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# ENERGY ANALYSIS AND RENOVATION PROPOSAL FOR A LIBRARY IN THE UNIVERSITY OF DEBRECEN

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# ABSTRACT

The European Union has made a strong effort in the last years to reduce the energy consumed in the housing sector, by implementing Energy Directive and planning to reach Nearly Zero Energy level for all buildings by the end of 2020. At present we are far away from this ambitious goal.
Considering that most part of dwellings in the EU have been constructed before 1990 it is required first of all to reduce significantly the energy consumption of these existing buildings.

The Energy Certification is a powerful mean to assess the energy performance of buildings and to suggest saving measures; this is what has been made for an existing library in the University of Debrecen in Hungary. To help the reader to understand the context, the European guidelines for buildings are introduced, with an overview of Hungary energy situation for housing, and the technical regulations for Hungary and Italy are presented to be able to carry out the calculations.

The building is analyzed with the Hungarian Regulation, by assessing an energy performance rating, and then it is certified again with the Italian specifications.

This contrast shows how many similarities and at the same time differences occur in an energy certificate made for the same building following two different procedures, both based on European Directive, and can help to find incomplete points in the certification.

At the end of this work a list of recommendations have been found by the designer, and they have been analyzed basing on feasibility and cost effectiveness.

L'Unione Europea si sta impegnando da anni per ridurre il consumo energetico nel settore edilizio; le Direttive emanate per le prestazioni energetiche degli edifici ne sono un esempio, così come l'obiettivo di costruire edifici "Nearly Zero Energy" fissato per la fine del 2020.
Sebbene tale ambizioso traguardo sia ancora distante, è possibile ridurre in maniera rilevante il consumo degli edifici esistenti, che rappresentano la percentuale più elevata del settore edilizio.

La Certificazione Energetica è lo strumento adatto a questo scopo, permettendo una valutazione delle prestazioni e dell'efficienza degli edifici e suggerendo soluzioni tecniche che permettano ai cittadini di risparmiare e allo stesso tempo consumare meno energia riducendo l'impatto ambientale. Per comprendere meglio tale analisi sono state dapprima introdotte le linee guida europee in campo energetico, e di seguito la situazione energetica in Ungheria correlata dalle normative tecniche ivi vigenti, con un accenno anche alla situazione tecnico-legislativa italiana.

A questo proposito è stata svolta l'analisi energetica di una libreria universitaria situata a Debrecen, in Ungheria; l'edificio è stato certificato con la normativa ungherese e successivamente con quella italiana. Da tale duplice analisi è possibile ricavare analogie e differenze che evidenziano possibili incompletezze e punti deboli nella certificazione.

Al termine di tale lavoro saranno fornite una lista di raccomandazioni individuate dal progettista per migliorare l'efficienza di esercizio dell'edificio, sostenute da uno studio di fattibilità e sostenibilità economica in rapporto costi-benefici.

# ACKNOWLEDGMENT

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Köszönöm szépen!

I want also to thank Prof. Michele De Carli for his support during the final part of my work in Italy.

Another mention has to be made for Mr. Viktor István Kiss for his collaboration, although the language difficulties he helped me providing me a lot of technical informations on the building I have certified.

I want also to thank all the students (and friends) I met during my staying in Debrecen, especially Fruzsina Gál, Ieva Savickaite and Anita Smajda who sometimes helped me as "assistants" to carry out my project.

Last, but not at least, I want to remember a friend that will never read these pages, but who is still in the minds and hearts of many. Even though this was not his field of interest, my thesis is dedicated to him. Ciao Zano!

# Summary

# INTRODUCTION

“ We must identify breakthrough points, future industries, which will enable us to vitalize the entire economy. We must identify the means to connect these breakthrough points and thereby weave a fabric of such points, which will serve as the driving force behind the most important economic playing fields: a health care industry based on local opportunities and highly labour-intensive enterprises, tourism, green economy, renewable energy, water based economic development, the automotive industry, the knowledge industry, transit economy, the food industry, business services, R&D. ”

Excerpt from the Programme of National Cooperation, May 2010

With these words the National Assembly of Hungary acknowledged the will of people for a change of the political, economic and social system in every area of life.
Is it really possible to find “ breakthrough points…behind the most important economic playing fields” ? The answer to this question, hopefully many of them, will influence in a tremendous way the future of many countries that are trying to step in the world’s economy without being only silent watcher of the show, and Hungary is one of them.
As the days of an economy based on cheap energy sources are coming to an end, the primary issues for the world economy will be energy, its access and the quality of natural resources as water, soil and wind.
A field of interest, where renewable energies can be successfully implemented by achieving relevant savings and improving energy efficiency, is the housing market.
Only in Europe buildings affect by over 40 % the total yearly consumption of energy; this situation cannot be sustained anymore. It is time for a change, and many efforts have already been made by EU towards this ambitious goal. As building engineer we have to be prepared to give cost effective solutions that can really improve energy efficiency, with a new way of thinking that has to spread all over, from the designer to the manufacturer and the public audience.

The European Union elaborated a Directive (EPBD) especially focused on the energy performance of buildings: as seen so far this is a sector where big savings can be achieved, with positive result for the economy.

A powerful mean to assess the quality of a building is the Energy Performance Certificate: this official document, that we will extensively discuss later, has to become a standard used to compare similar buildings and to find ways to improve their efficiency. We are about to analyze an existing buildings and to see how we can evaluate its performance and its "quality" in the energy usage. At the end of our report we will be able to give recommendations to save energy, which means money for the owners, with technical solutions that are sustainable and cost effective. This is very important if we refer to the public market where private citizens want immediate results with rapid return times of their investment, especially in a tumultuous and uncertain period for world economy as the one we are living in.

During the compilation of our certificate we will see how many different competence are required to properly estimate the energy performance of a building.

This reflects what happens nowadays, when the design of an energy efficient building has to involve civil and electrical engineer , HVAC systems designer and mechanical engineer working as a team together, with many difficulties and challenges that, once are straighten out, can lead to great results.

Since every European Member State developed its own Regulation to accomplish the European energy strategy, our work will compare the certification made following the Hungarian specifications and the same according to the Italian one. The result will be compared to find the common points and the differences with particular attention to the validity of the certificate as standard document to evaluate and group together buildings having the same energy consumptions.

This work can be helped by commercial software, that are currently provided by a lot of companies of the building sector; we will use on them during our analysis with the Italian regulations.

# FIRST CHAPTER

## Presentation of EPBD and Hungary energy report

The European Union considers as main goals in his future reducing energy consumption and eliminating wastage, and these goals are embedded in Europe 2020 – the EU's strategy for a smart, sustainable and inclusive growth. Therefore, EU support for improving energy efficiency will prove in a decisive way for competitiveness, security of supply and most of all for meeting the commitments on climate change made under the Kyoto Protocol.
We have to keep in mind that there is a significant potential for reducing consumption, especially for buildings; this is why the EU has introduced legislation to ensure that they consume less energy.
We will report the main goals and key points of EPBD with a report for Hungary energy situation so that the reader is aware of the general context in which our energy certification has been made.

## 1.1 Brief introduction to EPBD

A key part of this legislation is the Energy Performance of Buildings Directive, hereafter referred as EPBD, which requires all EU Member States (MS) to tighten their building energy regulations, introducing energy certification schemes for buildings, and to carry out inspections of boilers and air conditioner systems (A/C).
It is clear that the introduction of national laws that meet these requirements is challenging for many EU Member States, as the legislation has always many advanced aspects, and at the same time it's a great opportunity to further energy efficiency in EU buildings.
To support MS in this task, in 2005 the Concerted Action (CA) EPBD was launched by the European Commission to promote dialogue and exchange of best practice between the Member States.
CA became immediately an intensely active forum of national authorities from 29 countries, focusing on finding common approaches to the most effective implementation of this EU legislation.
The latest CA EPBD 2, launched in September 2007 and concluded in 2010, was organized around 5 Core Themes (CTs):

- Certification of buildings
- Inspections of boilers and Air-Conditioning systems
- Training of experts
- Procedures for characterization of Energy Performance
- Information campaign

Since the second phase was launched in 2007, CA has organized six major meetings between MS representatives, and ,in addition to plenary session devoted to issues of general interest, it also organized a total of 63 detailed technical sessions for discussing specific issues relating to one or more of the 5 CTs.
As presented in the program of work, "Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant. Additionally, MS shall take measures to ensure that buildings with a total useful floor area over 1000 $m^2$ occupied by public authorities and by institutions providing public services to a large number of persons…have an energy certificate placed in a prominent place clearly visible to the public."
Almost all MS have experience in this kind of activity, and in doing so many of them decided to converge on similar solutions, whenever possible, thus allowing a more harmonious implementation across the EU.
Since January 2006, energy performance certification (EPC) is gradually being introduced in the MS for different types of buildings, and specific experience can now be exchanged so that MS can see successes or, in many cases, problems, and take corrective measures that will lead to further convergence of methods, including administration systems, so as to give a robust effect to the Directive.
The first CT is the Certification of buildings, which will be the core and matter of interest in this thesis, and the discussions between MS related to it focused on nineteen topics here listed:

**Building certification in general:**

. measured or calculated energy performance rating
. certification of flats and blocks of flats
. certification of complex and mixed-use buildings
. energy certificates for display in public buildings
. processes for making recommendations
. national standards for benchmarking using measured energy rating
. interaction between certification and inspections
. voluntary certification in the USA

**Administrative aspects of building certification:**

. cost of certification
. Layout of certificates
. quality assessment of certification
. practical experiences on Quality Assurance of Experts
. database management
. extraction of additional value from EPCs databases
. Re-certification / re-scaling of EP scales
. design, operation and financing of central registers

**Implementation of energy performance certificates in MSs:**

. impact of certification
. compliance with and control of EP requirements and certification systems
. influence of EP certificates on the market value of the building
. study tours

We are going to focus our attention only on a few of the upper topics, which were the most challenging during the energy certification of the building we will analyze later.

## 1.2 Which energy performance rating?

One of the most serious problems that engineers find when preparing an energy certification is which energy performance rating they have to consider: the choice is as a matter of fact between the calculated rating and the measured one. Before deciding which approach has to be used, we have to keep in mind that the aim of building energy certification is to certify *the buildings* and not *the users* of the buildings; having said that, for larger non-residential buildings such as the one we are going to analyze a change in individual user behavior will not affect in a large way on the overall energy performance of the whole building.

The operational (measured) rating is based on meter reading, involving energy consultants, building owners and supply companies in the process: it's greatly influenced by the behavior of the occupants, and, consequently, eventual adjustments to a standardized energy use can lead to huge problems.

Furthermore, the operational approach is largely depending on recommendations, made by experts and energy consultants, that are often difficult to identify and to be used to give an accurate estimate of the potential energy savings. Besides this, measured rating will usually be cheaper than using calculated energy performance because it needs less time to collect information about the building, especially for old buildings which had several retrofits and renovation collecting enough information about the building (envelope, HVAC systems, previous renovations in case of old buildings) and in the establishing of a appropriate building model, as we will see further.

The optimal solution would be to have both calculated and measured EP rating, but it can be seen as this is not feasible because of the very high costs and the problems connected to the comparison of the measured and calculated energy performance in the same certificate.

during the years. It happens very often that the building under investigation has to be divided in sub-parts to take in account the different energy users; in these situations the measured rating can be more difficult to apply whenever energy meters are not installed in all the parts of the buildings and, consequentially, no energy saving measures can be suggested unless additional sub-meters are installed in sections of the building.

On the other hand there is the calculated (asset) rating, which requires building registration, manufacturer's data and calculations based on standard impacts for persons and standardized energy consumption for HVAC and DHW systems. This method offers the possibility of getting detailed information about the thermal envelope and the installations of the building and, in addition, the resulting energy certification will be based on a standardized calculation procedure by using standard loads and climate data. This is extremely interesting whenever it's needed a comparison between the energy performance of two buildings located in different areas but with similar characteristics and destination of use; the contrast can be made directly, without any kind of adjustment or standardization. However the cost of issuing an EP based on this rating is higher than the one based on measured data, because of the more time-consuming in the

| | Advantages | Disadvantages |
|---|---|---|
| Metered energy performance | The building survey is quick and energy savings are directly related to the real energy consumption<br>Often cheaper than calculated EPC, due to the short time needed to establish the energy performance | It is difficult to identify savings, as energy break-down is often unknown. Very dependent on the skills of the expert.<br>Requires a special method for adjustment of measured consumption to standard consumptions.<br>The time saved on certification can be lost on adjustments and recommendations. |
| Calculated energy performance | • In-depth knowledge about thermal envelope and installation is obtained.<br>• Possible to identify (calculate) energy savings for each individual measure.<br>Standard calculation makes it possible to compare (benchmark) different buildings. | Requires detailed information about the building and installations to set up an appropriate model (more time-consuming). |

Table 1. Advantages and disadvantages for metered and calculated EP certification

The reason for choosing whether one or the other approach in a MS is as a matter of fact a political decision; some Member States have adopted measured EP ratings for some type of buildings and calculated for other types basing the decisions on considerations of cost. There are also a few MS who decided to use both the two ratings, depending on building typology and age.

- Calculated: AT, BE(F), BE(W), CZ, DK, HU, IE, IT, NL, NO, PT, RO, SL, SK, UK
- Measured: SE
- Combination of both: FI, DE, LU

## 1.3 EPBD and penalties

The EPBD, has seen so far, has many goals to reach and in doing this it's very important that the legislative and regulatory requirements follows in practice the normative and are carried out in an orderly manner. To ensure the implementation of the directives penalties are used in the MS, and they can be divided into two main categories (in brackets, the number of countries using these penalty mechanism):

- Penalties for building owners for not making an EPC available:

  - Financial penalties (14)
  - Legal penalties (6)

- Penalties for assessors for issuing an incorrect EPC:

  - Cancellation and correction of the EPC (7)
  - Warning and compliant procedure (7)
  - Further training/examination of assessors (2)
  - Financial penalties (7)
  - Revocation of license (7)

The application of these penalties are quite different among the MS; a few countries decided to have an active control and sanctioning system, others have it only in theory but have not used it very much in practice yet. There are also some MS that are investigating the possibilities for sanctioning, and others who start actively the sanctions when they implement the EPBD recast. The possible penalties are fines on assessors for issuing an incorrect EPC range from 500 to 5000 €, or also liability for damages and revocation of license. In addition, the penalties for owners who fail to present a valid certificate range from no penalty, to prison sentences, to fines for tens of thousands of € for large non-residential buildings.
The Concerted Action participants analyzed the approaches to penalties from different perspectives and after many group discussions several interesting question were raised, inter alia:

- Are penalties really necessary?
- Do we know how big the compliance problem is, in order to apply the correct penalty?
- Is there room for human error?
- What is the effectiveness of applying penalties?
- Could further training help to overcome quality issues?
- What do we actually want to achieve with the penalty system?

The answers to such questions will allow the individual countries to establish appropriate penalty systems.

## 1.4 More effective ways to hit the consumer target

The fear of penalties is not and has not to be the only way to encourage building owners to issue a EPC certificate; they have to be aware of how energy is used in the buildings, of how energy efficiency and energy saving affect the costs of their buildings maintenance, and in which ways a EPC adds value to the building stock. At the same time also the consumers have to be motivated in many different ways to undertake energy savings, which is often difficult; in order to take this step a lot of barriers have to be removed. The project IDEAL-EPBD gives a strong effort to understand the response of dwelling owners, and the reason why some of them do not follow the recommendations given in the EPC. The study focuses on possible influential factors for individual households' behavior regarding residential EP, such as investments in renovations of the building shell or the technical systems, and based on the literature arising these topics the factors are the following:

- Financial issues, e.g. long payback time, that can hinder consumers to take energy efficiency investments.
- Social context; e.g., residents are more willing to adopt energy savings measures if these are both visible and contribute positively to a "statement" towards their family, friends, colleagues or neighbours.
- Information issues, most of all knowledge about costs, performance of the technical solutions and possible choices.
- Decision-making context; there is always a strong barrier for energy efficiency investments when the owner who needs to decide about it does not necessarily benefit from it in the operational phase.
- Perceptions of renovation; in case of major retrofit and structural interventions the amount of work and the mess created by the new technical improvement might cause a negative effect on the final decision of the customer.
- Perceptions of "green" issues; e.g., an individual's attitude towards the "green" topics (environment campaign, climate change, exc..) can have a positive impact whether or not he will implement energy efficiency measures.
- Life events and routines; it is the most uncertain factor, it refers to the different kind of sensitivity shown by people in specific periods of their existence, when they are more willing to make big changes in their daily lives and routines.

As seen above, all these factors together play a decisive role in the final decision of the consumers, and so they have to be taken all in account with a total approach that can remove the barriers and motivate the possible customers towards energy efficiency measures.
A list of possible solutions that respond to these requirements are:

- A significant lowering of investment costs, using first of all subsidies: it is clear that high initial investments are a high barrier to taking action for the consumers.
- Once the energy saving measures are operative, focusing on decreasing the energy bills.
- Pre-financing the investment costs: in this way more consumers, even the ones with a lower income, can implement energy saving measures.
- Communication and information in the right time and context: e.g. when consumers decide to purchase their first home, municipalities have to give them information about high efficiency houses. At the same time it is an important task for the central government to communicate and share information to the regional government and municipalities to promote the diffusion of energy efficiency measures to this target group. The municipalities have also to inform the consumers at the right time: when they ask for a building permit they have to inform them about implementing possible energy efficiency measures, with related info about subsidies and financial help.

## 1.5 How does the EPC influence the market value of a building

Once the barriers are removed by using the influential factors mentioned before and the possible consumers are attracted towards the energy savings in the building industry, their final decision can be affirmative when they realize how the market value of their building is positively affected by the EPC. This is why, starting from the second semester of 2009, investigations were carried out in each country to identify, characterize and present possible tools and strategies that can establish the correlation between EPC and market value of buildings.
An enquiry regarding the large scale deployment of certification and the existence- or not- of databases for housing transactions showed that, based on the 25 MS responding:

- 13 of them had, at that point in time, not yet witnessed a large scale introduction of EPC;
- only 1/3 of the countries had detailed databases for the housing market.

Even if the experience on this topic is still limited since most schemes have only recently been introduced, an empirical study conducted in the Netherlands[1] [1]showed that, on a sample of 180000 sold houses, 40000 of them with an energy label, a "green premium" of 2.7% was detected for the top category of EPCs.

Although no effect on the speed of sale was detected, considering the average value of a home in the country this premium means an added value of about 6000 €- In Poland about 60% of the building owners report that an EPC has a positive influence on the market value of buildings, based on Polish-case study with opinion survey with major companies, but it is not yet possible to actually quantify this effect. The conclusion about the EPC's effect on the market are that there is still a very limited knowledge in assessing their impact on the housing value, because the available and on-going studies about this topic vary in methodology, actors and target, and so the results are strongly country-specific at this stage. Anyway the need for consumers and market actors to have experience

[1] Brounen, D., Kok, N. and Quigley, J. (2009) The diffusion of green labels in the housing market, RSM, Rotterdam

on these effects is growing, and this can be a key driver for reaching the objectives of the EPBD and EU targets on energy efficiency. That's why it is recommended that MS start, or keep on, paying close attention to this topic and pass on the information acquired to the market, so that in the future EPC can become a decisive factor during housing transactions.

## 1.6 How does the EPBD work in practice?

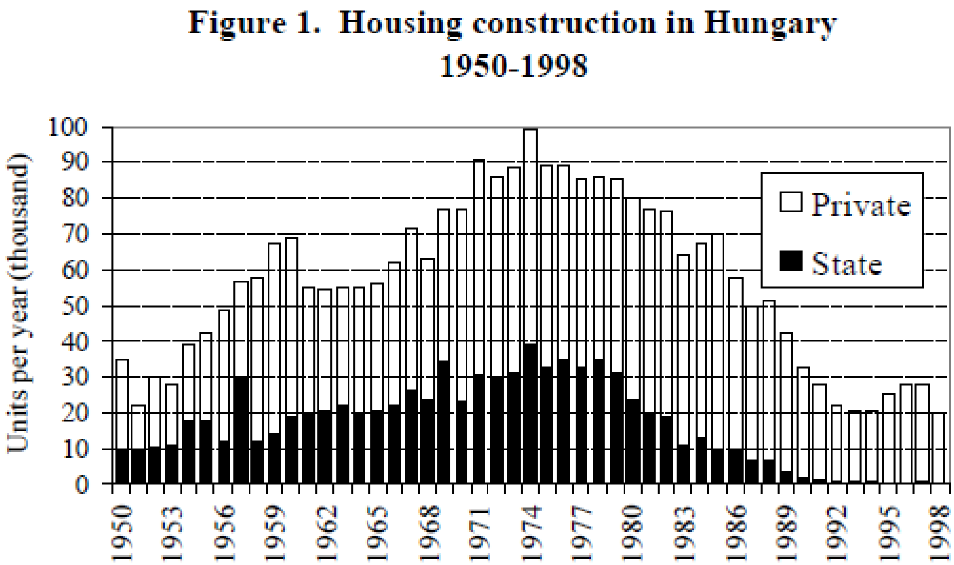
The immediate solution to maximize the effect of the EPBD is by providing an EPC to all the building covered by the Directive; an excellent way to promote this is via market initiatives. When professionals start using the EPBD and the EPC in their day-to-day work practice building owners can appreciate the overall added value. From an inquiry leaded in 2010 across Europe it can be seen how the market initiatives are grouped in 5 different categories:

- Financial initiatives, such as tax reductions and lower credit interest for high performance buildings.
- Initiatives from suppliers of energy efficient goods and services; e.g. installers offer packages of solutions, suppliers make advertise campaign about the thermal properties of their construction materials and how do they contribute to the improvement of the EPC's rating, etc.
- Initiatives of real estate agents or major building companies, e.g. public announcement of the EPC when a dwelling is put on sale, use of EPCs results in selling advertisements (as is now required by the recast Directive), etc..
- Information and communication initiatives that contribute to spread knowledge about the EPC, e.g. websites, seminaries, public campaigns, open forum that promote the EPC, the certification of building with addition of further information about the value of EPC, such as standardized recommendations or other related information.
- Specific governmental initiatives

An example from Luxembourg: a real estate agency placed the EPC in a prominent position on its homepage, i.e. visitors can use the energy label classification (A to I) as a prime criterion when searching for houses/buildings. The same agency reports that selling a house/building with a label D or lower is more difficult than selling a dwelling with higher label, A,B or C.
That's a clear example of how the EPBD and the EPC must become integrative part of the day-to-day work practice of all professionals, so that consumers are exposed to the Directive and to all the opportunities it creates. At the same time, by improving the understanding of what is energy and how it's used in the buildings, how energy can be used in efficient ways with money savings and with added value to the building stock, the EPBD and EPC will penetrate in the daily routine of the public and in the mind of building owners.

