- loss through the chimney with burner switched off
- loss through the chimney with burner switched on
- effective thermal performance at nominal power
- effective thermal performance at reduced power (in the case of condensation boilers at 30% of nominal power)



In the absence of all technical information, note the make and model, it is then necessary to recover the information from the manufacturer.

Apart from gathering information, it is also advisable to perform a visual check of the state of repair of the boiler:

- presence of rust
- presence of leaks
- insulation conditions
- etc...

(f) Burner characteristics

Equipment which carries out the transformation of chemical energy from a fuel (liquid, gas or powdered solid) into heat by means of combustion. The process must occur with the correct stoichiometric relationship between air and fuel, in order to minimise the formation of unburnt gases, and without using too much air.

The classification of burners can be in function of:

- fuel and air introduction system:
 - for liquid fuel
 - for gas and blown air fuel
 - for gas and aspirated or atmospheric air fuel
 - for powdered solid fuel
- pulverisation system
 - mechanical pulverisation (for fuel oil and diesel)
 - pneumatic pulverisation (for fuel oil)
 - by emulsion
- operating type
 - single-stage
 - multi-stage
 - modulating
- pressurisation conditions
 - non pressurised
 - pressurised

The visual controls that can be carried out on the burner are:

- when burner switched off:
 - general maintenance conditions
 - cleanliness
 - leaks
- when burner switched on:
 - colour of the flame
 - noise



Any anomalies detected should be noted.

(g) Chimneys

Chimneys are also subject to the regulations stipulated in (a) as far as planning, construction and use are concerned.

It is possible to check the following visually:

- Straightness: there should not be any sharp bends (in the event of installing a condensation boiler, it is necessary to incubate the flue for protection against acid condensation. This is possible only if the flue is perfectly straight).
- Openings: in the flue or the walls
- Presence of humidity due to possible steam condensation
- Condition of connections
- Presence of corrosion

(h) Characteristic of expansion tanks and their certification

The function of the expansion tank is to allow the water in the system to, during heating or in an emergency, to expand freely finding an outlet without causing damage. If the increase in volume is not accounted for, an increase in pressure will occur, risking deformation, leaks and damage to the tubes and equipment of the water circuit.

The expansion tanks may be *open* (although these are hardly ever used now) or closed, depending on whether the water in the tank is in contact with the atmosphere or not:

- *Open expansion tank (not present in the thermal plant)*
Consisting of a concrete or metal plate container, where the heat-carrying fluid can expand freely. The container, as it is in contact with the atmosphere, must be installed at the highest point of the water in circulation in the system (not less than 1 metre from the highest radiator), as otherwise it would empty. The tank must always be covered in order to limit evaporation when the water is in contact with the air. The container is parallelepiped with a cylindrical cover with two dome shaped bases positioned on the vertical axis in order to limit the contact between water and air.
If the tank is installed outside or in an attic, the safety tubes, the escape tubes and the tank itself should be protected against intense cold.
- *Closed expansion tank (present in the thermal plant)*
Characterised by the fact that the water contained within is not in contact with the atmosphere: expansion occurs in a hermetically sealed container, designed to resist certain values of temperature and pressure, generally installed in the thermal plant. A certain quantity of air is closed in the tank, called the air cushion, in direct contact with the air or separated by a membrane. During heating, the volume of water increases and consequently so does the pressure in the tank.

There are three types of closed expansion tanks:

- *Membrane (with diaphragm)*



- *Auto pressurised (without diaphragm)*
- *Pressurised (without diaphragm)*

In all cases, the internal gas pressure is controlled by a safety valve set to a pressure lower than the maximum acceptable level for any part of the system.

There must be a customised certification given that the equipment contains hot liquids under pressure.

It is also important to observe and note the overall state of the layout and the maintenance conditions.

(i) Characteristics of the circulation pumps

The circulation pumps give the heat-carrying fluid the necessary energy to travel throughout the circuit of the system.

Important information found on the licence is:

- Maximum power
- Maximum head
- efficiency (if not present this information can be obtained from the manufacturer)

The characteristics to be checked are as follows:

- State of the pump (leaks, rust, etc...)
- Actual functioning (with proof of switching on/off from the control panel)

(j) Tube insulation

The tubes through which the heat-carrying fluid flows must be insulated with insulating material and covered in plastic.

It is advisable to check that all tubes are covered and that the coverings are complete.

N.B.: gas adduction tubes should not be insulated, but they should be coloured yellow.