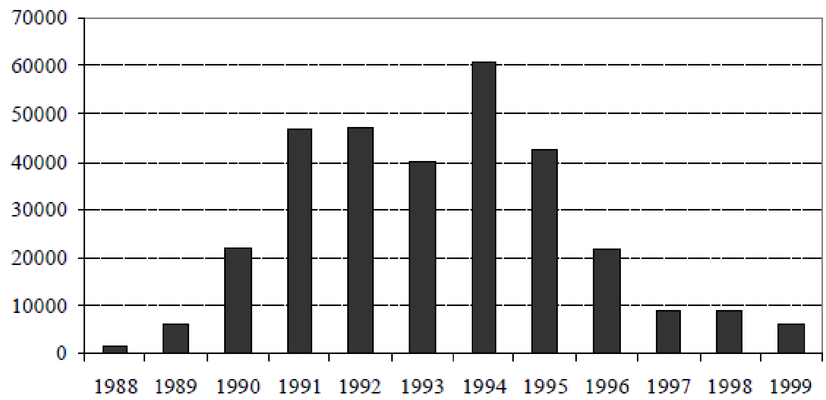
## 1.7 A few words on Hungarian housing sector

Considering that the building we will certify is located in Hungary we will give a quick look to the housing sector, its composition and evolution throughout the years.
A decisive factor affecting Hungary in every economic sector, including housing, was the political change of 1989-90, which represented a sharp turning point in its modern history.
The introduction of pluralistic multi-party democracy and the subsequent shift from central planning to market economy generated far-reaching socio-economic changes in the country. A fundamental aspect of transition was the radical rearrangement of the roles and duties of central and local governments, i.e. decentralization. Until 1990 housing in general, social housing construction and finance in particular belonged to the responsibility of the central state, whereas the allocation and maintenance of public housing remained the task of local councils.
In 1990, as part of the democratic reform of the public administration system property was transferred to the newly formed municipalities, who also had to elaborate and implement their own housing policies.
Following the collapse of state-socialism the withdrawal of state from the housing market accelerated significantly: the first ten years of transition could be characterized mainly by the privatization of the former state housing stock. In 1990 22 % of the dwelling stock in Hungary was state-owned, by January 2000 this ratio dropped to 5 per cent (see figure).




At the same time hardly anything happened in terms of the modernization and regeneration of the existing dwelling and building stock. The cities of Hungary, especially Budapest, are still suffering from massive urban decline, deprivation and social exclusion which is mainly caused by the long lasting neglect of the building stock, the radical withdrawal of state from the housing market and the increasing social polarization generated by the turbulent capitalist transformation of the economy. During the first decade of transition little or no attention was paid to the question of rehabilitation of deprived urban neighborhoods, simply because other issues including unemployment or homelessness overshadowed the question of urban renewal.

**Figure 2. Privatisation of public dwellings in Budapest 1988-1999**



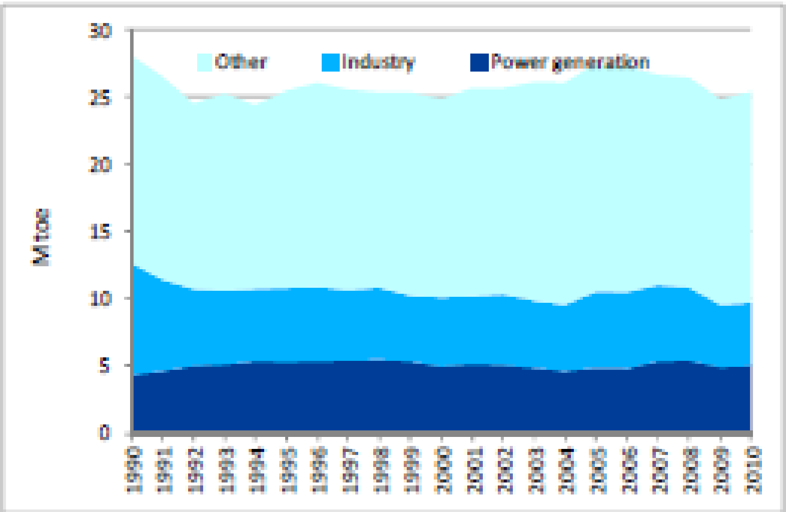

The refurbishment and renovation of the building stock is a great opportunity for energy saving, employment, technological and economic innovation that has not been exploited entirely so far.
We will not analyze in-depth the history and composition of the housing stock, because we have to focus more on the energy certification to see how it can positively affects the whole economy.

## 1.8 Hungary Energy report

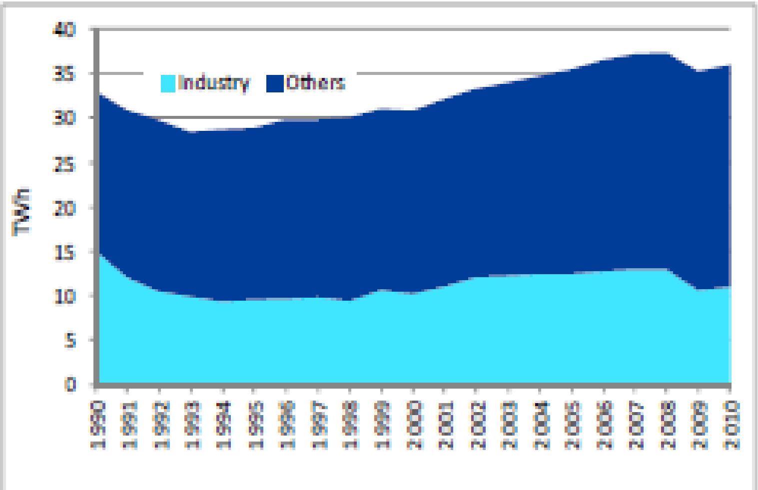
On a first overview of the Hungarian energy situation what strikes the observatory is that the energy consumption per capita is about 25 % below the European average (2.5 toe/capita in 2010) and, in addition, total energy consumption has remained relatively stable from 1990.
Primary energy consumption, after a fall between 1990 and 1992, increased slightly until 2005, and then started to decrease, only in 2009 the reduction reached the 9.1 % due to the global economic slowdown; in 2010 a positive increase of 2.3 % was registered.
The shares of the power sector and industry in total energy consumption are lower than the european averages: the power sector, including own uses and losses, accounts for 20%, while the share of industry, including non-energy uses, fell to 18 percent in 2010, from 29 percent in 1990.

| Overview | 2010 | | 2000-2010 (%/year) | |
|---|---|---|---|---|
| Primary intensity (EU=100)[1] | 119 | - | -1.9% | + |
| $CO_2$ intensity (EU=100) | 111 | - | -2.9% | + |
| $CO_2$ emissions per capita (in $tCO_2$/cap) | 5 | + | -0.7% | - |
| **Power generation** | 2010 | | 2000-2010 (%/year) | |
| Efficiency of thermal power plants (in %) | 33 | - | 1.0% | + |
| Rate of electricity T&D losses (in %) | 10 | -- | -3.2% | + |
| $CO_2$ emissions per kWh generated (in $gCO_2$/kWh) | 300 | + | -3.1% | ++ |
| **Industry** | 2010 | | 2000-2010 (%/year) | |
| Energy intensity (EU=100) | 72 | ++ | -3.6% | + |
| Share of industrial CHP in industrial consumption (in %) | 4 | -- | -2.9% | -- |
| Unit consumption of steel (in toe/t) | 0.33 | - | -1.5% | + |

++ Among best countries + Better than the EU average[1] - Below the EU average[1] -- Among countries with the lowest performances

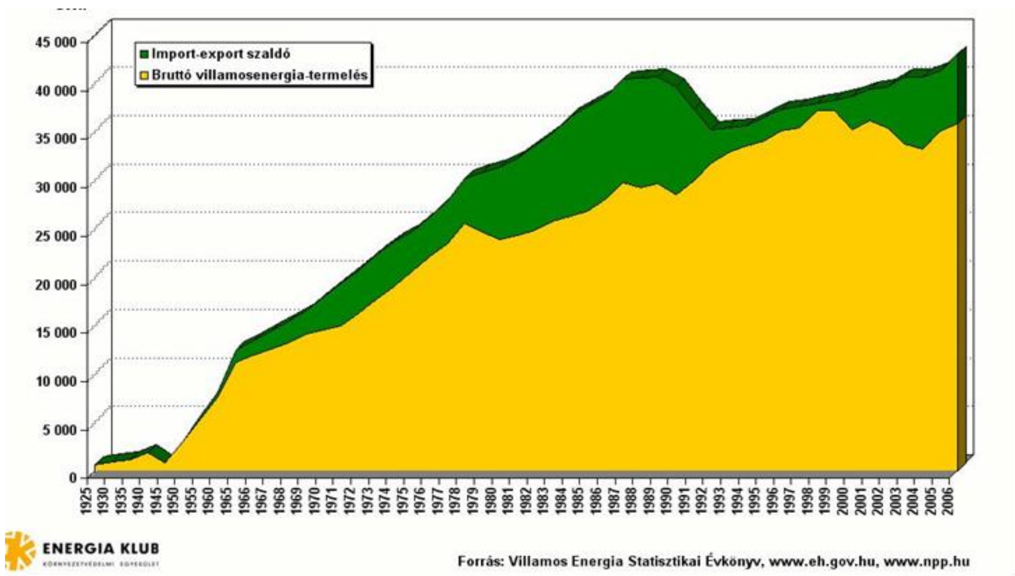


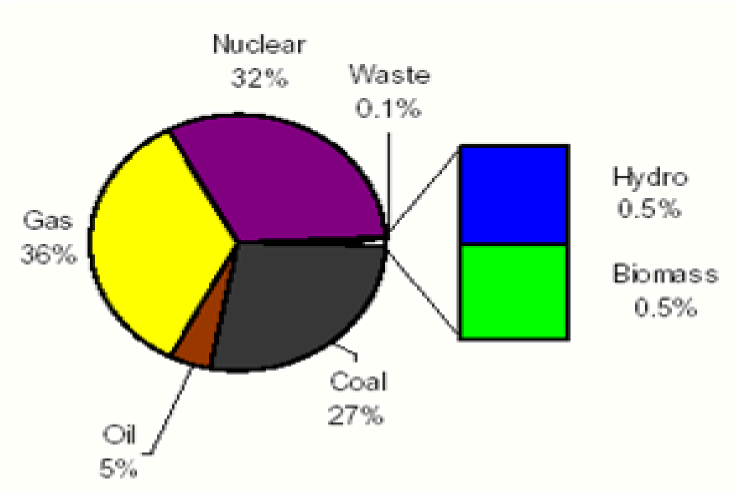

Source: Enerdata




Source: Enerdata

The bigger energy sources are coil and gas, which cover respectively 35 and 33 percent of final energy consumption, and are followed by electricity with 16 percent. The share of coal is rapidly declining, from 13 % in 1990 to 4 % in 2010, while biomass raise from 3 to 6 %, so as electricity, from 13 to 16 %. Electricity consumption per capita in Hungary is about 40 % lower than the european average, 3600 kWh in 2010, and here we start to see the influence of the residential and services sectors, which are the largest consumers with over the 66 percent of consumption, a share which is still raising (50 % in 1990). The share of electricity consumed by industry fell over the period, from 46 percent in 1990 to 31 percent in 2010.
Hungary set at 3.6 % the national target for electricity production from renewable sources by the end of 2010; this value was already achieved in 2005, and it’s currently over 5.8 % (Enerdata source). The renewable energy mix is dominated by biomass, followed by geothermal and communal waste, while solar power doesn’t play a leading role despite its significant potentials, and wind-power is expected to raise its share in the future.




Although the environmental impact of the energy sector has decreased over the last two decades, thanks to technology improvements, rundown of heavy industry and environmentally friendly changes in the fuel mix, energy efficiency is still far away from EU standards and behind the target level. There is also a strong dependency from importation and fossil fuels still play a leading role in the energy supplying while energy demand is now more influenced by the domestic and service, with the building sector assuming an increasing importance as energy consumer.

An important economic indicator to analyze more in-depth Hungarian energy efficiency is the Energy Intensity, defined as total energy consumption per unit of GDP (Gross Domestic Product) and measured in MJ/$: in Hungary energy intensity decreased by 1.9 percent/year between 1990 and 2010. This reduction was led by industry, while efficiency gains in the power sector were limited during this period; however, the replacement of oil and coal-fired facilities by high efficiency gas-fired since 2000 contributed to 21 percent of the reduction in primary intensity between 2000 and 2010. What about the efficiency? In Hungary the energy scenery is dominated by poor and low-efficiency technologies, nuclear and coal-fired power plants; nevertheless, electricity registered an increasing efficiency, from 29 percent in 1990 to 34 percent in 2010, thanks to new CCGT facilities in the power mix and shift from coal to gas in the power stations. It is significant to highlight the high percentage of the rate of transmission and distribution losses (T&D) that was nearing 9.8 % in 2010, i.e. 50 % higher than EU average, although a sensible reduction from 1993 to 2010 (-30%). The T&D rate was over 13 percent between 1993 and 2001, its high value due to electricity theft first, and technical problems on second step.

**Figure 4: Efficiency of power generation and thermal power plants**

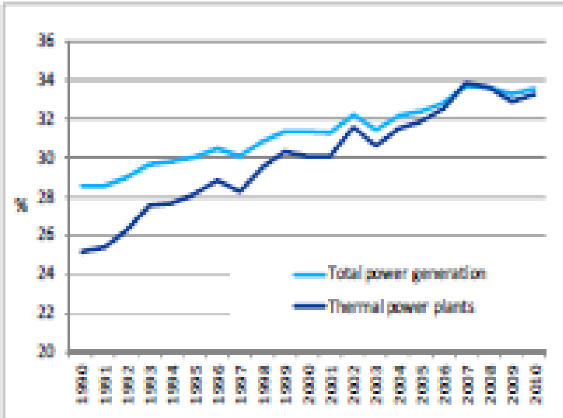
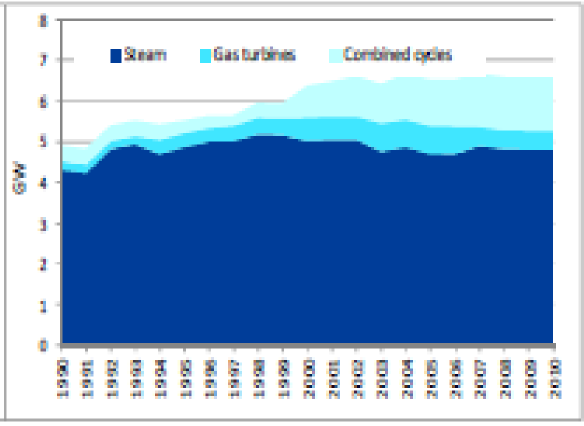
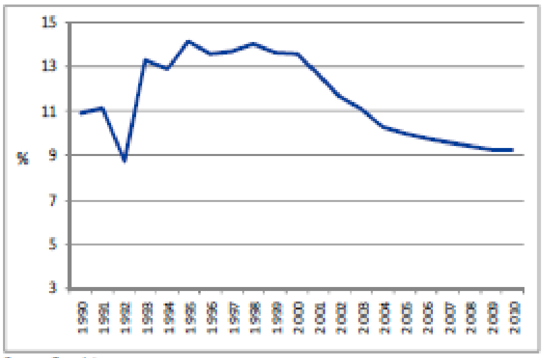



**Figure 5: Thermal electricity capacity, by technology**




Source: Enerdata

**Figure 6: Electric T&D losses**




Source: Enerdata

## 1.9 Energy suppliers

Hungary began the process of privatization and liberalization of the energy sector during the early 1990s and, after the EU accession in 2004, a positive influence has been recorded on the energy sector in terms of setting energy efficiency and RES targets as a top priority for the liberalization of the energy market. However, this process faces substantial financial, political and social challenges due to the heavy authority that big energy firms, E-On, and MOL above all, still have on the market.

Currently all the gas and electricity service providing companies are owned by these well-known international companies, e.g. E.On, EdF\GdF and RWE; these service providing groups are still functioning as regional monopolistic businesses in the B2C sector, but in accordance with European regulations the liberalization of these markets has already started. The market will soon be opened for residential customers in the case of electricity and is already open for gas services, providing consumers with the opportunity to choose between different energy vendors.

Responsibility for energy policy lies with the Ministry of Transport, Telecommunication and Energy (formerly the Ministry of Economy and Transport), where a separate Directorate-General deals with energy policy. The Ministry regulates the prices for electricity and for natural gas, with annual tariff schemes - creating prices substantially below real market prices.

The Energy Directorate-General of the Ministry of Economic Affairs and Transport and the Hungarian Energy Office currently share the regulatory tasks concerning electricity, gas, quality of public services and consumer protection.

Since only 25% of oil and of 20% of gas is produced in the country, energy dependence (71%, see Fig.1.) is very strong in Hungary and highly influenced by Russian energy imports. In 2005, the total primary energy supply was 1301,5 PJ (36.9% domestic production and 63.1% import) (KHEM 2008a). At the same time Hungary has an important role in the future of European energy imports due to its strategic geographical position in gas transportation through the Nabucco and/or the Blue Stream pipelines. As a consequence gas supply currently seems to be assured for future needs in Hungary.

The share of oil and coal in energy supply has slightly decreased in recent years to 25% and 15% respectively, while the role of gas has increased from around one third in 1990 to one half in 2003 (see Fig. 3.).

Here below (Table 2) are shown the World Bank indicators about energy production and its use in Hungary; among all it is relevant the percentage of electricity production from nuclear sources (Figure 3), accounting now almost 40% of the total electricity production.

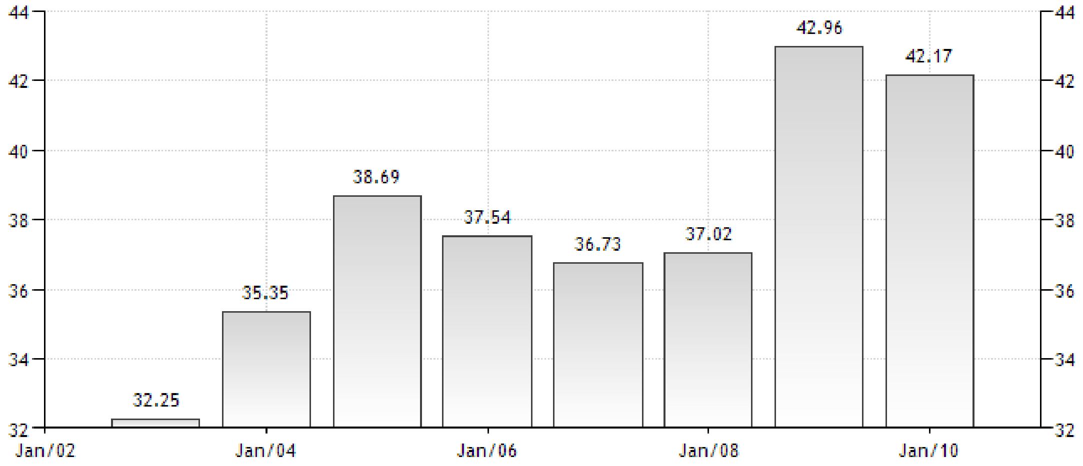
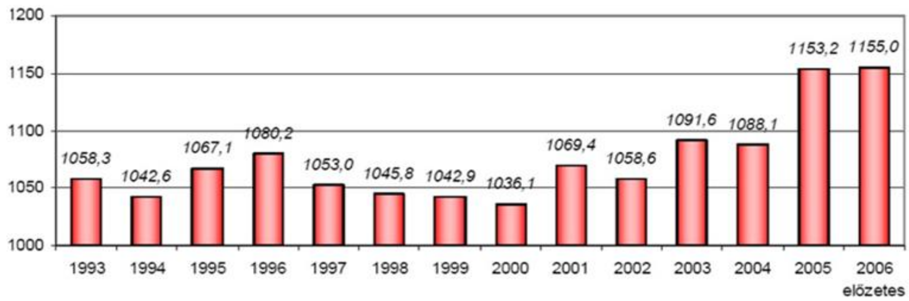
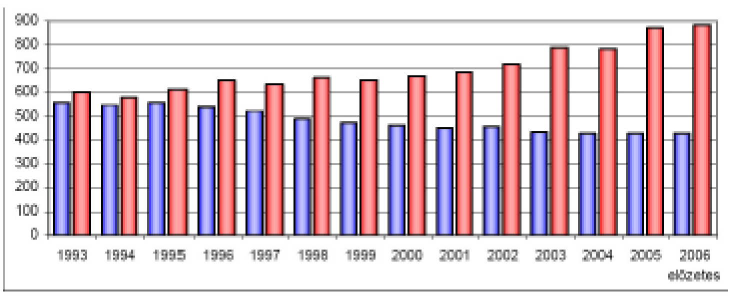



Figure 3: Percentage of electricity production from nuclear source

**Figure 2.: Domestic energy consumption 1993-2006 (PJ)**




Source: Energia Központ Kht. (KHEM 2008a)




Source: KHEM 2008

production

import

| | Previous | Last |
|---|---|---|
| Alternative and nuclear energy (% of total energy use) in Hungary | 14.8 | 15.2 |
| Combustible renewables and waste (metric tons of oil equivalent) in Hungary | 1323.3 | 1523.7 |
| Combustible renewables and waste (% of total energy) in Hungary | 5.0 | 5.8 |
| Electric power consumption (kWh per capita) in Hungary | 3976.5 | 3988.8 |
| Electric power consumption (kWh) in Hungary | 39987000000.0 | 40040000000.0 |
| Electric power transmission and distribution losses (kWh) in Hungary | 3959000000.0 | 3888000000.0 |
| Electric power transmission and distribution losses (% of output) in Hungary | 9.9 | 9.7 |
| Electricity production from coal sources (kWh) in Hungary | 7487000000.0 | 7205000000.0 |
| Electricity production from coal sources (% of total) in Hungary | 18.7 | 18.0 |
| Electricity production from hydroelectric sources (kWh) in Hungary | 210000000.0 | 213000000.0 |
| Electricity production from hydroelectric sources (% of total) in Hungary | 0.5 | 0.5 |
| Electricity production from natural gas sources (kWh) in Hungary | 15232000000.0 | 15176000000.0 |
| Electricity production from natural gas sources (% of total) in Hungary | 38.1 | 37.9 |
| Electricity production from nuclear sources (kWh) in Hungary | 14677000000.0 | 14818000000.0 |
| Electricity production from nuclear sources (% of total) in Hungary | 36.7 | 37.0 |
| Electricity production from oil sources (kWh) in Hungary | 535000000.0 | 355000000.0 |
| Electricity production from oil sources (% of total) in Hungary | 1.3 | 0.9 |
| Electricity production (kWh) in Hungary | 39960000000.0 | 40025000000.0 |
| Energy imports; net (% of energy use) in Hungary | 61.8 | 60.3 |
| Energy production (kt of oil equivalent) in Hungary | 10224.7 | 10496.5 |
| Energy use (kg of oil equivalent per capita) in Hungary | 2658.0 | 2635.7 |
| Energy use (kg of oil equivalent) per dollar1;000 GDP (constant 2005 PPP) in Hungary | 150.1 | 147.2 |
| Energy use (kt of oil equivalent) in Hungary | 26728.2 | 26457.7 |
| Fossil fuel energy consumption (% of total) in Hungary | 79.0 | 77.8 |
| GDP per unit of energy use (constant 2005 PPP dollar per kg of oil equivalent) in Hungary | 6.7 | 6.8 |
| GDP per unit of energy use (PPP dollar per kg of oil equivalent) in Hungary | 7.1 | 7.8 |

Table 1: World Bank Indicators, Energy sources and production percentage

## 1.10 Energy documents

The most recent strategic energy document is the Energy Policy Concept for 2007-2020 (40/2008.IV.17), which replaces the previous Energy Policy Concept in 1993, that was based on the former social-communist economic and political structure, as we have seen in the housing report, and focused only on supply-side interventions (Energia Klub 2006).

This new document is centered on three substantial pillars:

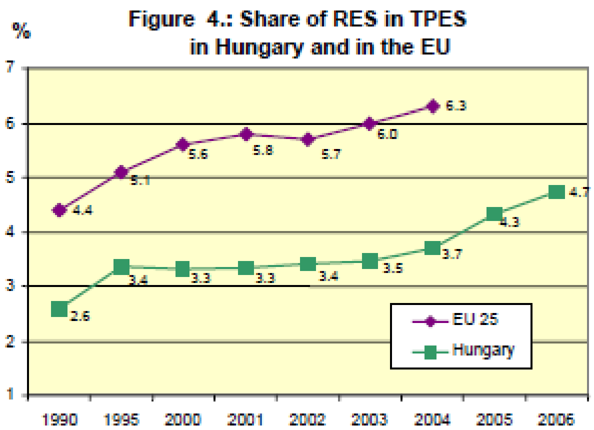
- Security of energy supply; the goal is to maintain and improve security and continuity in the energy supply, with particular attention to energy mix, energy import diversification, strategic energy stocks, infrastructure developments and social responsibility.

- Competitiveness of the energy sector; this is the most important initiative, which should contribute to increase the economic competitiveness of the country, by liberalizing energy markets and energy prices, integrating to the internal EU markets, supporting technological development and R&D.

- Sustainability; Hungary aims to reach a sustainable development by increasing energy efficiency and energy saving, renewable energy sources, and paying attention to climate response. It also focuses attention on the connections between energy and climate policies and energy and transport policies.

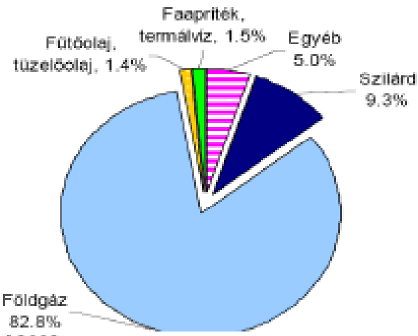
The Energy Policy Concept is a framework strategy connected to the Hungarian Renewable Energy Strategy (RES) 2007-2020 and to the National Strategy on Energy Efficiency Objective.
The target levels set by these strategies for renewable sources by 2020 are:

- Total primary energy supply, 14-16 %
- Biofuels: 5,75 % by 2010, 8 % by 2013, 10% by 2020




We conclude this overview by reporting that Hungary has a well-developed district heating and gas-distribution system, almost half of the energy supplying vector is natural gas, as result of the Soviet energy policy. The main source for heating is once again natural gas, (75%), and in 2005 more than 50% of the final energy consumption (926.5 PJ) was used for heating purposes, while renewable sources for heating in 2006 counted less than 10 % , based mainly on biomass.2013 RES projects are financed with 250 million € through EU structural funds, and additionally biomass production is supported through the 2$^{nd}$ National Development.

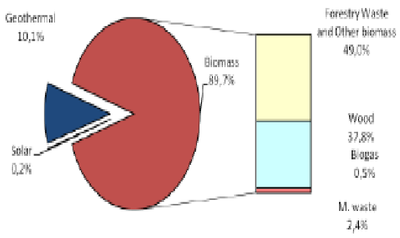
**Figure 10.: Composition of fuel for district heating, 2005**




Source: KHEM 2008a

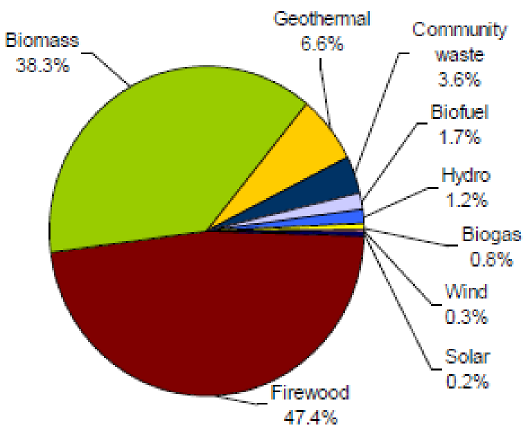
- natural gas (82.8%)
- other (5.0%)
- solid (9.3%)
- oil (1.4%)
- wood, water (1.5%)

**Figure 11.: RES-H fuel mix in 2006 (37.5 PJ)**




Source: Hungarian Energy Office, EREC 2008

**Figure 5.: Shares of different renewable sources**



# CHAPTER 2

## Status of EPBD in Hungary and Italy with technical specifications

Now that EPBD has been introduced it is time to see how Hungary and Italy have followed the EU directive with their own regulation, energy policies and methodologies; in this way we will find out how to carry out the energy certification in the two cases.

### 2.1 Energy strategies and action plans

The Hungarian housing policy has changed considerably and several times in goals and practice in the post-1945 period. Until 1960 the presence and role of state on the housing market increased continuously due to aggressive nationalization and to the Marxist-Leninist egalitarianism that fostered the redistribution of the housing stock among the poor.
Between 1960 and the early 1980s the role of state remained still dominant, mainly due to large-scale housing construction programmes; however, the whole housing market went through a gradual liberalization and private forms of housing were accepted, or even supported by the regime, which was unique among the communist countries. From the early 1980s, mainly due to economic recession the state started a slow withdrawal from the housing market which was accelerated by the political changes of 1989-1990.
In the 1990s, due to the very liberal privatization policy and the rearrangement of the municipal system of Hungary the share of public housing has dramatically declined on the housing market, and at the same time social polarization, extreme forms of social segregation and social exclusion became more and more evident. After ten years of neglect and passivity the state (both local and central) gained again more importance and played a more active role in the late 1990s. By 2000 the housing policy of Hungary has entered a new phase of its development where a stronger co-operation and interaction between the public and private (both domestic and foreign) sectors became possible.

The first energy strategy of the democratic era enforced in Hungary was the National Energy Saving Programme, i.e. NEP, launched in summer 2000 and focused on traditional buildings erected using masonry constructions.
In this new framework municipalities could apply for state funding in order to raise the number of disposable rental units in the following ways:

1. building new flats;
2. renovating old tenancies;
3. buying dwellings on the free market and then renovate them for rental purposes, or convert non-residential buildings into tenement blocks.

In order to apply successfully the municipalities had to formulate their local ‘social housing act’ and had to describe their plans concerning the allocation criteria and the management of the rentals to be created. The municipalities had two choices in utilizing their newly acquired housing stock:

- they could maintain them on a cost basis, i.e. they can estimate rents so that they cover the costs of maintenance,
- they could add subsidies via lower rents.

The municipalities could define the duration of stay for the families or could apply other conditions such as compulsory savings for buying an own flat in the future. All these features were taken into account when the applications were evaluated by the Ministry of Economic Affairs.
The program supported with 15-30 % non-refundable subsidies all kind of individual renovation, such as thermal insulation of envelope and building elements, exchange of windows, updating of heating systems and installation of RES systems. The application procedure was very simple, and every owner of a single apartment in a multi-flat building could exchange his or her windows within the programme without involving an energy expert. As a consequence, the achieved energy savings were not registered, the investments made were not controlled at all and thus the owners were not motivated to choose the most efficient solutions for their dwellings. The NEP was yearly financed with a support between 1 and 2 billion HUF, 3.5 to 7 M€, with a number of projects amounting to 1000-5000/year, mostly on small scale, one-flat or family house projects.
The programme was ended in the middle of 2009 and substituted by the GIS, Green Investment Scheme.

A separate programme was run for buildings realized with industrialized technologies; the Panel Programme was implemented only for whole buildings , starting from 30 to 300 flats, and as consequence these projects were much larger scale and with much stricter requirements.
The financial support ranged between 33% and 66% of the investment costs, independent of the achieved energy saving. Although energy calculations were required, seen the obligation from 2007 set out by the EPBD, the acquired benefits in terms of saved yearly primary energy consumption have not been analyzed, therefore the feedback was very limited.
The Panel Programme supported from 500 to 2000 projects/year, and the grant was a maximum of 20 billion HUF/year (70 M€/year). In the middle of 2009 the program was restructured and integrated in the GIS. This change only referred to the source of financing, though several important modifications in the requirements occurred.
Finally, every project hereafter needed an energy certification and the support provided by the programme was partly dependent on the achieved energy category. For projects achieving category D the support was only 30%, whilst for a category A+ 60% was granted. Nevertheless, starting from buildings targeted B category this action definitely represented a change in the energy world and in the efficiency level of projects; for the first time energy calculations had to be performed by licensed energy experts using standardized calculation software specifically created for the GIS. Although it was criticized by applicants because of its complexity and chaotic programme management, the Panel Programme was the first effort to motivate people using EPCs to achieve energy savings with more efficient projects. The plan lasted only half a year, with 800 projects

applications submitted, which was not less than in previous year, and the EE level was much higher than before.

The GIS Climate Friendly Home Programme, similarly to the GIS Panel programme, was first introduced in January 2010, and it is currently running and subsidising traditional building types.
The characteristics of the programme are almost the same, excepting for a few small differences; we mention as a positive new element the existing discrimination for projects applying KIVÉT products, which is an abbreviation of a Hungarian term referring to materials, elements and equipment of "Excellent Building Product" certification, even though the method for their qualification is not completely elaborated.
A major problem with GIS is that project preparation costs, as management, expert and design cost, are not eligible for subsidy and this strongly decreases the number of applicants, in particular the well-designed ones.
This lack is adjusted by the Environment and Energy Operative Programme, which provides subsidises for preparation costs and supports some projects through automatic application mechanism. The programme is highly attractive, giving form 30% up to 100% non-refundable grants for public and commercial buildings; in particular public buildings located in underdeveloped regions can receive 100% grants. In spite of that, the interest is not high enough because of the complicated administrative procedure, and consequentially the success rate for receiving funds is only 30%. Although energy calculations are required, according to the EPBD, the achieved energy label doesn't influence the amount of the grant. Interest was raising towards this program from second half of 2010, when altogether 831 projects were submitted, with a total grant request of 81 billion HUF (approximately 290 M€).

In late 2010 the new Hungarian government announced the intention of a radical change in the energy efficiency action plans in the building sector, with a new Energy Efficient Construction Programme that is under preparation. The ambitious aim is to retrofit 50'000-100'000 flats per year with an average energy saving of 60%. The program will involve all kind of buildings, including public ones and close to zero energy buildings, and it will gather together Energy Efficiency and Renewable Systems in the building sector under one umbrella.
The expected development for renovated buildings are presented in the following chart:

| year | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| traditional flat | 20 | 30 | 40 | 50 | 60 | 60 | 60 | 60 | 60 | 60 | 50 |
| panel | 40 | 40 | 40 | 40 | 30 | 20 | 20 | 20 | 20 | 20 | 29 |
| public building | 5 | 6.5 | 7 | 6 | 3 | 2 | 1 | 1 | 0.5 | 0.5 | 3.25 |
| new flat | 10 | 10 | 15 | 15 | 20 | 25 | 30 | 30 | 30 | 40 | 22.5 |

* *"Panel" refers to blocks of flats built with prefabricated sandwich panels*

*Table 1. - Planned development of yearly project numbers (thousand of flats, plan)*

It is planned that individual projects will be evaluated according to the achieved energy savings based on the EPBD certifications, and energy points will be granted to the projects as a function of the original and the targeted energy label, as presented here below for residential retrofit projects. In addition to these points, buildings can gain more bonus points, depending on sustainability, quality and social impact achieved.

This new energy programme is a direct consequence of the NREAP, with studies that highlighted the economic interest for Hungarian state to start a renovation programme with communal buildings and family houses first, and in the latter end focusing onto other buildings categories.

| original state | renovated st. | | | | |
|---|---|---|---|---|---|
| | C 100% | B 95% | A 75% | A+ 55% | A++ 45% |
| I | - | 3.5p | 5.0p | 7.8p | 12.0p |
| H | - | 3.0p | 4.5p | 7.1p | 11.0p |
| G | - | 2.6p | 4.0p | 6.5p | 10.0p |
| F | - | 1.8 | 3.5p | 5.0p | 8.8p |
| E | - | 1.0 | 3.0p | 5.0p | 7.5p |
| D | - | - | 1.5p | 3.0p | 5.0p |
| C | - | - | 1.0p | 2.0p | 4.0p |
| B | - | - | - | 1.6p | 3.5p |
| A | - | - | - | - | 3.0p |

*Table 2 - Energy scores based on energy certifications (plan)*

## 2.2 Hungary's NREAP

Hungary is a member of the European Union, and for this reason the adopted common legislation and long-term objectives set out several task for the country in the energy field.
EU's Renewable Energy Roadmap sets as targets a 20 percent share of renewable energy source, including a 10 percent share in case of transportation, and an increase of 20 percent in energy efficiency as well as a reduction of greenhouse gas emissions (GHG) of 20 percent by 2020.
The Member States (MS) are in charge for elaborating a National action plan to fulfill the EU targets; in Hungary the National Renewable Energy Action Plan, hereafter referred as NREAP, has been drawn up according to the Directive of the European Parliament and of the Council (the Renewable Energy Directive, referred as RED) and in compliance with the format laid down in the Commission Decision on the related single template (2009/28/EC). The NREAP draws upon Hungary's renewable energy strategy[2], but also supersedes and overwrites it, keeping in consideration the several changes occurred since the adoption of the strategy, first of all the global economic recession and the new economic development priorities decided by the Government to help restructuring Hungarian economy.

[2] Government Decision No 2148/2008 of 31 October 2008 on the 2008-2020 strategy to increase the use of RES in Hungary.

It seems immediate now to realize that Hungary does not consider the use of RES only an obligation, but rather as an exceptional opportunity for a decisive economic development, and their use becomes in this way both a necessity and an opportunity.

On one hand, there is an essential need for finding solutions to the problems resulting from an overuse of fossil energy sources (climate change, dependency on imports, imbalance s of the foreign trade balance, energy poverty, etc.), which will provide the maximum advantage from a social, economic and environmental point of view. On the other hand RES are an opportunity for the restructuring of the national economy, for extensive production and market reforms, and for the introduction of new, marketable domestic products, and ultimately for the creation of jobs. In a general renovation view the development of a green economy represents, in accordance with the New Széchenyi Plan, a breakthrough point for a “renewable” Hungary and, moreover, the NREAP will contribute to jobs creation, substitution of natural gas imports and an increase of competitiveness that will extend the Governmental objectives relating national economy. This will guide the planning approach set by the NREAP for the next ten years,

which will be more ambitious than those of the previous years.

The RED of the European Parliament and of the Council specified a legally binding obligation for Hungary to ensure a 13 percent minimum share of renewable energy in gross final energy consumption by the end of 2020. The NREAP, taking in account the importance of green economy on the development of national economy and its important effects on employment and domestic value creation, sets out the achievement of a realistic target of 14.65 % by 2020, exceeding the obligatory minimum target. It’s important to underline that the development of a green economy can only be successful if it is combined and supported with the development of all national sectors, i.e. industry and agriculture. Nevertheless, a green economy should be based on a reasonable use of biomass originating from forest and agriculture, an extensive use of biogas, the utilization of geothermal and solar energy, the rational spreading of wind power plants and small-scale hydro-power plants and a general diffusion of biofuels and alternative fuels. Only in this way a real green economy can stand up on its legs and raise steady, with solid foundations melted with renewable energy sources and relative production, technology-supplying and manufacturing plants. During the implementation process the Government intends to make use of all possible means in order to achieve a higher share of RES than the above-mentioned EU targets; these means will be technological progress, decrease of investment cost and use of direct Community resources, along with the review and necessary adaptation of the regulatory framework, the re-thinking of aim schemes and simplification of authorization procedure. In other words, Hungary must implement developments in the field of renewable energy in such a way that they provide the greatest possible economic, social and environmental benefit to all citizens. The National Action Plan is founded on calculations made on the basis of the Green X Model, and this work phase was coordinated by the Hungarian Energy Office. In the preparation of NREAP professional assistance was provided by the international consortium established by the EBRD.

The consortium, whose members have solid experience in policy making and preparation of national action plans, is headed by the Dutch ECO-RYS and counts as members the German ECOFYS, the Energy Economics Group at the Vienna University of Technology, GKI Energy Research and Consulting Ltd. And the Hungarian Energy Klub.

The NREAP was elaborated on the following public tasks:

- the elaboration of a new act on sustainable energy management in 2011;
- restructuring of the implementation of existing aid schemes and making it more efficient and more simple;
- launching an independent energy support scheme (co-financed by the EU) between 2014 and 2020;
- a comprehensive adaptation of the mandatory off-take scheme for renewable electricity (thereinafter referred as green electricity) ;
- examination of the possibilities for subsidizing green heating;
- facilitating a more active participation in direct Community support and other support schemes;
- review of the incentives incorporated into energy regulations for buildings (in accordance with Directive 2010/31 EC);
- review of spatial plans, creation of regional energy concepts;
- establishment of green forms and programmes of financing (green bank);
- review and simplification of regulatory and authorization systems and procedures;
- drafting of awareness-raising programmes and information campaigns (integrated information programmes);
- launching educational and training programmes based on RES and energy efficiency;
- launching employment programmes in the field of RES;
- launching development programmes for the purpose of developing the related industries;
- encouraging research and innovation incentive programmes;
- programs and measures for spreading second-generation bio and alternative fuels;
- drafting of an agricultural energy programme;
- preparation of the administrative staff taking part in regulatory and authorization procedures in relation to renewable energy and related fields.

The aim of the National Action Plan is to provide the greatest possible benefit to the entire society by drawing on Hungary's natural, economic, social, cultural and geopolitical assets. The main objective of the utilization of renewable and alternative energy is to reduce dependency on gas and crude oil imports.

Table F/13

**Estimated costs and benefits of the renewable energy policy support measures**

| *Measure* | *Expected renewable energy use (ktoe)* | *Expected cost (in million EUR)* 2010–2020* | *Expected greenhouse gas emission reduction in 2020 (million t $CO_{2eq}$/year)* | *Expected number of jobs created* |
|---|---|---|---|---|
| Measures 1–23 and 27–29 | 2,344 | 2,381 | 4.91 | 51,200 |
| Measures 25–26 | 535 | 73 | 0.74 | |

* at the official ECB exchange rate of 1 January 2010

## 2.3 Regulations for energy certification

As seen before, buildings in Hungary are currently responsible for 40 % of total energy's consumption, and approximately two thirds of this is used for heating and cooling.
Buildings and construction standards are closely linked to the use of renewable energy sources for heating and cooling; the heating of buildings, in particular, is one of the highest source of $CO_2$ emissions, and the perfect candidate to adopt renewable energy powered systems.
Furthermore, the energy condition of buildings in Hungary is below the EU average, and their reconstruction and modernization represents an especially significant potential in the field of energy and, nevertheless, a great business opportunity.
When referring to increasing the use of renewable energy sources in buildings, the supply of renewable electricity from the national grid should not be considered. The NREAP is focused on increasing local supply of heat and/or electricity to individual buildings; thus, the direct supply of heat or cooling through district heating and cooling in buildings could also be taken into account.
In Hungary, prior to 2004, the responsible for the implementation of EPBD was the Minister of Interior, through the National Office for Housing and Building; after joining the EU, the Minister worked with professional bodies in outlining a set of regulations and rules of certifications, as well as creating certification software, and finished in January 2006.