(k) Safety systems, protection and control

The systems for safety, protection and control are made up of all the equipment capable of guaranteeing a normal operation and ready to intervene in case of anomalies, before the system is ruined or, due to the malfunction, before people are injured or equipment damaged.

In the heating system the two most important things to check are the following:

- Temperature
- Pressure

It is advisable to have more than one way to measure these values for the system.



The equipment to be installed with hot water heating systems is divided among:

1. *Control systems*: able to allow the reading of the temperature, information and pressure of the water in the heat generator
2. *Protection systems*: they intervene only upon reaching a specified value of a control parameter or in case of damage to their system; these systems allow the safety systems to operate
3. *Safety systems*: they are activated by the same fluid, controlled without the need for external energy and guarantee that neither the temperature nor the pressure reach the specified values.

Control systems are:

- Thermometers for temperature control
- Manometers for pressure control

They are necessary in order to establish the correct temperature and pressure conditions for the operation of the system.

Protection systems are:

- Regulatory thermostat (or automatic thermal switch)
- Manual recharge thermostat (or automatic thermal switch)
- Pressure switch for the manual recharge thermostat
- Flow switch

Safety systems are:

- Safety tubes
- Safety valve
- Thermal discharge valve
- Fuel interception valve

In order for the overall operation of the system to be efficient, it is advisable to ensure that all of these systems are in a good state.

(l) *External gas interception valve*

(m) *Water treatment (water softening systems)*

(n) Layout of the operating diagram If the operating diagram of the system is not available, it will be necessary to design one based on the state of the thermal plant, preferably in .dwg format.

(o) Climate control, the overall operations through which an attempt is made to maintain climactic comfort in inhabited environments, within economic and safety conditions of the system, with respect to the prescribed regulations.

The temperature of the environment is usually the parameter used to regulate the systems for winter climate control, as this is the parameter which has the greatest effect on the perception of comfort.



The ambient temperature control related to external temperature, comes by way of a regulatory system driven by a probe that measures the external temperature (T_e).

This probe should be positioned in such a way as to avoid exposure to solar rays: usually at the height of the first floor, facing north, or, if this is not possible, facing east with protection from the morning sun. A south facing position should be avoided.

The parameter that is controlled in function of the external temperature is the temperature of the heat-carrying fluid (T_m) measured at the beginning of the distribution circuit.

These two amounts (T_e , T_m) are connected by a curve (usually a line), called the thermoregulation curve, which is placed inside the climate control centre.

If the recorded values of T_e and T_m do not fall on the thermoregulation curve, the regulator intervenes with a corrective action from the motor-operated valve until the value is brought back on the curve.

Nowadays there are some thermal plants driven by external temperature, that even have a thermal sensor connected to the inside of the heated environment. In this way the system adapts to the conditions of the building automatically taking into account the external thermal conditions and the contribution from the thermal charge.

(p) Motor-operated control valves

Three-way motor-operated valves

The control system of centralised systems, driven by the external temperature by activation of a three-way mixing valve, makes up the main reference diagram.

In this case the motor-operated valve is a mixing valve with two points of entry and one of exit. The water coming from the system tube mixes in the valve with water coming from the generator, leaving at a lower temperature with respect to the water coming from the boiler.

Four-way motor-operated valves

external temperature-driven control systems operating on a four-way valve, there are two hydraulic circuits, a primary (from the generator) and a secondary circuit (from the user). The temperature control again occurs through mixing.

The four-way valve is made up of four orifices organised in a cross and assumes one of the following positions:

- a) Condition of maximum load: all water heated in the boiler is sent to the heating bodies
- b) Condition of partial load: mixed water (at a lower temperature and constant supply) is sent to the heating bodies, partly from the boiler and partly from the return tubes of the heating bodies
- c) Condition of no thermal load: recirculated water is sent to the heating bodies.

It is necessary to establish the state of repair of all control valves.



(q) Placards

“Boiler house” must be clearly indicated outside the plant with all relevant danger warnings. Furthermore the operating times and the name of the person responsible must also be displayed.

2.1.1.3. AUTONOMOUS THERMAL SYSTEMS (<35 kW)

2.1.1.3.1. General

Autonomous heating systems are based on boilers with burners with thermal power 35 kW (about 30,000 kcal/h).

The vast majority of these systems run on gas fuel (usually methane and LPG) and often also provide for the production of sanitary hot water.