The first Ministerial Order, which included the requirements, the design input data and, most of all, the calculation method, was released and issued in May 2006 and has been in force since the 1st of September 2006. Starting from this date, the fulfillment of requirement is a mandatory condition to acquire a building permit in Hungary. Furthermore, a commercial-based software became available in January 2006. The result of the implementation of EPBD was impressive, and consisted in an increase of the thermal performance of building envelopes. In terms of U-value it corresponds to a decrease of 36%, 50% and 43% for, respectively, exposed walls, roofs and windows. The overall average U-value of an envelope, including thermal-bridge effects, ranges at the present moment between 0.45 and 0.65 $W/m^2K$, depending on the surface to volume ratio.
The Ministerial Order ( *Decree No 7/2006 (V. 24.) )* additionally provides for the following: during the preparation of investment programmes for new buildings with a useful area of more than 1000 $m^2$, and during planning, the possibility of using decentralized energy supply systems based on renewable energy sources, district or block heating and cooling or heat pumps must be assessed from a technical, environmental and economic point of view . In terms of RES, in particular solar energy devices, as a general rule *solar cells and solar collectors* can be installed without a final construction permit in Hungary. In certain cases, however, a construction permit must be obtained, for example if the required equipment is intended to be installed on buildings under monument protection, or if the installation involves significant changes to the facade of the building or if a large open-air system is concerned. The following regulations apply to small-scale power plants and household-scale power plants (up to 50 kVA) during *energy authorization*: in the case of solar cell systems connected to the grid it is the size of the system which determines what further procedure the investors must expect. In the case of solar cell systems with an output of more than 500 kW, the authorization procedure for small-scale power plants applies, during which a permit must be requested for their installation from the competent construction authority, and a combined small

scale power plant permit from the HTLO (Hungarian Trade Licensing Authority). Pursuant to the implementation decree of the effective Electricity Act (EA Imp.), construction authority permits are issued by the Authority of Metrology and Technical Safety of the HTLO having territorial competence. The process is complemented by the network access contract concluded with the licensee, which is a prerequisite for the Office's permit.
The classification "household-scale power plant" offers more simple conditions, and refers to power plants that are connected to a low-voltage grid and the connected load of which does not exceed 50 kVA. The legislator's intention with the introduction of this category was to facilitate, from an authorization point of view, residential users reducing the amount of electricity obtained from the grid by using electricity generated by devices of their own. This category is also more advantageous from a financial point of view, as through so-called "give-take" accounting the electricity supplier applies annual balance accounting, i.e. it deducts the amount of solar energy generated into the grid from annual consumption. The electricity supplier having territorial competence must be contacted in the case of household-scale power plants as well. The supplier must be informed about the operation of solar cell systems by way of a request form, in which a declaration must be made as to whether the owner of the solar cell intends to use the energy produced solely for private purposes or also intends to feed energy into the public network. In the latter case the electricity purchase contract must be adjusted accordingly.

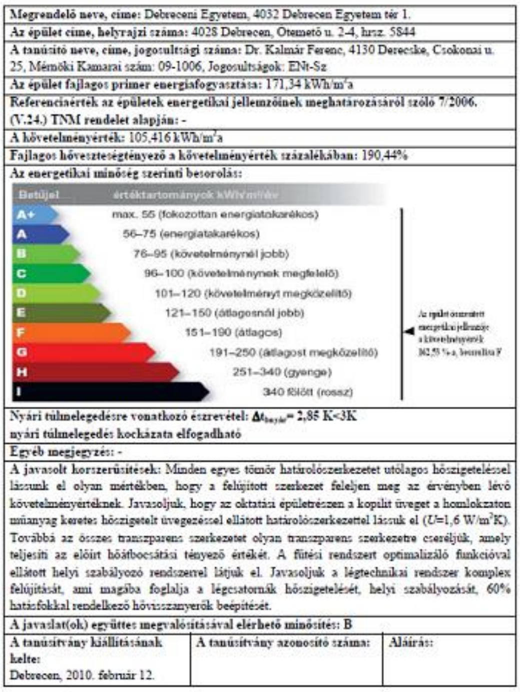
During 2007 intensive discussions took place between the different Ministries to decide which method of certification should be adopted; at first place the asset (calculated) energy performance rating was developed considering that, in this case, the same procedure can be applied in the design phase for the certification of new and existing buildings, using design data, and it is also easy to check real and survey data. Thus, the asset based method allows to use a "standard user" in order to avoid and neutralize inhabitants behavior. The operational method raised many concerns for the possible reactions to the price of certification, since it is a service that the general customer must pay for, whose cost is based on energy bills. In the end the government order issued in 2008 included both methods, and the protocol for certification based on operational rating has been published and is now subject of conciliation at the Chamber of Engineers. The deadlines for the initiation of certification processes were defined as well in the same order: for new buildings it started in January 2009, whilst compulsory certification of existing buildings has started from 1st January 2012, although on a voluntary basis and in the case of subsidized energy conscious retrofit was already in effect since 2008. Starting from January 2009 49'000 certificates has been issued for new buildings and about 4'000 for existing buildings, in the latter case with the intention from the owners to apply for subsides for major renovation.
These subsides exist from 2008, promoted by energy saving programmes which offer financial help for investments on retrofits of existing buildings: the two preconditions to get economic support are certification of the building in its actual state and identification of the higher category to be achieved after the renovation. In public buildings the display of EPCs has already begun, by applying an operational method since the users of the dwelling remain the same, thus both technical conditions and user behavior can and should be evaluated.

## 2.4 The EPC

The Energy Certificate assigns an energy performance label to residential and non-residential buildings or building-units on a efficiency scale ranging from A+ (high energy efficiency) to I (poor efficiency), and it lists cost-effective measures that can be taken to improve the energy performance. The positive effect of the certification are the recommendations provided to the building owner, which can be found in a summary on page 2 of the certificate; it contains a short description of the improvements proposed and their impact on the energy label if all measures would be taken in account. For existing buildings these suggestions are more detailed depending on the building owner intentions whether or not he's applying for a subsidy. If he intends to do so, an evidence of the expected outcome of the retrofit in energy terms must be provided, and a financial one is recommended, as well as more accurate survey and calculations are necessary to guarantee the satisfaction of the subsidy conditions. It is possible for building owners to estimate the rating of their building using the online calculator, and they can also create their own certification which, in any case, does not substitute an official one issued by a licensed expert. EC are valid for 10 years, and starting from January 2012 all existing residential and non-residential buildings need to be certified, when sold or rented. The owner must present a valid certificate to the buyer, when the sale or rental contract is agreed upon. For existing buildings there is no minimum requirement, i.e. it can be labeled from A+ to I, since according to EPBD the aim of certification is **informative**, while new buildings must achieve at least a C label. In the case of major renovation of buildings with a net floor area over than 1000 $m^2$ the same rule has to be applied.
The energy certification procedure require detailed calculations to estimate the thermal characteristics of the building and its energy consumptions for heating, cooling, domestic hot water, lighting and ventilation. As for all the MS, also Hungary has a Technical Regulations which provides all the calculations and procedure step by step, giving all the standards and the energy categories. This regulation is issued by the Minister of Interior and its staff, and published on the national Gazette "Magyar Közlöny", and it is regularly updated to respond to the technical evolution of the energy and building market.
The last update, with the Ministerial Decree 40/2012 VIII.13, has been published in August 2012 and gives indications about renewable energies, HVAC systems, major renovations and new requirements for building elements and primary energy consumption.
The aim of the regulation is to provide all the necessary informations and technical data to accomplish the calculations about the building energy performance in a **general way** , not based on the particular situation of the building under analysis but for building categories. In this way any building can be compared to another of the same category, because the energy calculations are the same, sharing a common procedure that allows direct comparisons with an objective and general approach. All the Qualified Experts have to follow the Regulation step by step to issue an official Energy Performance Certificate acknowledged by the law: the regulations gives also the possibility of a simplified method, with calculations that do not require a specific technical knowledge of HVAC systems and building elements.

In Hungary the definition of a public building includes every state-owned non-residential building, and the larger ones exceeding 1000 $m^2$ floor area are required to display their energy certificate so that they are visible to the public.

The requirement system has three facets, as far as new buildings and major renovations are concerned; maximum permitted values are set for the U-values of building elements and for the specific heating energy need (W/m$^3$K) as a function of the surface to volume ratio.



**Megrendelő neve, címe:** Debreceni Egyetem, 4032 Debrecen Egyetem tér 1.

**Az épület címe, helyrajzi száma:** 4028 Debrecen, Otemető u. 2-4, hrsz. 5844

**A tanúsító neve, címe, jogosultsági száma:** Dr. Kalmár Ferenc, 4130 Derecske, Csokonai u. 25, Mérnöki Kamarai szám: 09-1006, Jogosultságok: ENt-Sz

**Az épület fajlagos primer energiafogyasztása:** 171,34 kWh/m$^2$a

**Referenciaérték az épületek energetikai jellemzőinek meghatározásáról szóló 7/2006. (V.24.) TNM rendelet alapján:** -

**A követelményérték:** 105,416 kWh/m$^2$a

**Fajlagos hőveszteségtényező a követelményérték százalékában:** 190,44%

**Az energetikai minőség szerinti besorolás:**



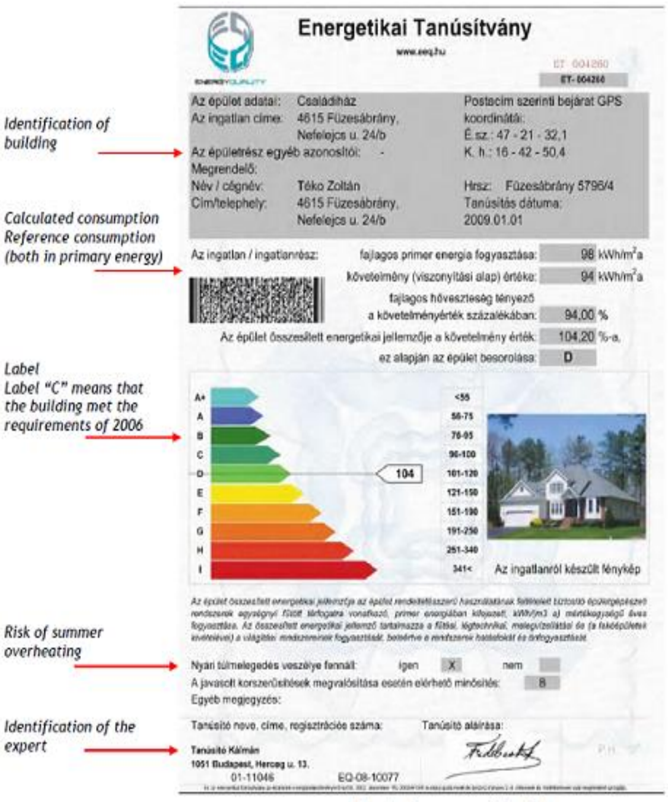
**Nyári túlmelegedésre vonatkozó észrevétel:** $\Delta t_{bnyár}$ = 2,85 K<3K
**nyári túlmelegedés kockázata elfogadható**

**Egyéb megjegyzés:** -

**A javasolt korszerűsítések:** Minden egyes tömör határolószerkezetet utólagos hőszigeteléssel lássunk el olyan mértékben, hogy a felújított szerkezet feleljen meg az érvényben lévő követelményértéknek. Javasoljuk, hogy az oktatási épületrészen a kopilit üveget a homlokzaton műanyag keretes hőszigetelt üvegezéssel ellátott határolószerkezettel lássuk el ($U$=1,6 W/m$^2$K). Továbbá az összes transzparens szerkezetet olyan transzparens szerkezetre cseréljük, amely teljesíti az előírt hőátbocsátási tényező értékét. A fűtési rendszert optimalizáló funkcióval ellátott helyi szabályozó rendszerrel látjuk el. Javasoljuk a légtechnikai rendszer komplex felújítását, ami magába foglalja a légcsatornák hőszigetelését, helyi szabályozását, 60% hatásfokkal rendelkező hővisszanyerők beépítését.

**A javaslat(ok) együttes megvalósításával elérhető minősítés:** B

| **A tanúsítvány kiállításának kelte:** | **A tanúsítvány azonosító száma:** | **Aláírás:** |
|---|---|---|
| Debrecen, 2010. február 12. | | |




Examples of EPC for an educational and residential building

The building and its elements must satisfy these **three levels** requirement group.
The *basic requirement* is related to external building elements (opaque and transparent). Practically the heat transfer coefficients *U* [W/m$^2$K] are limited, with uppermost admissible values reported in *Table* 1.

*Table 1*

| Building element | Admissible value for Heat transfer coefficient, *U* [W/m$^2$K] |
|---|---|
| External walls | 0,45 |
| Flat roofs | 0,25 |
| Ceiling on the cellar | 0,50 |
| Walls between heated and unheated rooms | 0,50 |
| Attic ceiling | 0,30 |
| Floor on the soil | 0,50 |
| Windows with wood or PVC frames | 1,60 |
| Windows with Al frames | 2,00 |
| Roof windows | 1,70 |
| Entrance doors, or doors between heated and unheated rooms | 1,80 |

The *second level* of requirements is focused on the whole building, and sets a maximal value for the specific heat losses $q_m$ [W/m$^3$K], depending only by the ratio of envelope area to heated volume (ΣA/V). The $q_m$ value may be determined using one of the following relations:

$$\begin{aligned} &\Sigma A/V \leq 0{,}3 && q_m = 0{,}2\, W/m^3K \\ &0{,}3 \leq \Sigma A/V \leq 1{,}3 && q_m = 0{,}086 + 0{,}38(\Sigma A/V)\, W/m^3K \\ &\Sigma A/V \geq 1{,}3 && q_m = 0{,}58\, W/m^3K \end{aligned} \qquad (1)$$

or using the diagram from *Figure* 1.

This value does not depend on the building function. This second requirement level should be used in order to avoid situations when the uppermost requirement level is satisfied for a building with low thermal characteristics of the envelope assuming high-tech building service systems.
It is to be emphasized that using building elements of the allowed U-value does not guarantee the fulfilment of the $q_m$ requirement, but depending on the ratio of wall, windows and roof area often stricter insulation requirements must be undertaken.

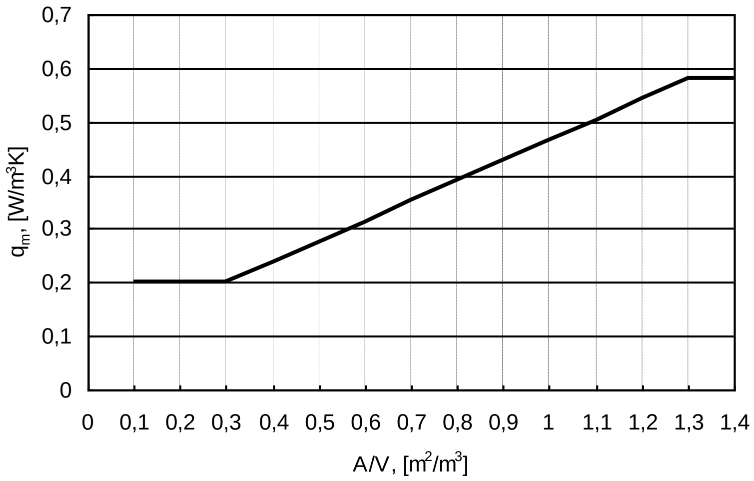



Fig. 1 Requirement for specific heat losses

It is important to notice that the elements of heating or air conditioning systems may be replaced during the construction with others having lower efficiency or the function of building may be changed in time, but even in these situations the building must fulfil the second level of requirements. The losses from thermal bridges are also considered in this level of calculation.

The *uppermost level* of requirements is related to primary energy consumption of buildings, and at this point both the building and its service systems are included. Maximal admitted values for yearly primary energy consumption $E_P$ [kWh/m$^2$a] are given, depending on the building function and the ΣA/V ratio, and expressing the yearly primary energy consumption per net floor area. The requirement can be determined using the following diagram (fig. 2). The primary energy needs include heating, domestic hot water, cooling and, for non-residential buildings, lighting.
There are buildings where the third level of requirements concerned to primary energy consumption is impossible to be stated: in these situations where the destination of use is rather complex, e.g. a building with offices, flats and sport facilities) the standard consumer is practically impossible to be defined. In these cases since in the building there are spaces with different functions, the designer can decide to choose as requirement for primary energy the value corresponding to the main function, but in this case the requirement may be determined as an average value of requirements for different destinations weighted by their volumes. When there are no requirements for the analysed buildings only the basic and second levels have to be fulfilled.

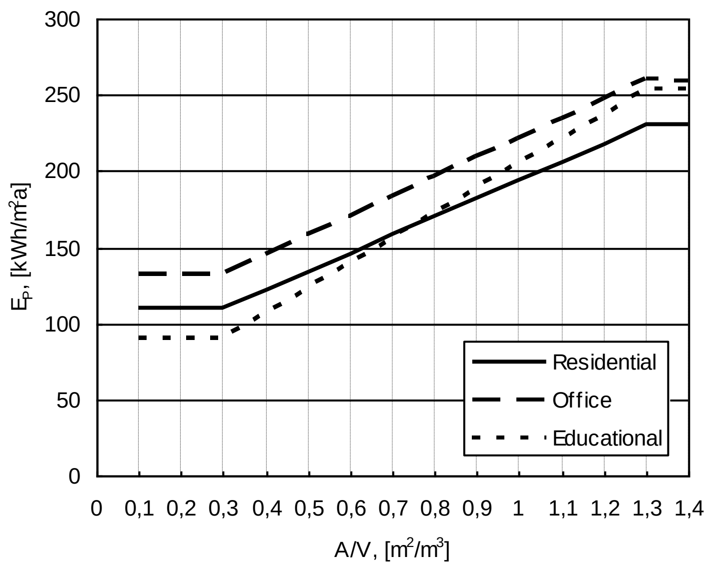



Fig. 2 Primary energy consumption requirement.

## 2.5 Impact of the EPBD at national level

Building regulations in Hungary deeply changed through the years: before 1991 the only existing requirement was a maximum acceptable limit for the U-values of building element. At a later stage the regulation was extended, starting from 1991, by including also specific heating energy losses as a function of the external envelope surface to volume ratio. As we can see from the figure 3 down below, the limit set for the $q_m$ value is stricter for large and compact buildings, with a low shape factor $\sum A/V$ . Anyway also the average U value of the envelope can be seen as a function of the surface the volume ratio, and for buildings with higher $\sum A/V$ it is required a more efficient thermal insulation as the decreasing slope of $U_m$ indicates (Fig.4).

Let's look more carefully to figure 3: the lower line represents $q_m$ trend in case of continuous heating, while the upper one in case of intermittent heating, which depends on the use of the building. This requirement became stricter in 2006 as it can be seen. If we take as example a typical residential single house this means an overall average U value of the envelope, including all elements as walls, roof, window, entrance door and taking in account thermal bridges losses, ranging from 0.45 to 0.50 $W/m^2K$.

As we will see more in detail later, utilized passive solar gains can be taken into account in the calculation of the specific volumetric value of $q_m$ once the presence of solar access is demonstrated. The influence of these free gains depends on the thermal mass of the building, with proper utilization factors provided by the normative. The $q_m$ value will finally include all the parameters closely related to the building that will affect its energy performance: form, envelope, insulation, orientation, shadow factor and solar access.

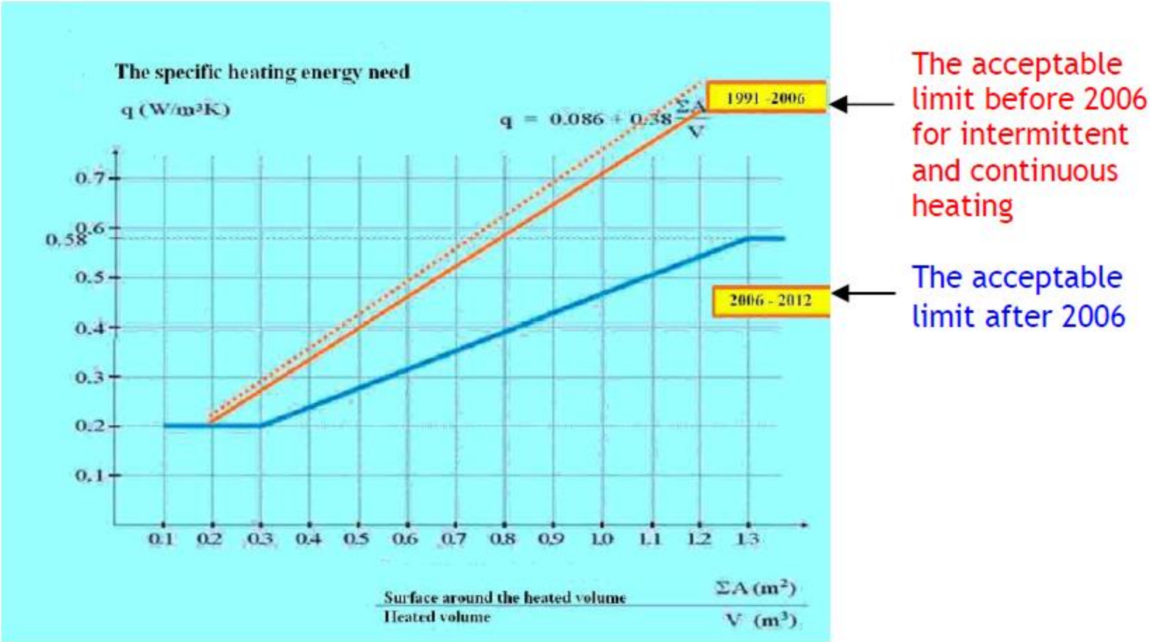



Figure 3: Specific heat losses requirement before and after 2006

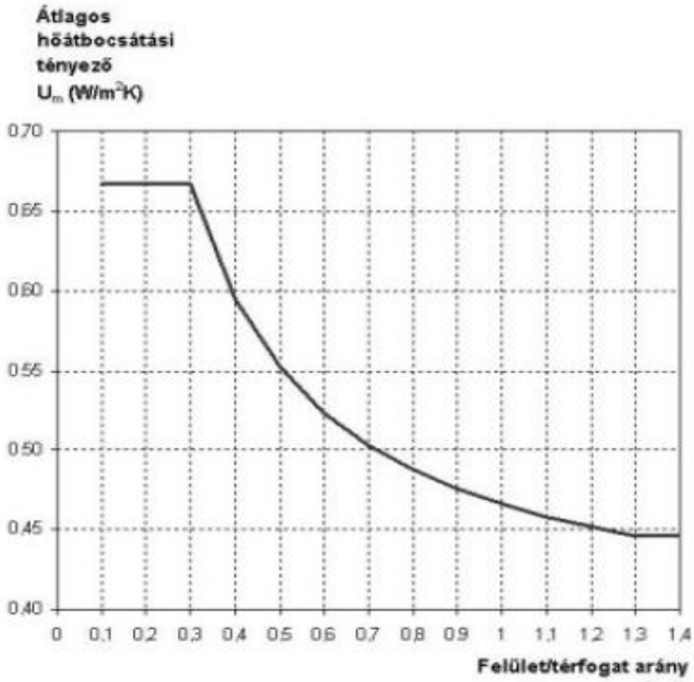



Figure 4: Average U value of the envelope depending on shape factor

The latest regulation considers also the risk of summer overheating, and to prevent that it suggests a simplified calculation which takes in account internal and solar gains, position of openable windows and fans, possibility of night ventilation and thermal mass of the building.
The requirement system is supposed to be reviewed every five years and, considering the recast of EPBD, this will mean a fundamental revision in 2016 that will strengthen the existing regulation.
The requirements must be updated in a continuous and dynamic way considering that technology evolves and provides new devices and systems in the building market; active solar and PV systems

in particular will emerge, and elements of the Life Cycle energy balance will be included in the calculations, based on the most cost effective method.
The WinWatt software provided by the normative already allows to calculate the cost and expected savings of different retrofit measures, by renovating the building or the mechanical systems. In a few time, once the data of the building are entered, several solutions can be compared and the results can be discussed according to payback time or investment costs, or it's possible to show all possible combinations below a given investment cost or the payback time achieved with a set-up investment cost.

In conclusion it's important to say that new and renovated buildings, which are the designated candidates for the implementation of energy savings, represent only a small share of the entire building stock in Hungary. Therefore the impact of applying EPBD is obviously limited and will not lead, within a useful timeframe, to significant reduction of energy consumption in the building sector. Currently, less than 35000 new buildings are built each year in Hungary and, despite the recent growth in the building market, major renovations do not have a relevant role yet.
For this reason to achieve remarkable energy savings significant incentives towards the improvement of existing buildings are needed, and the recommendations made by experts in the EPC have to become important guidelines that the owner of the building has to make good use of, either for a major renovation or as an individual cost-effective measure.
Anyway, financial concerns about the investment costs of using energy efficient technologies and their payback time still represent a huge obstacle. A breakthrough may happen in the field of subsidised projects, considering that the state administration has already adopted the methodology of offering subsidies based on EPC that stimulate project developer to apply more efficient technologies.
In the future it will be possible to approach to nearly-zero or zero energy buildings with a new rate based on *embodied energy*; this new quantity has been defined and studied in-depth only in the last years and refers to the amount of energy required to produce, transport on site and dispose down a product, material, good or service. It is a new concept that still finds obstacles in its definition and unit of measure, but is very interesting to assess the impact of the life cycle of a product or service on the environment, calculating the amount of $CO_2$ emissions or the equivalent quantity of oil used in its supply chain and end-life disposal.
When the yearly rate of embodied energy will become comparable to the yearly operational energy consumption, as expected by 2020 in the EPBD goal, the Life Cycle energy balance is to be considered.
In this new energy vision, the components of embodied energy have first to be distinguished into those pertaining to elements directly connected to energy operational consumption (envelope, mechanical systems) and others (basement, partition, stairs). On a second step, since the operational energy consumption mostly depend from building related elements, such as H&C systems and user dependent components, a rational balance between the embodied energy of these elements and the embodied energy of elements directly influencing the operational management of the building should be aimed at. Nevertheless, some practical problems should be discussed, first of all what is the conventional lifetime of the analyzed building and its elements. In this way the cost of an investment will be proportionate to the embodied energy, with an approach not far from the concept of cost effectiveness

## 2.6 Status of EPBD in Italy

In Italy the implementation of EPBD is particularly intriguing, with some peculiar differences with Hungary, since it is a shared task between the State and the 21 Regions and Autonomous provinces. Implementation started in 2005, with a national transposition Decree that established a transitional period during which:

- the minimum requirements were tightened by 30%, with respect to the previous levels;

- methodologies for determining energy performance of buildings were confirmed, by referring to the already existing advanced regulations;

- Energy Certification of Buildings (ECB) was replaced by a declaration produced by a professional designer (assessor accreditation was not available at the time) which was limited to new or renovated buildings, and then extended in 2006 to buildings on sale and rental;

- Boiler inspections procedures were slightly improved, in respect of the existing regulation from 1993.

At the end of 2010 the revision process of the current legislation at the national level was completed and an initial group of 10 active Regions implemented their transpositions, according to the national model and guidelines.
In Italy the regulation on ECB is handled by the Minister of Economic Development in collaboration with the Ministry of Environment and the Ministry of Infrastructure.
Before it can be approved, the opinion of the Committee of Regions is required, obtained through the State-Regions Conference. It’s clear how the energy policy is quite messy, by leaving the drafting of the general framework to the central government, according to the modification of the Italian Constitution , Part V, and at the same time being partially delegated to the Regions and Autonomous Provinces that have the final power to adapt it to their individual requirements. The Regions are in charge of the entire certification system, which is based on regional registries and databases. The timetable for the implementation of the Energy Certification of Buildings in various building categories was graduated, and reached its full implementation on the 1st of July 2009, when all the required buildings were included in the certification system: new buildings, major renovations, public buildings and all buildings when sold.
In Italy the definition of public buildings include all buildings owned by the State, regional or local administrations, or other public organizations, no matter what activity performed therein, or any building not publicly owned but used by a public body. Every public building larger than 1000 $m^2$ is required to **display the energy certificate** in a place easily visible to the public, though no fine or deadline has been specified whenever this requirement is not complied.
All public buildings must have an EPC when an operation and maintenance contract is signed for their management.

| Date | Type of building |
| --- | --- |
| 1st of July 2007 | Transfer of whole building > 1,000 $m^2$ |
| 1st of July 2008 | Transfer of whole building < 1,000 $m^2$ |
| 1st of July 2009 | Transfer of flats |

*Table 1. Timetable of implementation of ECB.*

On the 10th July 2009 in the Official Gazette was published the Ministerial Decree DM 26/06/2009,which officially sanctioned the actuation of European Directive 2002/91/CE art.7 and DLgs 192/05 art.4 comma 1 related to the energy certification of buildings, and which entered into force on the 25th July 2009.

The Ministerial Decree is composed by eight articles and two attachments; attachment A contains the guidelines for EPC while attachment B reports the updated technical specifications and standard used in the calculations.

The energy performance of buildings is calculated with an indicator called EP: for residential buildings it is measured in $kWh/m^2$, for non-residential buildings in $kWh/m^3$ of primary energy, while the efficiency scale is ranging from A+ to G. Performance is expressed for the whole primary energy used in the building, and separately for the single uses: heating, hot water, cooling and lighting for non-residential buildings only.

The global $EP_{gl}$ is the sum of the partial EPs:

$$EP_{gl} = EP_i + EP_{acs} + EP_e + EP_{ill}$$

where:

- $EP_i$ is the EP for heating
- $EP_{acs}$ is the EP for DHW;
- $EP_e$ is the EP for summer;
- $EP_{ill}$ is the EP for lighting.

There are two methods to calculate this energy performance marker (EP) established by the Ministerial Decree, one for existing buildings and one for new buildings.
For new buildings, major renovation, demolition and reconstructions the DM sets up a calculated methodology based on the UNI/TS 11300 to calculate the energy performance of the building. At present, the UNI/TS contains Part 1 for the calculus of heat need in summer and winter season and Part 2 for primary energy and efficiency of air conditioning systems and production of hot domestic water.
For existing buildings it is foreseen a calculated rating that takes as input the existing data about the building with three different levels of analysis:

- For every category of buildings: all the data about the building can be calculated by instrumental analysis or by consulting the database and abacus of UNI/TS 11300 to acquire the thermal characteristics of the envelope, and the energy consumption calculation has to be referred as well to UNI/TS 11300.

- For existing buildings with net floor area less than 3000 $m^2$ : the input data can be obtained by comparison with similar buildings or by databases and abacuses. To calculate the $EP_{glob}$ it is recommended to use the software DOCET, arranged by CNR and ENEA in conformity to UNI/TS 11300.

- For existing buildings with net floor area until 1000 $m^2$ : using the main geometrical and climatic data of the building the $EP_i$ is calculated with a simplified method that is reported in Attachment 2 of  the DM with the National Guidelines and the $EP_{acs}$ is calculated with a similar simplified method contained in UNI/TS 11300.

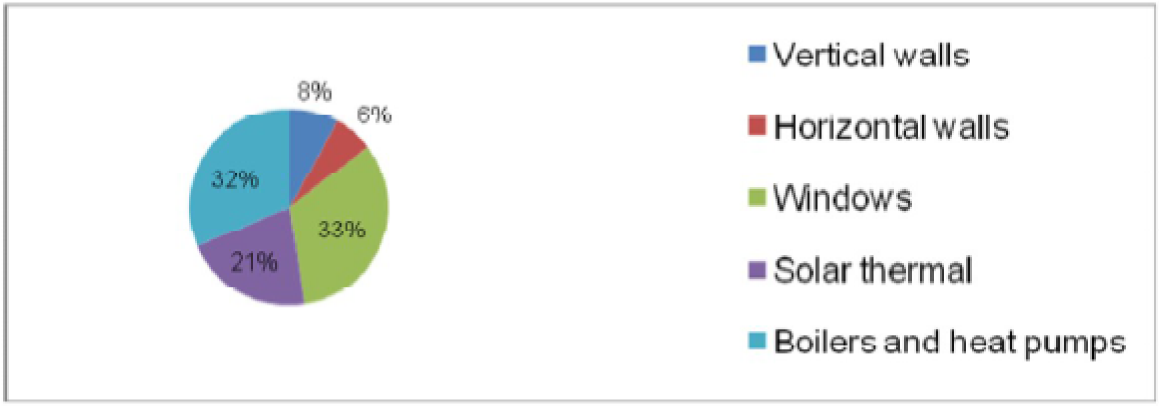
Presently, all **existing residential and non-residential buildings** need to be certified when they are sold. The Legislative Decree transposing the Directive 2009/28/EC also requires a valid EPC to be presented to the buyer or renter, even if for rental this is limited to cases where the EPC is already , and imposes the publication of EPC data in advertising of homes for sale. In addition, when registering a contract of sale, Italian notaries have to inform the parties involved of the obligation of having an EPC and check that there is an agreement between the parties concerning the issue of an EPC. In 2 Regions the notary has to annex the EPC to the sale contract. There is no national fee for EPC registration, but this is usually applied at regional level. Fines are foreseen for building owners refusing to deliver the certificate, and in at least 2 Regions the notary refuses to register the contract of sale if the certificate is not shown.
Moreover, certification is compulsory to have access to most public incentives for energy efficiency that we are going to discuss.

## 2.7 National incentives and subsidies

The most important subsidy is the "Tax credit programme", which provides a 55% refund grant to be distributed in ten fiscal years maximum, and is available for the following measures:

- Electric, absorption cycle and geothermal heat pumps, condensing boilers, solar thermal collectors;
- Retrofitting of building envelope elements that satisfy the minimum;
- Building renovations that globally satisfy building performance of less than 20% of the Energy Performance requirements in force.

This programme has been a great success in term of saved energy, induced investment and benefit to small and medium enterprises and employment (the breakdown of the results can be seen in figure for the two years 2007 and 2008).




In the whole period of application, since 2007 and including 2010, over 840'000 interventions have been supported, involving 2 million flats, which represent 7.7 % of existing flats. The overall energy saving obtained was 6'500 GWh/year, with 42'000 jobs created, with a peak of 56'000 in 2009. The annual data are reported below:

| | 2007 | 2008 | 2009 | Total |
|---|---|---|---|---|
| Number of interventions | 106,000 | 247,000 | 236,000 | 589,000 |
| Primary energy saved (MWh) | 800,000 | 2,000,000 | 1,600,000 | 4,400,000 |
| Net intervention costs (€) | 1,500,000,000 | 3,500,000,000 | 2,800,000,000[4] | 7,800,000,000 |
| Income tax deduction (€) | 825,000,000 | 1,925,000,000 | 1,540,000,000 | 4,290,000,000 |

We also report in the framework of Photovoltaic the presence of a "feed-in premium": the energy produced with the PV system, that can be self-consumed or sold to the national grid, receives a financial subsidy with a tariff taking in account the energy price plus a benefit. At the same time it is also available a "feed-in tariff" for all RES systems, except for PV and solar thermal: in this case all the energy produced is sold to the grid with a unique 20 years contract premium tariff.
These facilitations are available for buildings submitted to a renovation, leading to a reduced energy consumption by at least 10%. A valid EPC before and after the renovation is the necessary requirement, with the demonstration of the achieved result.

A decree of March 2010 offers  public grant of 83 €/$m^2$ and 116 €/$m^2$ for new residential buildings in which family homes are housed, if the achieved EP is less than 30% and 50% respectively of the minimum requirements in force. This subsidy could cover about 60% of the extra costs per $m^2$, but was limited to 5'000 € and 7'000 € per intervention. Because of this, only a very small part of the available budget, estimated initially around 10'000 flats, has been used so far.
Since December 2006 about 8 M€ has been budgeted for energy diagnosis and certification of public buildings, throughout the Regions.

The Ministry of Environment has budgeted a revolving fund "Kyoto Fund" for sustainable energy which will be managed by the Regions willing to assume responsibility for the setup of the calls to projects.

## 2.8 The Energy Classification for buildings in Italy

The Energy Performance Certificate is the most visible and immediate aspect of the ECB: as said before, the document assigns an energy performance label to residential and non- residential buildings or building units, and it lists some recommendations for improving their energy category sorted by cost-effectiveness.

| 6. RECOMMENDATIONS | | |
|---|---|---|
| Measures | EP and Class after implementation | Payback time (years) |
| 1) | | |
| 2) | | |
| 3) | | |
| 4) | | |
| 5) | | |
| ACHIEVABLE NEW Energy Performance EP | ......... kWh/$m^2$ year | ...... years |

The ECs are valid for 10 years, but they have to be updated whenever the energy performance is modified by interventions on the envelope or mechanical systems.
As usual, the real benefit for the owners lies in the recommendations given by the expert, and summarized on page 2 of the certificate; they are a list of actions, EP and class obtained after the eventual implementation, with relative payback times.

First step of the DLgs 192/05 is to create classes for **heating** energy consumption for winter season, defined with reference to the minimum energy performance requirements, which entered into force on the 1st of January 2010. The $EP_i$ of a class depends on the climatic zone and on the shape factor S/V of the building where:

- S is the envelope area ($m^2$) that delimits the heated volume to the outer unheated spaces,
- V is the gross volume ($m^3$) defined by the heated surfaces of the heated space.

These limit values for $EP_i$ are given depending on shape factor and Degree Days (GG): for buildings with S/V between 0,2 and 0,9, and similarly for buildings with number of degree days out of ranking, a linear interpolation provides the requirements. Here below are summarized the $EP_i$ for residential buildings, with the updates from 2008 to 2010.

**Edifici residenziali della classe E1, esclusi collegi, conventi, case di pena, e caserme**

| TABELLA 1.1 | $EP_i$ limite (valori in kWh/m² anno) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zona climatica | | | | | | | | | |
| | A | B | | C | | D | | E | | F |
| | <600 GG | 601 GG | 900 GG | 901 GG | 1400 GG | 1401 GG | 2100 GG | 2101 GG | 3000 GG | >3000 GG |
| ≤0.2 | 10 | 10 | 15 | 15 | 25 | 25 | 40 | 40 | 55 | 55 |
| ≥0.9 | 45 | 45 | 60 | 60 | 85 | 85 | 110 | 110 | 145 | 145 |

| TABELLA 1.2 | $EP_i$ limite dal 1 gennaio 2008 (valori in kWh/m² anno) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zona climatica | | | | | | | | | |
| | A | B | | C | | D | | E | | F |
| | <600 GG | 601 GG | 900 GG | 901 GG | 1400 GG | 1401 GG | 2100 GG | 2101 GG | 3000 GG | >3000 GG |
| ≤0.2 | 9.5 | 9.5 | 14 | 14 | 23 | 23 | 37 | 37 | 52 | 52 |
| ≥0.9 | 41 | 41 | 55 | 55 | 78 | 78 | 100 | 100 | 133 | 133 |

| TABELLA 1.3 | $EP_i$ limite dal 1 gennaio 2010 (valori in kWh/m² anno) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zona climatica | | | | | | | | | |
| | A | B | | C | | D | | E | | F |
| | <600 GG | 601 GG | 900 GG | 901 GG | 1400 GG | 1401 GG | 2100 GG | 2101 GG | 3000 GG | >3000 GG |
| ≤0.2 | 8.5 | 8.5 | 12.8 | 12.8 | 21.3 | 21.3 | 34 | 34 | 46.8 | 46.8 |
| ≥0.9 | 36 | 36 | 48 | 48 | 68 | 68 | 88 | 88 | 116 | 116 |

A point of interest is the fact that **all non-residential buildings** have the same requirement for primary energy consumption $EP_{lim}$, expressed in $kWh/m^3$ as the total primary energy consumption divided by the heated volume. This will be underlined during the energy analysis with the Italian regulation to show how it affects the energy classification of these buildings.

A general building, residential or non-residential, meets the requirement for $EP_i$ when its $EP_i$ value fits between C and D category.

The person, generally a technician or engineer, issuing the energy certification will have to follow the path set by UNITS-11300 by calculating the primary energy consumption: this requires to properly calculate all the heat losses, i.e. transmission and ventilation, from the heated spaces to the outer unheated ambient and all the free gains, internal and solar. Thereafter also the generation, distribution and supplying systems has to be considered, with their electric consumption and energy efficiency. The global primary energy need of the building is given by the net heating requirement plus the electricity need, expressed in primary energy by using its transformation factor, i.e. efficiency of the national electric grid.

There are also requirements for the U-value of vertical and horizontal opaque surfaces, for floors that separate heated and unheated spaces, roofs and windows (See Appendix).
The regulation gives also a requirement for the average seasonal efficiency of the heating system , depending on the installed power:

$$\eta_{glob} \geq (75 + 3 \log P_n)\% \qquad \text{if } P_n < 1000 \text{ kW}$$

$$\eta_{glob} \geq 84\% \qquad \text{if } P_n \geq 1000 \text{ kW}$$

For new buildings and major renovations, and as well for building units in new buildings or major renovations, the minimum EP required is a C rating, to be approved at the planning stage before construction begins.
As repeated before, the calculation methodology is based on the national technical specifications of UNI TS 11300 which specify the mode of use of several CEN standards for Energy Conservation of Buildings in Italy. The selected method provides a monthly calculation of primary energy, taking in account heating and cooling building load, domestic hot water, H&C systems, renewable energies and lighting for non-residential buildings, even if the technical specifications about this latter one are not yet available.
The energy certification is formed by two documents, an Energy Certification Document (ACE) and a Qualifying Energy Document (AQE). The ACE is supposed to assess the energy performance of the building based on the National Ministerial Decree DLgs 192/05 but, since no national guidelines on energy certification of buildings have been published so far, **it is replaced on all effects by the AQE**.
The AQE is issued by a Qualified Expert, that can be actively involved in the early design phases and construction of the building, and contains:

- the calculated primary energy consumptions
- the energy category of the building or real estate, referring to the certification system in force
- the related maximum acceptable limits for primary energy for the specific building under analysis, or whenever not available for a similar new building
- recommendations to improve the energy performances and energy category of the building, with possible changes of the category i.e. for existing buildings.

As said before, the energy category in Italy is a global marker that is a sum of sub-indicators of the different energy services used in the buildings, as heating, cooling, DHW and lighting.
At present the $EP_{glob}$ is expressed only by the sum of $EP_i$ and $EP_{acs}$ as reported below.

$$EP_{glob} = EP_i + EP_{acs}$$

The energy certificates gives a comparison between the $EP_{glob}$ of the building under analysis and the required $EP_{glob,req.}$ provided by the normative depending on the building category, shape factor and climatic zone. This certification is based on the requirements for energy performances shown before and provided by DLgs 192/05; since $EP_i$ are corrected by percentage factors $K_n$ also the $EP_{glob}$ has to take in account these corrections, and so:

$$EP_{glob}(class) = K_n \, EP_{i,\,limit} + EP_{acs}$$

In the tables below are reported the energy labels from A+ to G for residential buildings, considering only heating energy and domestic hot water energy requirement in the $EP_{glob}$.

**Tabella 1: Classificazione EPi**

| | | |
|---|---|---|
| | **CLASSE $A_i$ +** | < 0,25 EPi(limite 2010) |
| 0,25 EPi(limite 2010) ≤ | **CLASSE $A_i$** | < 0,50 EPi(limite 2010) |
| 0,50 EPi(limite 2010) ≤ | **CLASSE $B_i$** | < 0,75 EPi(limite 2010) |
| 0,75 EPi(limite 2010) ≤ | **CLASSE $C_i$** | < 1,00 EPi(limite 2010) |
| 1,00 EPi(limite 2010) ≤ | **CLASSE $D_i$** | < 1,25 EPi(limite 2010) |
| 1,25 EPi(limite 2010) ≤ | **CLASSE $E_i$** | < 1,75 EPi(limite 2010) |
| 1,75 EPi(limite 2010) ≤ | **CLASSE $F_i$** | < 2,50 EPi(limite 2010) |
| | **CLASSE $G_i$** | ≥ 2,50 EPi(limite 2010) |

As seen so far only heating and DHW consumption are taken in account in the energy indicator $EP_{glob}$: however there are other important energy sources which contribute in significant way to the primary energy need of a building, first of all cooling.
The cooling demand is continuously increasing nowadays, becoming sometimes even higher than the heat gain, and cannot be neglected.
That is why the energy certificate contains also a requirement for cooling, $EP_e$, expressed as usual in $kWh/m^2$ for residential and $kWh/m^3$ for non-residential buildings.