In the standard configuration, an autonomous heating system is made up of the following components:

- A heat generator (autonomous boiler): this can be wall- or floor-mounted and also includes the heat-carrying fluid circulation pump (using hot water in almost all cases), control and safety systems, including the expansion tank, and accessories.
- A heat-carrying fluid distribution network, made up of a series of tubes that connect the boiler to the heating elements
- The control systems, that can be of various types and that include the systems for automatic ambient temperature control both from inside the system (time thermostats) and from individual locations (thermostatic valves) or from individual areas, that is a group of locations having the same characteristics and exposure.
- The heating bodies

The system solutions as regards the distribution of hot water to the heating bodies are as follows:

- distribution by collector*: the hot water produced in the boiler is sent to a distribution collector that feeds all the heating bodies in the building in parallel
- distribution by collector by area*: similar to the previous system but subdivided into separate areas, fed by other distribution collectors, activated or deactivated by electromagnetic valve
- ring distribution*: the radiators are arranged in series without a distribution collector. In this case the hot water temperature at the beginning of the various heating bodies decreases by passing from the first to the last element while the supply remains constant. This system solution is less common than the previous ones.

2.1.1.3.2. Inspection

This type of system does not need to be placed in a suitable boiler house and is much simpler than the previous example.



(a) Boiler

There are different types of boilers for autonomous heating systems. A general classification can be made referring to the following characteristics:

- *system*
 - unsealed fuel combustion boiler: equipment which allows the flue or discharge system to be connected to the location where the equipment is installed. The collection of comburent air is from the system location and the discharge of the products of combustion is outside the location itself.
 - sealed fuel combustion boiler: equipment where the combustion circuit (collection of comburent air, combustion chamber, heat exchange and discharge of products of combustion) is kept with respect to the location in which the equipment is installed. The collection of comburent air and the discharge of the products of combustion occur directly outside the location.
- *function*
 - boilers for heating
 - boilers for heating and the production of sanitary hot water with instantaneous exchange
 - boilers for heating and the production of sanitary hot water with accumulation tank
- *fuel*
 - boilers for single gas
 - boilers adaptable to various gases (methane, LPG...)
- *type of burner*
 - boilers with atmospheric burners
 - boilers with blown air burners
- *regulation systems for gas flow*
 - boilers with ON/OFF fuel valves
 - boilers with two-stage fuel valves
 - boilers with electromechanical fuel valves modulated by water temperature sensors in the boiler
 - boilers with fuel valves modulated by electronic control display
- *method of system*
 - ground boilers, to be installed to the floor
 - wall boilers, to be installed to vertical walls
 - boilers to be installed externally, for example on balconies or verandas
- *energy efficiency*
 - high performance boilers (effective performance nominally superior to a power of 90%)
 - temperature flow boilers
 - condensation boilers

The information to gather is:

- maker and model: registered on the identification plate
- burner power: indicated on the identification plate in terms of boiler modulation
- nominal power: indicated on the identification plate in terms of boiler modulation
- electrical power absorption
- loss through the chimney with burner off



- loss through the chimney with burner on
- effective thermal performance at nominal power
- effective thermal performance at reduced nominal power (in the case of condensation boilers, 30% of nominal power)

The main checks necessary as regards the general conditions are as follows:

- Ventilation checks: For unsealed systems there must be a ventilation opening. The state of repair must also be checked: that it is not blocked or covered.
- Check conservation conditions (dirt, obstructions, flammable material nearby).
- Last actual maintenance operations. See the new regulations (European directive 2002/91/EC):
- Age of the boiler (if more than 15 years, replace with a condensation boiler, equipped for the production of sanitary hot water).

2.1.2 SYSTEM FOR SANITARY HOT WATER

The types of system with which sanitary hot water can be produced may be:

- Centralised thermal system with production of sanitary hot water
- Autonomous thermal system with production of sanitary hot water
- Centralised system for production of sanitary hot water solely
- Individual system for production of sanitary hot water solely

2.1.2.1. CENTRALISED THERMAL SYSTEM WITH PRODUCTION OF SANITARY HOT WATER

The sanitary hot water is produced in the thermal plant by the same heat generator that produces the heating. In this case thermal accumulation is present in the thermal plant. As a consequence it is necessary to note the following:

- State of repair of the accumulator
- Capacity of the accumulator
- Insulation of the connecting tubes
- Year of system of the accumulator
- Presence of a recirculation system of sanitary hot water

2.1.2.2. AUTONOMOUS THERMAL SYSTEM WITH PRODUCTION OF SANITARY HOT WATER

2.1.2.3.