**Tabella 2: Classificazione EPacs**

| | | |
|---|---|---|
| | CLASSE $A_{ACS}$ | < 9 kWh/m² anno |
| 9 kWh/m² anno ≤ | CLASSE $B_{ACS}$ | < 12 kWh/m² anno |
| 12 kWh/m² anno ≤ | CLASSE $C_{ACS}$ | < 18 kWh/m² anno |
| 18 kWh/m² anno ≤ | CLASSE $D_{ACS}$ | < 21 kWh/m² anno |
| 21 kWh/m² anno ≤ | CLASSE $E_{ACS}$ | < 24 kWh/m² anno |
| 24 kWh/m² anno ≤ | CLASSE $F_{ACS}$ | < 30 kWh/m² anno |
| | CLASSE $G_{ACS}$ | ≥ 30 kWh/m² anno |

**Tabella 3: Classificazione EPgl**

| | | | |
|---|---|---|---|
| | | CLASSE $A_{gl}$+ | < 0,25 $EPi_{lim2010}$ + 9 kWh/m²anno |
| 0,25 $EPi_{lim2010}$ + | 9 kWh/m²anno ≤ | CLASSE $A_{gl}$ | < 0,50 $EPi_{lim2010}$ + 9 kWh/m²anno |
| 0,50 $EPi_{lim2010}$ + | 9 kWh/m²anno ≤ | CLASSE $B_{gl}$ | < 0,75 $EPi_{lim2010}$ + 12 kWh/m²anno |
| 0,75 $EPi_{lim2010}$ + | 12 kWh/m²anno ≤ | CLASSE $C_{gl}$ | < 1,00 $EPi_{lim2010}$ + 18 kWh/m²anno |
| 1,00 $EPi_{lim2010}$ + | 18 kWh/m²anno ≤ | CLASSE $D_{gl}$ | < 1,25 $EPi_{lim2010}$ + 21 kWh/m²anno |
| 1,25 $EPi_{lim2010}$ + | 21 kWh/m²anno ≤ | CLASSE $E_{gl}$ | < 1,75 $EPi_{lim2010}$ + 24 kWh/m²anno |
| 1,75 $EPi_{lim2010}$ + | 24 kWh/m²anno ≤ | CLASSE $F_{gl}$ | < 2,50 $EPi_{lim2010}$ + 30 kWh/m²anno |
| | | CLASSE $G_{gl}$ | ≥ 2,50 $EPi_{lim2010}$ + 30 kWh/m²anno |

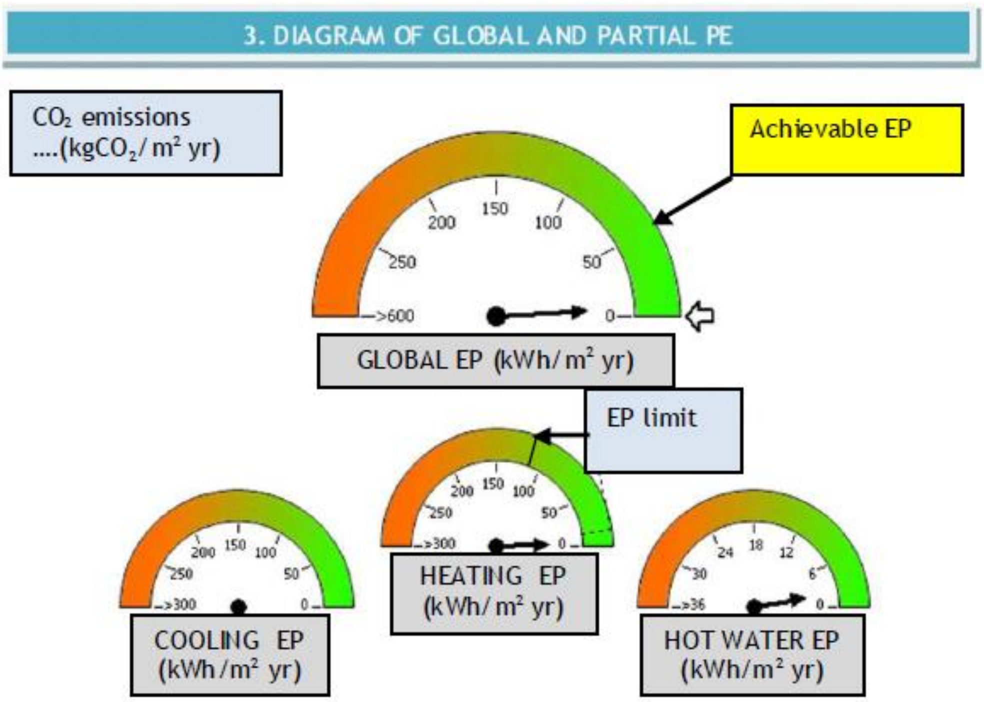



*Figure 2. Energy Performance (EP) for each end use and overall performance are expressed graphically in the EPC using this format. The maximum allowed EP (EP limit) is displayed as a line in the heating EP diagram.*

At present $EP_e$ is calculated as the net energy required to maintain the comfort conditions of $T_{int}$ = 26 °C inside the building during summer season: there are no specifications to calculate the primary energy consumption for cooling. This $EP_e$ has to be reported in the Energy Certificate and Qualifying Certificate: for residential real estates with floor area less than 200 $m^2$ this evaluation is discretionary, as long as they use the simplified method for the energy consumption during winter season. A performance summer rating equal to level V (the lowest efficiency) will be attributed to these properties.

There are two methods available to calculate $EP_e$: the first and quickest way is based on UNI/TS 11300 part 1, and calculates the $EP_{e,inv}$ expressed in $kWh/m^2$ year as a ratio of the thermal energy required to keep the comfort conditions inside the building and the net floor area of the heated volume.
In the case of existing buildings with $A_n$ less than 1000 $m^2$ it is possible to use a second method based on UNI EN ISO 13786 with an energy rating considering a dynamic thermal analysis of heating process.
The requirement is the same for all kind of buildings, based on the assessment of two parameter:

- attenuation factor Fa, adimensional coefficient given by the ratio of the module of dynamic thermal transmittance and thermal transmittance in stationary conditions;

- phase shift S, expressed as the delay (hours) between the maximum heat flow incoming in the heated volume and the maximal external temperature.

The tables providing the requirement values for Fa and S and relative energy categories are attached in Appendix.

In the case of apartment blocks, certification concerns the single flat: multi-family buildings get the certification from the EPC of the whole building, of from groups of similarly performing flats. In the case of single apartments with autonomous system or heat accounting a single certificate for the apartment has to be issued, based on its shape factor; for flats located in buildings with a centralized boiler and no heat metering, i.e. apartments in old condominiums, the EPC for the single flat can be derived from the EP of the whole building by dividing with charts based on the floor area of the flat. For apartments with centralized heating system which had major renovations or installation of regulation systems the calculations is similar to the autonomous case, by taking in account standard values for the efficiency of common systems.
It is also possible, for buildings of less than 1000 $m^2$, to avoid certification by declaring that they have the minimum requirement, class G, due to high energy costs. Buildings without heating and domestic hot water systems are also obliged to have certification performed, with substantial simplifications in the procedure.

It has to been reported that the regionalization of the ECB system has produced some positive and some potentially negative aspects. Among the positive aspect there is the valorization of local initiatives which started before the existence of national guidelines, and that have become examples of best practice for the whole country, above all the *CasaKlima/KlimaHaus system* developed by the Bolzano/Bozen autonomous Province. On the other side, this regional approach produces lots of differences in the identification of the final building category for the building designers moving from one area to another of the country, considering the high number of regions and autonomous provinces in Italy. There are difficulties in the circulation of Qualified Experts from one Region to another, and uncertainty in the market about the real significance of a certain building class for buyers coming from other Regions. The national rules are effective until a Region produces its regional legislation, furthermore the Region has to organize training, accreditation and so on. The main differences among the 10 issued regional systems are summarized below.

| Region | EPBD<br>Art. 3<br>Methodology | EPBD<br>Art. 7<br>Certification | EPBD<br>Art. 10<br>QEs |
|---|---|---|---|
| **Valle d'Aosta** | - | - | Assessors: training with examination or experience. |
| **Piedmont** | - | EPC is annexed to the sale and rental contract (+ fines).<br>No class G declaration. | - |
| **Lombardy** | Slight deviations from UNI-TS 11300. Official SW tool. | EPC is annexed to the sale and rental contract (+ fines). No class G declaration. | Assessors: training with examination |
| **Liguria** | Official SW tool. | No class G declaration. | - |
| **Aut. Pr. Bolzano** | Official SW tool. Reference to EN 832. The classes are related to absolute EP values. | No class G declaration. | *CasaClima/KlimaHaus Agency* exercises control. |
| **Aut. Pr. Trento** | | The national guidelines apply, therefore rental is excluded. | |
| **Emilia Romagna** | The classes are related to absolute EP values, not to minimum EP. | EPC is annexed to the sale and rental contract. No class G declaration. The notary has to annex the certificate to the sale act. | Assessors: training with examination or experience, but also registration in professional boards. |
| **Tuscany** | - | Class G if EPC is missing. | - |
| **Apulia** | - | EPC does not apply to sale and rental. | - |
| **Friuli Venezia Giulia** | | An energy-environmental classification (VEA) is used for building certification. | Training courses started in 2010, certification is postponed to November 2011 (new) and January 2012 (sold and rented). |

## 2.9 Impact of the EPBD at regional and national level

During the transactional period from 2006 to 2009 more than 2 million “certificates of qualification” were released, paving the way to the EPC; at the end of this period, new EPCs have been issued in the Regions that had produced their own legislation, while other Regions lagged behind.

| **EPC in the transitional phase** | 2006 | 2007 | 2008 | 2009 | Total |
|---|---|---|---|---|---|
| New construction | 110,000 | 315,000 | 295,000 | 255,000 | 975,000 |
| Sales | - | 60,000 | 240,000 | 640,000 | 940,000 |
| Renovated flats (55% tax credit) | - | 106,000 | 102,000 | 20,000 | 228,000 |
| Renovated flats (FV Premium tariff) | - | 650 | 1,200 | 1,650 | 3,500 |
| | | | | | 2,146,500* |

*more than 8% of existing buildings

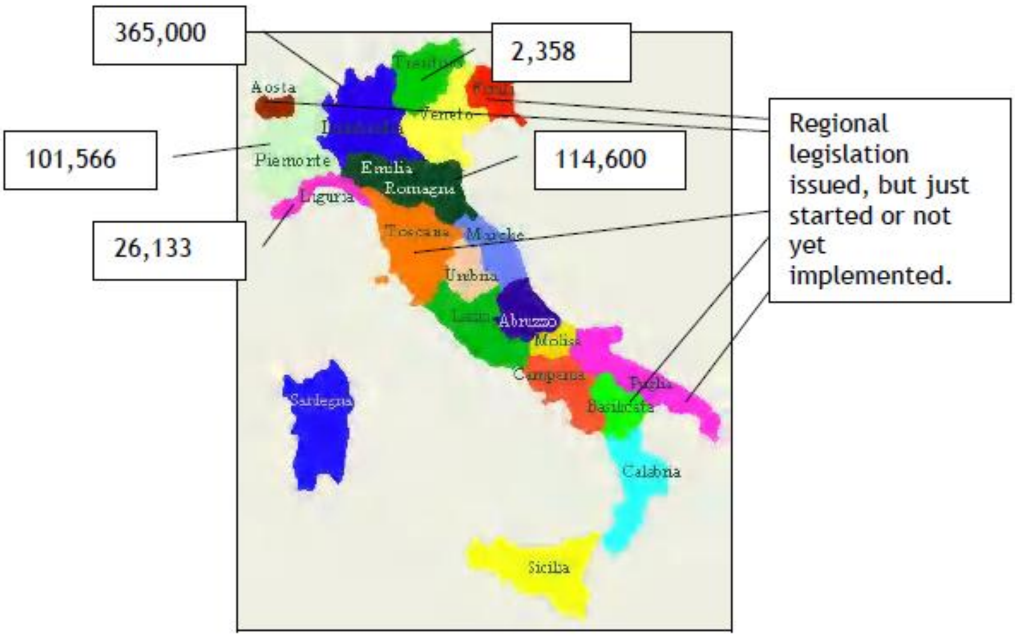



*Figure 5. Number of EPCs issued in the first five Regions and Autonomous Provinces that organised their Energy Certification of Buildings (ECB) system, and indication of the other 5 Regions and Autonomous Provinces that have issued legislation, but not yet fully implemented a certification scheme.*

Certificates can only be issued by Qualified Experts (QE): they may be architects, engineers and technicians with a secondary school technical degree, duly qualified and recognized by their professional associations. When required, the QEs have to attend a training course arranged by special organizations accredited by the Regions and in the end they have to pass an examination. There is a list of accredited QEs available to the public at the regional websites which is regularly updated.

Administrative penalties are foreseen for assessors' non compliance with the certification rules (30% of invoice), misconduct (70% of invoice and communication to the professional association) or falsification of the certificate (fine ranging from 500 to 3'000 €). There are also penalties for the work supervisor in case of omission of the compliance declaration (50% of invoice and report to the professional association), or in case of falsification of data (500 € or imprisonment of up to 6 months), and for end users, for not assuming the responsibility of producing and delivering the certificate (fine ranging from 500 to 3'000 €).

As said for Hungary, the national regulations on energy savings are continuously evolving, and so the minimum quality requirement are updating and becoming stricter; however, this process is difficult because of the differentiation of climates and shape factors.

Taking climatic zone E and a shape factor (ratio between envelope surface to heated volume) of 0.5 as an example, the first EP legal requirements on building energy performance stated in 1993, which can be assumed as approximately 120 kWh/m$^2$ year, as final primary energy needs, and this value has been reducing to 87.5 in 2006, to 80.5 in 2008 and to 71.2 in 2010 (figure below).

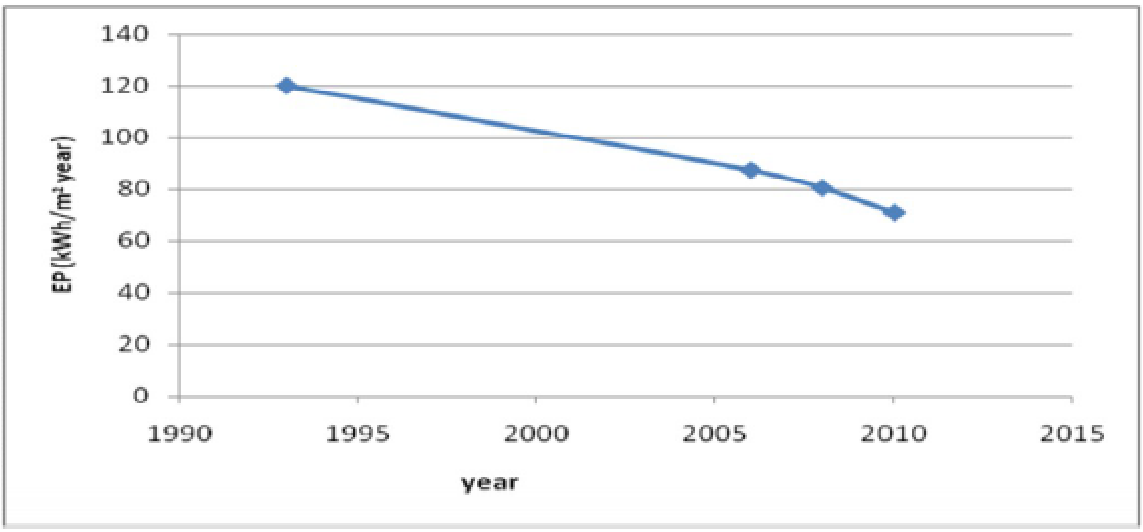



*Figure 12. Decrease of the maximum legal EP with time.*
*(Final energy consumption, climatic zone E, shape factor 0.5)*

The impact of EPBD on employment is difficult to assess, as the professional dealing with EPC of buildings are also involved in more conventional activities (second jobs). Nevertheless it can be stated that the implementation of EPBD, by training Qualified Experts, has increased the number and quality of architects, geometers and technicians who deal with buildings, but who had no familiarity with aspects of energy performance.

There is a larger number of companies specializing in low energy buildings, both for new constructions and for renovations: some clusters of enterprises are appearing on the market to provide a complete and skilled offer for major building renovations.

EPBD will be able to provide significant benefits only if it will be properly supported by financial incentives regarding the improvement of existing buildings, considering that new and renovated buildings, like in Hungary, represent a very small share of the entire building stock.
A main challenge is to make the public aware of their real energy use. There is a still a widespread sense of misunderstanding and ignorance among the consumers about:

- How much energy are they consuming in their buildings, which makes it difficult to understand the benefits of energy efficiency measures;

- What are the available energy efficiency measures, which renewable technological solutions and opportunities can be adopted realistically in their dwellings.

This situation is slowly getting better thanks to the government's continue promotion of these technologies through the media and the energy market.
These obstacles can be exceed with developments of the certification system for the short and medium term, that can be summarized in:

- Improving the regional IT platforms supporting the ECB, including online audit reports, data entry validation and automation of the Quality Assurance (QA) process;

- Reinforcing the QA scheme, increasing the number of light checks on input data and some on-site random verifications;

- Providing additional training for system designers and installers, concerning efficient HVAC, DHW and RES systems, as well as more effective auditing techniques;

- Developing a simplified methodology for periodic inspections of air conditioning systems;

- Developing technical specifications for artificial lighting certification in tertiary sector building;

- Developing an efficient monitoring system of ECB at national level, based on input of the Regions and Autonomous Provinces, in order to detect the level of **homogeneity** of operations, costs, and methods adopted in different parts of the country.

The experience acquired so far will certainly be of great help to achieve the ambitious EPBD goals, and also to reach the final aim of the Net Zero Energy new buildings estimated by 2020.

# CHAPTER 3

## ENERGY ANALYSIS OF AN EXISTING BUILDING

After a proper introduction of the content of EPBD, its goals and its implementation in Hungary, let’s now see a real example of energy certification. The analysis is conducted on an existing building located in Debrecen inside the University Main Campus, “Élettudományi Központ és Könytár”: it is a library and meeting center of the faculty of Life Sciences built in October 2005 together with the next Laboratory Building.
The building has 5 storeys and it is a mixed-use real estate with a cafeteria on the ground floor, offices and common spaces on the upper floors and a library storing books in the basement floors.

## 3.1 Building data and first calculations with a simplified approach

The building is located in Debrecen, in the north-east of Hungary: to have an idea of the climatic conditions here above are summarized the major Hungarian cities with relative duration of heating season and degree days. The building has a rectangular plant, with the two major façades oriented to North and South, the first one is almost completely covered with glazed elements supported by extruded aluminum profiles. Right next to the east façade the designer decided to erect a concrete structure with a green copper patina cladding jointed to the rest of the building by an extension on the roof, with fountains on the basement. The library was part of a major project and was built together with the opposite building, a bigger academic Research Centre with laboratories, university classrooms and offices. This building, called Laboratory Building, will be quoted later considering that the cooling machines that supply our building are located on its roof.

| **Location** | Budapest | Debrecen | Miskolc | Pécs | Nyiregyháza | Békéscsaba | Sopron | Becs |
|---|---|---|---|---|---|---|---|---|
| **No. Days** | 188 | 200 | 201 | 187 | 203 | 187 | 205 | 211 |
| **Degree days** | 3061 | 3353 | 3414 | 2650 | 3372 | 3001 | 3283 | 3500 |

The high-performance glazed elements are all manufactured by "Gastaldello Sistemi" for the north façade and for the windows and doors of the cafeteria on the ground floor, while the windows for the offices are normal double-glazed elements supplied by a local company.

The energy certification procedure, as said before, is based on the Ministerial Decree No. 7/2006. (V. 24.) TNM issued by the Minister of the Interior and its government members. The latest update of the regulation was published in the Hungarian Gazette on July 2012, and entered in force on 12$^{th}$ August 2012, annex 40/2012 VIII.13.

The regulations gives all the requirement for U-value, specific heat losses $q_m$ and primary energy consumptions; these calculations require several numerical computations, and the normative provides all the physical quantities involved and all the factors to accomplish their calculus with numeric tables and charts. All the quantities used during our work are reported in Appendix, while the full Hungarian Specification can be consulted as indicated in the References. The document reports also numerous technical specifications to reduce energy demand of ventilator, by improving insulation of air ducts and limiting pressure drop as indicted in EN 13779.

It is also reported, as indicated by EN 15251 standard, a table with design values of the internal temperature that have to be used depending on the building category.

The first calculations accomplished were the determination of all floor areas and vertical facades, all referred to the internal dimensions of the building; furthermore the heated volume was calculated, and so the shape factor which will later provide the requirement $q_m$.

Net floor area: $A_n = 3829{,}47\ m^2$

Total envelope: $\sum A = 3651{,}17\ m^2$

Heated Volume: $V = 12303{,}8\ m^3$

Shape factor $\sum A/V = 0{,}297\ m^{-1}$

These results were obtained by consulting the plans of the building; this preliminary work required time and energies due to the translation from Hungarian original project. All the building elements, floors, walls, windows and roof were analyzed and their thermal transmittance was calculated using the thermal resistance of the elements and the convective resistance provided by the Hungarian normative for walls, ceilings and floors. The first requirements limits the U-value of every element to an admissible value reported in the table below:

Admissible values for heat transfer coefficient

| Building element | Heat transfer coefficient, $U$ [$W/m^2K$] |
|---|---|
| External walls | 0,45 |
| Flat roofs | 0,25 |
| Ceiling on the cellar | 0,50 |
| Walls between heated and unheated rooms | 0,50 |
| Attic ceiling | 0,30 |
| Floor on the soil | 0,50 |
| Windows with wood or PVC frames | 1,60 |
| Windows with Al frames | 2,00 |
| Roof windows | 1,70 |
| Entrance doors, or doors between heated and unheated rooms | 1,80 |

All the elements satisfy the requirement, except for the floor on the soil $P_{kp1}$ that does not meet the requirement with a $U > 0.5\ W/m^2K$.
It is time for the second level of requirements which assess a limit for the specific heat losses $q_m$, depending only by the shape factor $\sum A/V$.

These admitted values are provided by:

$$\Sigma A/V \leq 0{,}3 \qquad q_m = 0{,}2\, W/m^3K$$
$$0{,}3 \leq \Sigma A/V \leq 1{,}3 \quad q_m = 0{,}086 + 0{,}38(\Sigma A/V) W/m^3K$$
$$\Sigma A/V \geq 1{,}3 \qquad q_m = 0{,}58 W/m^3K$$

or using the diagram from *Figure* 1.

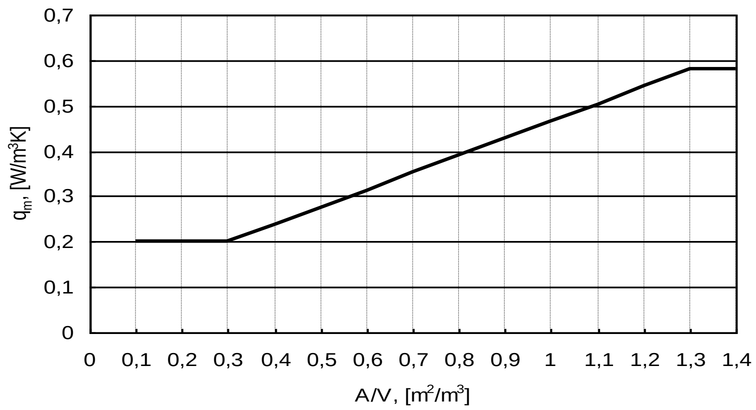


Fig. 1 Requirement for specific heat losses

In our case the requirements is:

$$q_m = 0{,}20\ W/m^3K$$

The specific heat losses of our building will have to be at least equal or lower than this value, and they can be calculated with a simplified method as:

$$q = \frac{1}{V}\left(\sum AU + \sum \Psi l - \frac{Q_{sd} + Q_{sid}}{72}\right) \qquad W/m^3K$$

Eq. 3.1

In this expression the first factor takes in account the heat losses through the envelope, opaque and transparent, the second the thermal bridges and the third considers the direct and indirect solar gains.

The first factor has to be calculated considering the different transmittance of every external walls and the relative opaque surfaces, and the glazed surfaces of the windows with their transmittance. The influence of thermal bridges has to be taken in account, calculating their total length and the ratio between total length and façade surface.

The thermal bridges are edges, joints between external wall and internal wall, external walls and ceilings and the perimeter of windows and entrance doors.
From the ratio $\sum l / A_{facade}$ it is now possible, as suggested by the normative, to correct the U-value of the opaque elements with a correction factor for external walls:

$$U_{Rwall} = U_{wall}(1+\chi)$$

Eq. 3.2

Our building has two floors under the ground: for these basement floors the heat losses through the envelope are not taken in account as usual with the product of a transmittance per opaque surface. The regulation standard, based on studies on heat losses for underground spaces, establishes that the heat transmission losses have to be considered by using a fictive heat transfer coefficient Ψ, one for the floor on contact with the soil, depending on the thermal resistance $R_d$ of the structure (i.e. $P_{kp1}$), and one for the external walls depending on their U-value. For the two basement floors the heat losses will be expressed as thermal bridges losses:

$$\Phi_{-01,-02} = \psi_w \cdot P_{int} + \psi_f \cdot P_{int} \qquad W/K$$

Eq. 3.3

In the upper equation $\psi_w$ and $\psi_f$ are fictive heat transfer coefficient for external walls and basement floor, $P_{int}$ is the internal perimeter of the underground storeys.

Now that all the heat losses have been taken in account it is time to decide whether or not take in account the solar gains; it was decided to go on with a two-side parallel calculation, one case with and one case without solar gains. This decision reflects a lack in the regulation procedure: indeed, the normative allows certificate technicians not to take in account solar gains with a simplified method. This aspect is extremely dangerous, because it can lead, for the same building analyzed with or without solar gains, to a different energy category. Thus, the certification loses its uniqueness and utility as standard to make comparisons, becoming misleading and useless for building owner or sellers.
After this important clarification, let's calculate the direct solar gains through glazed elements, given by:

$$Q_{sd} = \varepsilon \sum A_{ij} g Q_{TOT} \qquad \text{kWh/a}$$

Eq. 3.4

where ε is the utilization factor for solar gains, depending on the thermal mass of the building:

heavy building: ε = 0,75

lightweight building: ε = 0,5

The heavy and light structure category is established in function of specific thermal mass of the building (total thermal mass/heated floor area):

$$m \geq 400 \; kg/m^2 \qquad \text{heavy structure building}$$

$$m < 400 \; kg/m^2 \qquad \text{light structure building}$$

The total thermal mass for a building can be determined using the following equation:

$$M = \sum_i \sum_j \rho_{ij} d_{ij} A_j \qquad [kg]$$

Eq. 3.5

where: $\rho_{ij}$ – material density of layer *i* in the building element *j*; $d_{ij}$ – thickness of layer *i* in the building element *j*; $A_j$ – area of building element *j*. The standard calculation for thermal mass imposes to take as thickness 10 cm for all the internal and external walls; this thickness of 10 cm is calculated from the first layer of the inner surface to the centreline of the wall. If the wall is insulated, the thickness is calculated from the inner surface to the insulation layer. This standard considers that most of the heat transfer occurs in the early layers of the structure, which is the only active thermal mass involved.
The building is a heavy structure as it can easily be calculated.

In the equation 3.3 $A_{ü}$ are all the glazed areas, g is the total solar energy transmittance for the glazing elements, provided by the suppliers in the catalogues, and $Q_{tot}$ are the specific solar gains during heating season, expressed in $kWh/m^2a$.

| Orientation of the facades | N | S | E-W |
|---|---|---|---|
| Solar gains, [kWh/(m$^2$·a)] | 100 | 400 | 200 |

The indirect solar gains through stairwells, transparent insulation and solar spaces have to be determined using MSZ EN ISO 13790 standard (EN 832), but since none of these elements present a relevant solar gain in the building they are ignored in our calculations.
As said before, using the simplified method also the direct solar gains can be neglected: as it can be seen in this case the value of specific heat losses will be higher, and this leads to a higher value for specific primary energy consumption for heating. The solar gains can be taken into account only when the transparent surfaces are "seen" by the Sun at least 4 hours per day.

In the first case without solar gains the specific losses are:

$$q = \frac{1}{V}\left(A_{wall} \cdot U_{Rwall} + A_{Ü} \cdot U_{wındäows} + A_{roof} \cdot U_r + A_d \cdot U_d + \Psi \cdot l_f\right) = 0{,}198\ W/m^3K$$

Eq. 3.6

In the second case this value has to be decreased by the direct solar gains; they are divided by 72, which is the conventional number of thousands of degree days, calculated with a limit temperature for using of heating of 12 °C and a Δt of equilibrium equal to 8 °C. It follows:

$$q = \frac{1}{V}\left(A_{wall} \cdot U_{Rwall} + A_{Ü} \cdot U_{wındäows} + A_{roof} \cdot U_r + A_d \cdot U_d + \Psi \cdot l_f - \frac{Q_{sd}}{72}\right) = 0{,}137\ W/m^3K$$

As it can be seen, in both cases the requirements is fulfilled.

The procedure considers now the yearly energy consumption during heating season $Q_F$, calculated by three steps, each one more in-depth. Firstly:

$$Q_F = 72V(q + 0{,}35n)\sigma - 4{,}4A_N q_b \qquad [kWh/a]$$

Eq. 3.7

In the expression above, the air change rate $n$ of the A/C system is an average value based on the user profile and provided by standard tables , σ is a correction factor considering the intermittent operating mode of the ventilation system, $A_n$ is the net floor area already calculated and $q_b$ represents the sensible internal heat gains $W/m^2$ provided for the three categories of the normative.

Considering that the main function of the building is a public library and meeting point, the value for $q_b$ is taken as if it was an office building.

In a second step the energy need is corrected by considering the effective length of heating season, based on the real degree days curve and number of hours during heating season.
So the energy consumption is:

$$Q_F = HV(q + 0{,}35n)\sigma - Z_F A_N q_b \qquad kWh/a$$

Eq. 3.8

We have to determine $H$ and $Z_F$ : these two quantities are function of the inner-outer temperature difference, considering that the heating system, to maintain the comfort condition of 20 °C inside the heated spaces, is switched off when the external temperature is equal to 12 °C.
This balance point difference temperature is given by:

$$\Delta t_b = \frac{Q_{sd} + Q_{sid} + A_N q_b}{\sum AU + \sum l\Psi + 0{,}35nV} + 2 \qquad [K]$$

Eq. 3.9

The ratio is between the free energy sources and the thermal losses through the building elements and ventilation systems. The sum $\sum AU$ is referred to the external envelope with walls and roof, the basement floors are considered only with the product $\sum l\Psi$ related to the thermal bridges, but are not taken in account with the envelope since no people are allowed there and they can be considered unheated spaces. The ventilation losses are calculated with a value $n$ for air change per hour that is, as said before, an average based on the usage time and provided by standard tables. With $\Delta t_b$ it is now possible to determine the real degree days H and hours during heating season $Z_F$ from the diagram 3.1.
Now that we know the real values for the duration of heating season, we will use the same $\sigma$ value seen before to take in account the discontinuous operating mode of the A/C system, and as well the same air change per hour $n$ and we are able to determine the consumption with the second step.

The internal gains contribute is considered only for the floors above the ground, with a value $A_N$ lower than the net floor area of the whole building. This decision has been taken considering that no people are present in the two basement floors: in these spaces there are only books shelves, with two employees that spend a few hours per week in catalogue mansions. Since no sensible heat flows are produced, these floors do not affect the production of internal gains.

| Egyensúlyi hőmérséklet-különbség [K] | Hőfokhíd [hK] | Idény hossza [h] |
|---|---|---|
| ≤ 8,0 | 72000 | 4400 |
| 9,0 | 70325 | 4215 |
| 10,0 | 68400 | 4022 |
| 11,0 | 66124 | 3804 |
| 12,0 | 63405 | 3562 |
| 13,0 | 60010 | 3295 |
| 14,0 | 55938 | 3003 |
| 15,0 | 51191 | 2687 |
| 16,0 | 45766 | 2346 |
| 17,0 | 39666 | 1980 |
| 18,0 | 32889 | 1590 |
| 19,0 | 25436 | 1175 |

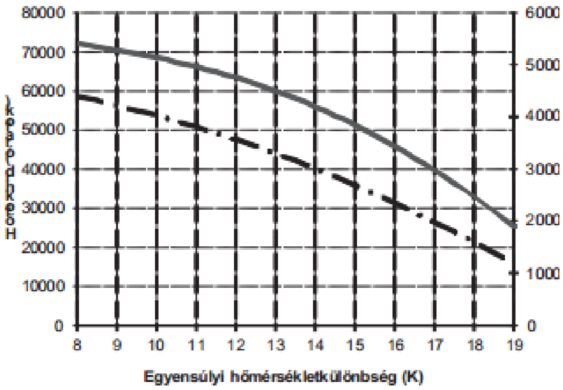



Diagram 3.1

The third and last step goes into-depth of the calculation, by considering differently all the thermal losses:

$$Q_F = HV\left[q + 0{,}35 n_{inf}\frac{Z_F - Z_{LT}}{Z_F}\right]\sigma + 0{,}35 n_{LT} V\left(t_i - \overline{t_{bef}}\right) Z_{LT} - Z_F A_N q_b \qquad [kWh/a]$$

Eq. 3.10

In 3.10 the first quantities considered are the specific losses q, with and without solar account, and the ventilation losses calculated only when no people are inside the building. During this period only the air change is provided by the HVAC system, with a lower air change rate $n_{inf}$ equal to the standard for office buildings.
The number of operation time for the ventilation system $Z_{LT}$ is a design choice, affecting the percentage of heating that will be covered by the air conditioning system. For our building, considering the huge volume, the ventilation system is also conditioning the air, operating 17 hours per day. Therefore $Z_{LT}$ will be, considering that the A/C system is covering part of the heat demand:

$$Z_{LT} = \frac{Z_F}{24} \cdot 17 \qquad hours$$

Eq. 3.11

It follows a value of 7 hours per day when no people are inside the building and the heating is switched off.
It has to be considered also the energy wasted when the A/C system is running, caused by the temperature difference between the set-point inlet temperature $t_i$ = 22 °C and the real inner temperature of the spaces. The latter one, i.e. $\bar{t}_{bef}$, has been calculated as an average internal temperature weighted on the volumes of all the heated spaces served by the A/C system during the heating season, and has resulted equal to 20.8 °C. Considering this last data, the needs of energy during heating season are:

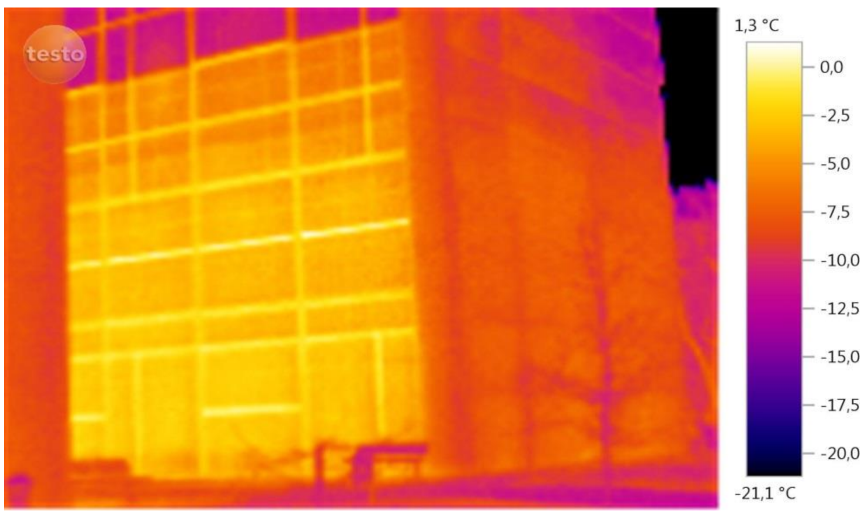
$Q_{F1}$ = 107173.63 kWh/a without solar account

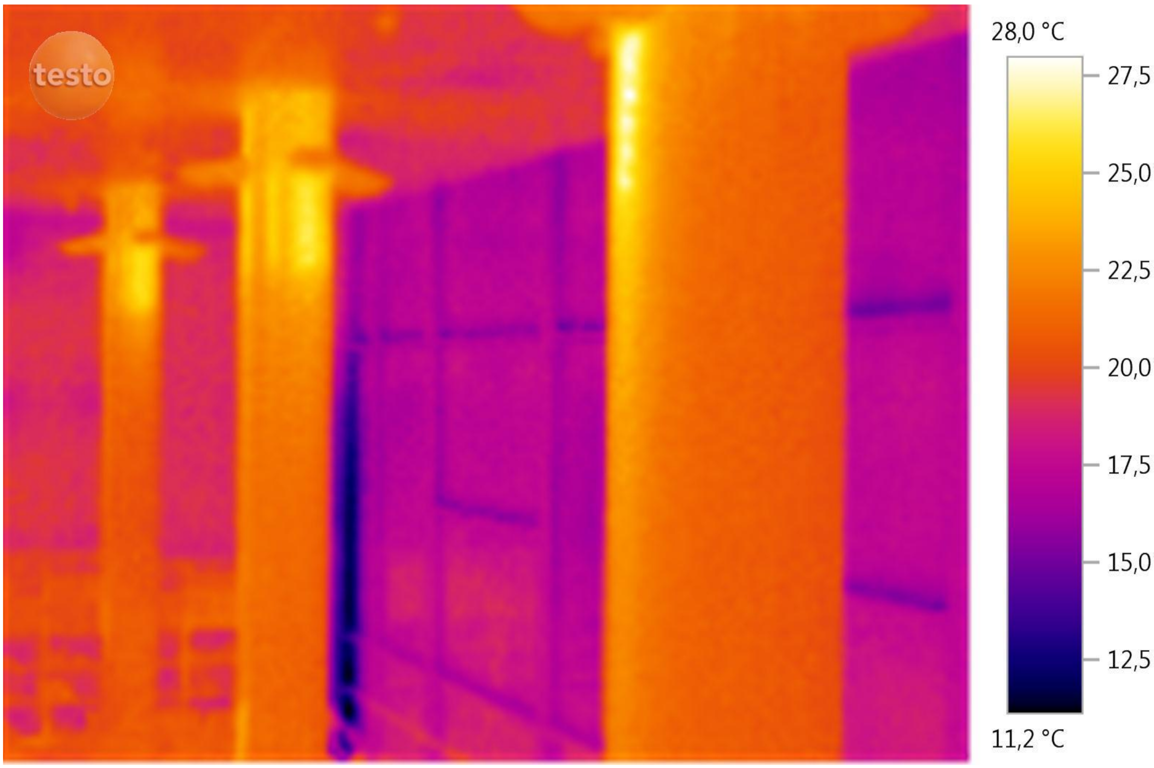
$Q_{F2}$ = 72919.9 kWh/a with solar account

And a specific energy need for heating of:

$$q_f = \frac{Q_F}{A_N} = 28{,}15 \qquad [kWh/m^2a]$$
$$q_{f,solar} = 19{,}14 \qquad [kWh/m^2a]$$

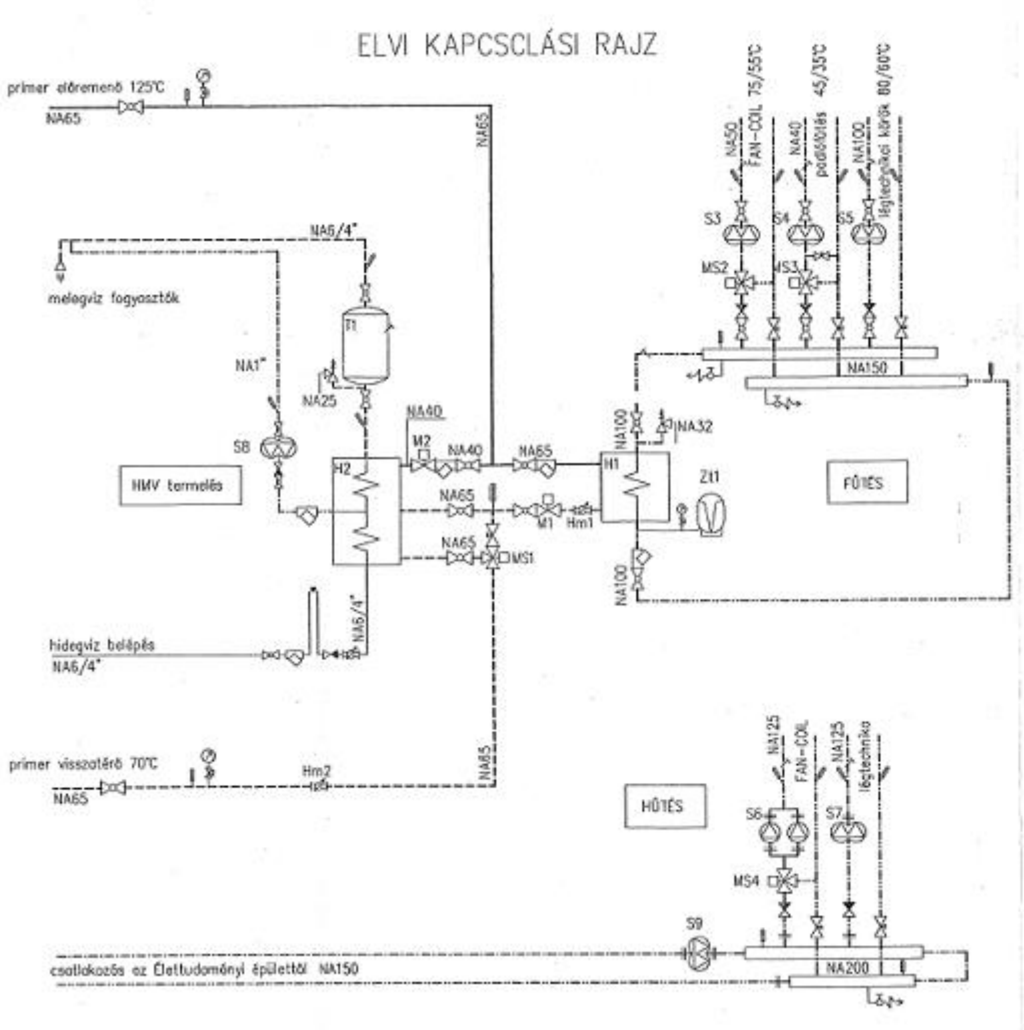
At this point the calculation goes on with the third level or requirement, that requires to calculate the primary energy consumption for the building. We have to keep in mind, however, that the library is a building that does not fit into the three categories disposed by the Hungarian regulation. We can't say, indeed, it is an educational building considering the presence of a bar-cafeteria and offices all over the floors, and nevertheless we could say it is only an office building.
In these cases the absence of requirements for primary energy allows the designer to fulfil only the first two levels of the calculation. We can affirm, then, that the library meets the requirement for building element U-value and specific heat losses, but how can we give an energy certification?
We need first of all to assess the primary energy consumption of our building, and then we will see how to "create" a requirement to compare to the primary energy consumption we have calculated.