Boilers used both for heating and for the production of sanitary hot water (also called mixed boilers), provide for the production of sanitary hot water in two fundamental ways:

- Production of sanitary hot water in suitable instantaneous exchangers (water/water)



- By means of a suitable accumulation container, generally contained in the same place as the boiler, where the sanitary hot water is kept at the required temperature, by the heat generator, by means of a coil exchanger.

In this case it is also necessary to note the following:

- State of repair of the accumulator
- Capacity of the accumulator
- Year of system of the generator

2.1.2.4. CENTRALISED SYSTEM FOR PRODUCTION OF SANITARY HOT WATER

In this case the sanitary hot water is produced by a dedicated gas boiler usually situated in the thermal plant. Given that it supplies many users a thermal accumulator is present.

It is necessary to note the following:

- Make and model of the generator and the accumulator
- State of repair of the generator and all the connected equipment
- State of repair of the accumulator and all the connecting tubes
- Power of the generator
- Capacity of the accumulator
- Year of system of the generator and the accumulator

2.1.2.5. INDIVIDUAL SYSTEM FOR SANITARY HOT WATER

In this type of system the sanitary hot water is produced by a gas or an electric boiler. Older ones tend to be situated in rooms such as the bathroom, kitchen etc, but recent regulations set out more restrictive prescriptions about the choice of placement. As a result, in case of replacement it may be necessary to change the location.

It is advisable to note the following:

- Make and model
- Power
- Capacity
- State of repair
- Year of system of the boiler



2.1.3 FORCED VENTILATION SYSTEM

The air treatment system is a system designed to provide for mechanical ventilation and to effect the exchange of air inside the building with that outside the premises to ensure a high level of relative comfort regarding:

- Air temperature
- Relative air humidity
- Air quality (purity, percentage of CO₂)

Usually, the air in circulation is a mixture of external air and air taken from inside. The reason for this is to maintain a constant ambient temperature without too many costs for heating air coming from outside.

The minimum requirements that must be met are contained in specific regulations (expressed in volume per hour of air exchange specified by the various types of buildings and by quality parameters).

The principal air treatment system components to check are as follows:

- battery after heating
- motorized ventilators: check the motors work properly
- filters: if they are clogged it is necessary to replace them
- if present and in working order a differential pressure switch (made up of two pressure sensors placed before and after the filter that demonstrate if the filter has become clogged)
- inspection windows: not always present
- ventilation group
- control framework
- connections and cables: state of repair
- probe for measuring CO₂ levels in the air recovery conduits: if installed and functioning
- thermostat: if installed and functioning correctly
- air humidification system

The most modern systems have cross-flow heat exchangers which, connected to the air treatment system allow the air to be pre-heated thanks to the heat recovered from the hot air that is expelled from the building.

The information to note (usually written on the registration plate) is:

- capacity (m³/h)
- power (of the motor in kW)



2.1.4. COOLING SYSTEM

A cooling system is generally made up of the following components:

- Cold generator: this is the system that produces and distributes the cold. The principal cold generators are: large cold production plants, heat pumps, spits, absorbers, the Solar Cooling system and district cooling. It is important to verify if the generators are fitted with inverter systems, that is if they are capable of modulating the power of the working motor on request, avoiding energy waste.
- terminals: they are the systems that supply cold to the environment locally. The principal terminals are: fan-coils, radiant panels, absorbers and spits, these last two serve simultaneously as generators and terminals.
- Distribution network: these are the tubes that distribute the cold to the premises through the circulation of water in the system. In the spits the distribution is made up of tubes that connect the compressor with the condenser and the evaporator.
- Control system: this is the system that allows the desired temperature regulation and the corresponding power that the generator needs to supply.

The system can be centralised or autonomous.

The distribution terminals are usually:

- fan-coils (these can be the same used also for heating)
- splits
- vents (positioned in the walls or in the conductor)

Apart from any anomalies found in the various components, it is important to note the following information about the system:

- capacity (frigories/h)
- power of the motor
- presence or otherwise of motor with inverter

2.1.5. ELECTRICAL SYSTEM

As far as the electrical equipment is concerned, a census has already been carried out during the inspection of the building noting the following:

- consumption
- state of repair
- age
- list of possible interventions/replacements

Apart from the equipment inside the building, it is also necessary to survey external lighting equipment. In particular it is necessary to verify if it conforms to national /local regulations on light pollution.

Finally it is necessary to establish whether the whole system is in accordance with national-local norms and regulations. It may be necessary to rely on a technician to verify that the system is compliant.