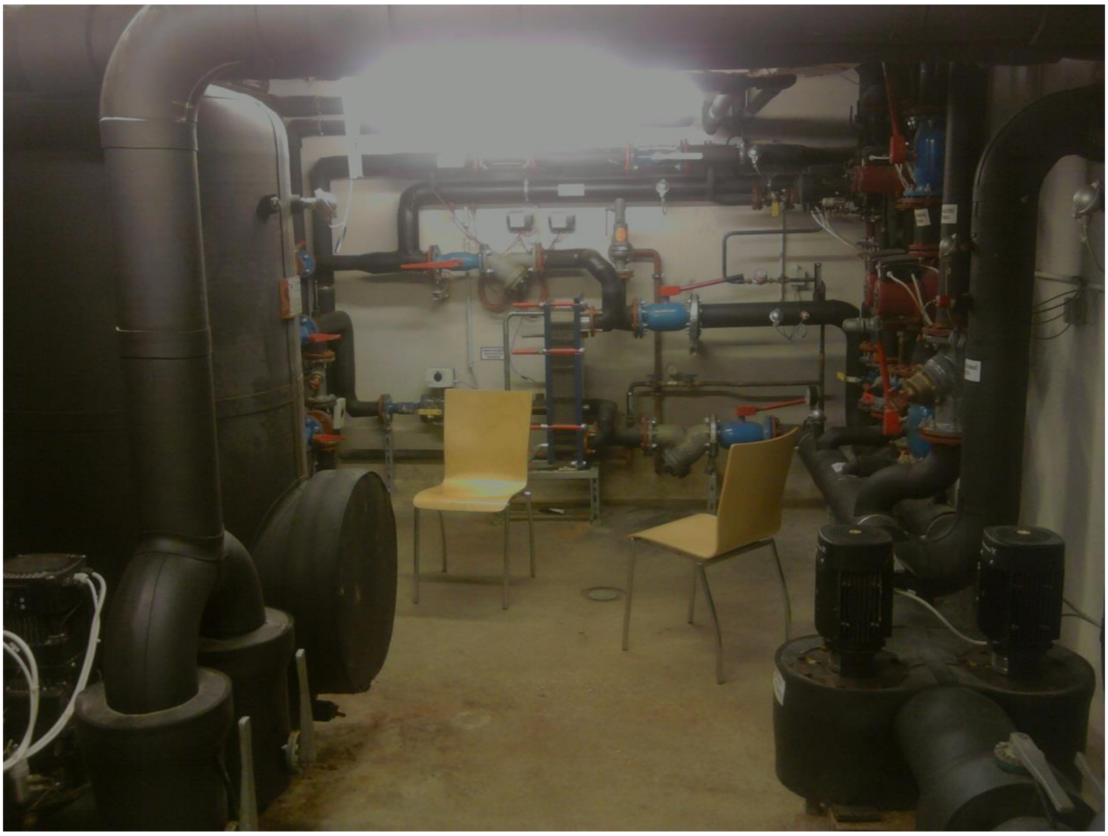

## 3.2 Power plant and Primary Energy consumption

The calculation of primary energy consumption, which will allow us to issue the Energy Certificate and give an energy category to the building, is broken down by considering the different service systems which provide energy: heating, cooling, domestic hot water and lighting.
First of all we have to analyse the power plant to understand how the energy is produced and handled from the production site to the users.
The building under analysis is supplied by district heating, therefore its power plant is simpler and less bulky than a standard centralized production plant. The district heating supply circuit provides superheated water at 125 °C: the supply flow is split between DHW and heating production with two plate heat exchangers, and then comes back to the D.H. return pipe at 70 °C. The mechanical room is located in the cellar, and as it is clear from the image below it contains a storage tank to accumulate DHW and the primary hydraulic circuit with supply and return pipes from district heating, water pumps for the terminals, 3 and 2 ways valves and regulation devices. All the water pipes in the circuit share a common expansion vessel, that is well visible in one of the following pictures next to the DHW tank.




The heat gain, considering the design of the building, is supplied by a combination between water and air terminal: radiators and fan coil in the offices, floor radiant panel system combined with air vent and diffusers for the library open spaces and ground floor.
The HVAC system provides to the ventilation and air conditioning: thermal comfort and indoor air quality are guaranteed during the heating and cooling season using 3 Air Handling Units installed on the roof that, respectively, serve the upper floors, the underground floors and the toilets and cafeteria. As said before, the offices are served by radiators and fan coils, while the rest of the building is served by primary air: the air inlets through diffusers on the ducts for the basement floor, through air vent integrated in the columns for the floors above the ground. The extraction of the exhausted air flow rate is supplied by air-grilles.

The plans and sections of the building were fundamental to understand how the H&C are produced. The heating plant has a primary and secondary circuit with two collectors, as they are always required to balance the water flows to the users, one for the supply line and one for the discharge. The same happens for the cooling circuit as well.



In the image above it can be seen the mechanical room, with all pipes, pumps and valves that are insulated to minimize circulation heat losses. The expansion vessel in the image down here.

There are also two server rooms on the 3rd floor and one in the basement which require cooling and are served by air split conditioner that we will analyse later. All the open spaces on the floors above the ground are heated by a radiant floor system, while the offices use radiators; the heating is an air/water combined system, with air terminals, fan coils and air diffusers, that ensure the comfort conditions and the air change throughout the building.
We report also the use of natural convection coils on the upper floors: they are located around the perimeter next to the façades. These air/water terminals are specifically used to ensure comfort on the open spaces by heating up the cold air with an exchange battery; the warm air now circulates by natural convection all over the inner space. These modules have to be installed in proximity of the external walls but with a minimum distance to the glazing elements to avoid superficial condensation of the warm air.

In the two basement floors as said before no people are allowed to stay, and the spaces are entirely occupied by books shelving; in these floors there are the electrical room, the mechanical room, a server room and two small restroom with toilets and wardrobe for the office employees. The only services on these spaces are the air ventilation, that is always running to maintain the comfort conditions and to prevent damages to the books, the air extraction in the restrooms and the cooling of server room. That is why, as we will repeat later, these two floors are taken in account in the active volume for ventilation but are not taken in account for the internal gains since no people are there.
We will now present the heating and cooling systems, using both thermal and normal photos.
In the inside and outside spaces the thermo camera allows to see where the losses occur with a spectrum that changes colour depending on the surface temperature. It is only a qualitative measure to give the idea of how and where heat losses affect the energy performance of our building.

## 3.3 Primary energy consumption for heating

The primary energy consumption for heating is calculated as following:

$$E_f = \left(q_f + q_{f,h} + q_{f,v} + q_{f,t}\right) \cdot \sum \left(C_k \cdot \alpha_k \cdot e_f\right) + \left(E_{FSz} + E_{FT} + q_{k,v}\right) e_v \qquad [kWh/m^2 a]$$

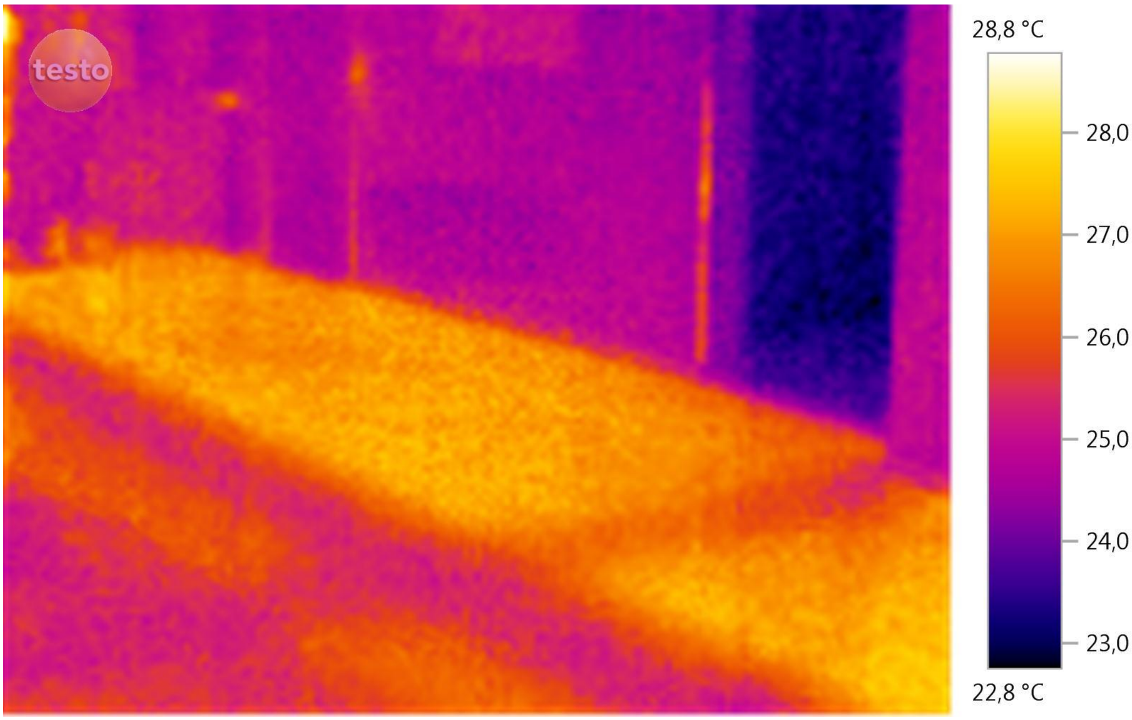
Eq. 3.12

The building is served by a district heating network which provides hot water without the necessity of installed boilers, heat pumps or other generation systems. The efficiency of district heating depends on how it is managed, in our case the heat is produced largely by cogeneration with gas turbine in a CHP power plant located in Debrecen and in a minor part, to avoid breakdown in case of interruption of the service, by a generator with gas thermal engine installed on the basement of the neighbour building and connected to the heating distribution system.
The heat terminals, with their operative supply and return temperature, are: radiators 75-55 °C, convections floor modules 45-35 °C, fan coils 75-55 °C and radiant floor panels 45-35 °C.

In the case of district heating the power factor $C_k$, which represents the inverse of energy production efficiency, is equal to 1,01; it is a very high value, which corresponds to an efficiency of 99,99%.
Thus, $q_f$ has already been discussed, while $q_{f,h}$ represents the specific heat losses caused by the control system that is necessary to turn on and off the terminals; in the current case the system uses a proportional-integral PI controller, a common loop feedback mechanism measuring the difference between the temperature inside the heated space and the set-point temperature.
The heat losses in the distribution system are considered with $q_{f,v}$ depending on the power plant: in our case the pipes of the hydraulic circuit are coming from outside of the heated space, because of the use of district heating. That's why no heat storage is operating, with no energy and electricity needed, and so the two terms $q_{f,t}$ and $E_{f,t}$ ,which represent the heat losses due to storage tanks and the electricity needed to manage them, are equal to zero.

To complete the formula above, $\alpha_k$ are the share of each source in the energy mix to produce the heat, in our case they are cogeneration with gas turbine and diesel motor with a share of 80% and 20% respectively, while $e_f$ are the energy transformation factor from thermal energy to primary one, provided by opportune table (see Appendix). The second addend represents the electricity used in all the devices and mechanical systems, first of all the circulation pumps with $E_{FSz}$ , that is given depending on the net floor area $A_N$, the Δt used in the terminals and the type of pumps, variable or constant speed (in our case they are inverter pumps). The auxiliary energy demand, eventually, represented by $q_{k,v}$ is neglected because of district heating does not require any auxiliary plant. The electricity conversion factor is $e_v$ equal to 2,5, which means an average efficiency $\eta_{el}$ of 40 %, .

Before analysing the other contributes to the primary energy consumption, it has to been emphasized the extremely high value for district heating efficiency, equal to 99,9%.
This value was decided by the regulation supervisors, and does not reflect the real situation of district heating in Hungary, since such value of efficiency is not realistically feasible. It is a decision to encourage the use of district heating in the building service systems, to avoid the proliferation of single heating system with gas boilers for residential flats and single houses that are less efficient than cogeneration power plants and produce $CO_2$ emissions by the combustion of fossil fuels. It also helps to reduce the use of natural gas, that has to be imported, and represents one of the most expensive energy asset. As a matter of fact, it is a political decision that affects energy strategies and economy development. For the same reason also the primary energy transformation factor for district heating are lower than any other energy sources, no matter how the power plant is handled ( gas or steam turbine, gas engine, ecc..). If we give a look to the table for DH primary energy transformation factor in Appendix *e* ranges between 0.86 and 0.26: this means that 1 kWh of heat generated in a DH plant is more valuable than 1 kWh of primary energy.
In other words here's a strong effort to promote the widespread application of district heating in the building service systems. This consideration about the efficiency and primary energy will be fundamental when we will analyse the possible energy saving measure.




It can be seen above the radian floor panel system and below the engine generator GP 380 A/V, producing both electricity and hot water using a diesel motor Volvo Penta.

## 3.4 Primary energy for DHW

$$E_{HMV} = q_{HMV}\left(1 + \frac{q_{HMV,v}}{100} + \frac{q_{HMV,t}}{100}\right) \cdot \sum (C_k \alpha_k e_{HMV}) + (E_C + E_K) e_v \qquad [kWh/m^2a]$$

Eq. 3.13

The production of domestic hot water is demanded, as repeated so far, to the district heating, which provides hot water in pressure at 125 °C in winter and 60 °C in summer, running in a plate heat exchanger to warm up the cold water coming from the aqueduct. This indirect heating is used to preserve the quality and to avoid contamination of the hot water that will be used in the building facilities (showers, washbowls, kitchen sink..). A recirculation circuit is installed to respond quickly to the users demand, and a 1200 liter storage tank is used to accumulate the hot water, so that the production time is reduced and the users demand is always satisfied without a continuous production that would require much more energy.

Back to the formula, once again $q_{HMV}$ is a factor given by standard, depending on the category of the building, representing the specific energy demand for hot water (kWh/m$^2$a); in fact, this consumption has to be increased by all the losses, first the ones in the distribution system,

$q_{HMV,v}$ which uses hydraulic pumps with recirculation circuit, with pipes placed outside of the heated volume, since they come from the district heating network.
On second hand, the losses in the storage system are considered, $q_{HMV,t}$ depending on the location of the storage, inside or outside of the heated volume, and the technology used to heat up the water; in our case the tank as said is outside the heated volume and is heated indirectly. As seen before, these specific need for energy are opportunely multiplied by the efficiency of their processes, which is the same of heating, shared by cogeneration in district heating plant and gas generator. The term $E_C$ takes in account the electricity absorbed by the electric engine of circulation pumps, depending on the net floor area, while $E_K$ considers the auxiliary power demand, that is neglected once again.
The $E_{HMV}$ is now assessed.

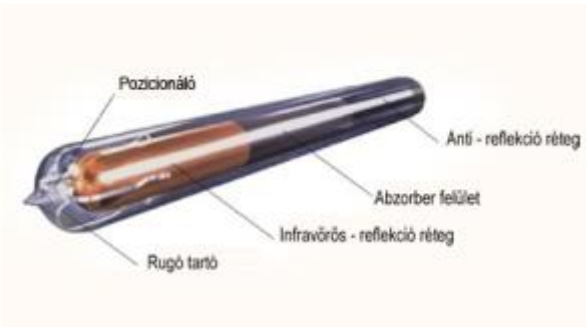
## 3.5 Primary energy for HVAC systems

The primary energy consumption for HVAC is the most complex term to be correctly assessed, because of the multiple sources of thermal losses and energy absorbed by ventilators and auxiliary devices. Let's remind that our building has an A/C system with three Air Handling Units placed on the roof that guarantee the air change during all the day and the air conditioning during the opening hours, for winter and summer season. The air ducts carry the inlet flows inside the spaces, through fan coils, diffusers and air vent, and then pick up the outlet flows which are headed through the expulsion channel to the outside and through the recirculation channel to the AHU. The expression for the primary energy consumption is the following:

$$E_{LT} = \{[Q_{LT,n}(1 + f_{LT,sz}) + Q_{LT,v}]C_k e_{LT} + (E_{VENT} + E_{LT,s})e_v\}\frac{1}{A_N} \qquad [kWh/m^2a]$$

Eq. 3.14

Considering the high flow rate and the high number of hours for heating season heat recovery systems were installed in the AHU: they are heat pipe exchanger with a seasonal efficiency of 42%.
A heat pipe is a heat-transfer device that combines the principles of both thermal conductivity and phase transition to efficiently manage the transfer of heat between two solid interfaces. At the hot interface within a heat pipe, which is typically at a very low pressure, a liquid in contact with a thermally conductive solid surface turns into a vapor by absorbing heat from that surface. The vapor then travels along the heat pipe to the cold interface, condenses back into a liquid, releasing the latent heat. The liquid then returns to the hot interface through either capillary action or gravity action where it evaporates once more and repeats the cycle. In addition, the internal pressure of the heat pipe can be set or adjusted to facilitate the phase change depending on the demands of the working conditions of the thermally managed system
It is a very efficient transferring mechanism because latent heat is exchanged ,with higher heat fluxes that can be up to 230 $MW/m^2$.
In HVAC systems, heat pipes are positioned within the supply and exhaust air streams of the AHU: the heat is recovered by a multi-row finned heat pipe tubes exchange battery located within both the supply and exhaust air streams. On the expulsion side of the heat pipe, the exhaust air warms the refrigerant that evaporates. The vapors move towards the cooler end of the tube, where it condenses and gives up its heat to the supply air. The condensed refrigerant returns by a combination of gravity and capillary action in the wick. In this way heat is transferred from the exhaust air stream through the tube wall to the supply air stream, that is pre-heated. This means a reduced capacity for the warm exchange battery, that will be smaller and less expensive, with both energy and money saving.
Heat pipes must be designed with particular attention to the choice of pipe material, size and coolant, that have an effect on the optimal temperatures in which heat pipes work.
When heated above a certain temperature, all of the working fluid in the heat pipe will vaporize and the condensation process will cease to occur; in such conditions, the heat pipe's thermal conductivity is effectively reduced to the heat conduction properties of its solid metal casing alone. As most heat pipes are constructed of copper (a metal with high heat conductivity), an overheated heat pipe will generally continue to conduct heat at around 1/80 of the original conductivity.
In addition, below a certain temperature, the working fluid will not undergo phase change, and the thermal conductivity will be reduced to that of the solid metal casing.
To avoid this situations with efficiency collapse the working fluid has to be chosen depending on the operational temperature range of the application. The lower temperature limit typically occurs a few degrees above the freezing point of the working fluid.



The yearly demand of heating to the ventilation system is now decreased, since the air is pre-heated before entering in the AHU, and it can be expressed with:

$$Q_{LT,n} = 0{,}35 V n_{LT}(1-\eta_r) Z_{LT}\left(\bar{t}_{bef} - 4\right) \qquad kWh$$

Eq. 3.15

To accomplish this calculation it is required the exact value of  the number of hours for ventilation during heating season $Z_{LT}$: they are calculated from $Z_F$ considering a runtime of 17 hours per day, value given by the technical operator manager of the building and already calculated (see Eq. 3.10)

Coming back to 3.14, $Q_{LT,n}$ is increased in percentage by $f_{LT,sz}$ , which represents the losses due to the joints in the air ducts, given by tables depending on the central or local control of air parameters and on the inlet air temperature, above or less 20 °C.
There are also losses distributed along the air ducts due to the different inner - outer temperature and depending on the geometrical size and way of installation of the ducts, inside or outside the heated spaces; they are taken in account with $Q_{LT,v}$, expressed with:

$$Q_{LT,v} = U_{kör} l_v \left(t_{l,köz} - t_{i,átl}\right) f_v Z_{LT} \qquad \textit{circular ducts}$$

Eq. 3.16

$$Q_{LT,v} = U_{nsz} 2(a+b) l_v \left(t_{l,köz} - t_{i,átl}\right) f_v Z_{LT} \qquad \textit{rectangular ducts}$$

Eq. 3.17

In the expressions, $U_{kör}$ and $U_{nsz}$ are fictive transmittance , respectively in W/mK and W/m$^2$K, tabulated depending on diameter of the duct, velocity of air and insulation layer thickness. The inlet temperature $t_{l,köz}$ is set up at 22 °C, while $t_{i,átl}$ is the average external temperature during heating season, equal to 4 °C and provided by the normative.
To take in account the eventual extra thermal losses caused by the passage through heated spaces there is the factor $f_v$ , in our case equal to 1 since the air ducts do not pass through the heated spaces but are integrated in the ceiling frame. Once again the energy efficiency $C_k$ is the same, since district heating supplies hot water for the exchange batteries, and $e_{LT}$ is a linear combination of the two sources in the energy mix.
It has to be taken in account the electric power absorbed by the ventilators, expressed by:

$$E_{VENT} = \frac{V_{LT} \Delta p_{LT}}{3600 \eta_{vent}} Z_{a,LT} \qquad kWh_e/a$$

Eq. 3.18

considering every AHU with their inlet and outlet ventilator, its static pressure and its efficiency.

The efficiency of ventilators is given by standard depending on the air flow rate elaborated, and $Z_{a,LT}$ is the yearly number of hours of operation of the ventilation system, that corresponds to $Z_{LT}$ since the ventilation is always matched with a conditioning of the air.

It has to be accounted also the energy $E_{LT,s}$ consumed by the auxiliary services: these systems operate in the transmission, distribution and generation plant, and their consumption is not to be neglected.

The two services taken in account are: hydraulic pumps and frost protection devices.

The pumps represents the major part of the auxiliary consumption: they are used to supply water to the hot and cold batteries in the AHU and to supply water to the fan coils. The frost protection auxiliaries are also very important in a ventilation system: when the inlet air flow enters in the AHU it comes in contact with the pre-heating battery, and the vapor contained in the air condenses, increasing the heat exchange with its latent heat. When the temperature of the air is below the dew point, however, the vapor condenses and immediately freezes on the finned tubes of the battery, clogging up the channels and decreasing the heat exchange. This process tends to increase its negative effects, because the valve on the supply line of the battery closes to low down the pressure and bring back to normal the heat exchange, but at the same time the pressure reduction becomes a temperature reduction, with a major freezing and the growing of ice blocks.

The air freezing affects also the regulation organs: as the frost is accumulated it increases the electric power absorbed by the electric engines that drive the shutter and gate valves when opening and closing, and can eventually cause their breakdown.

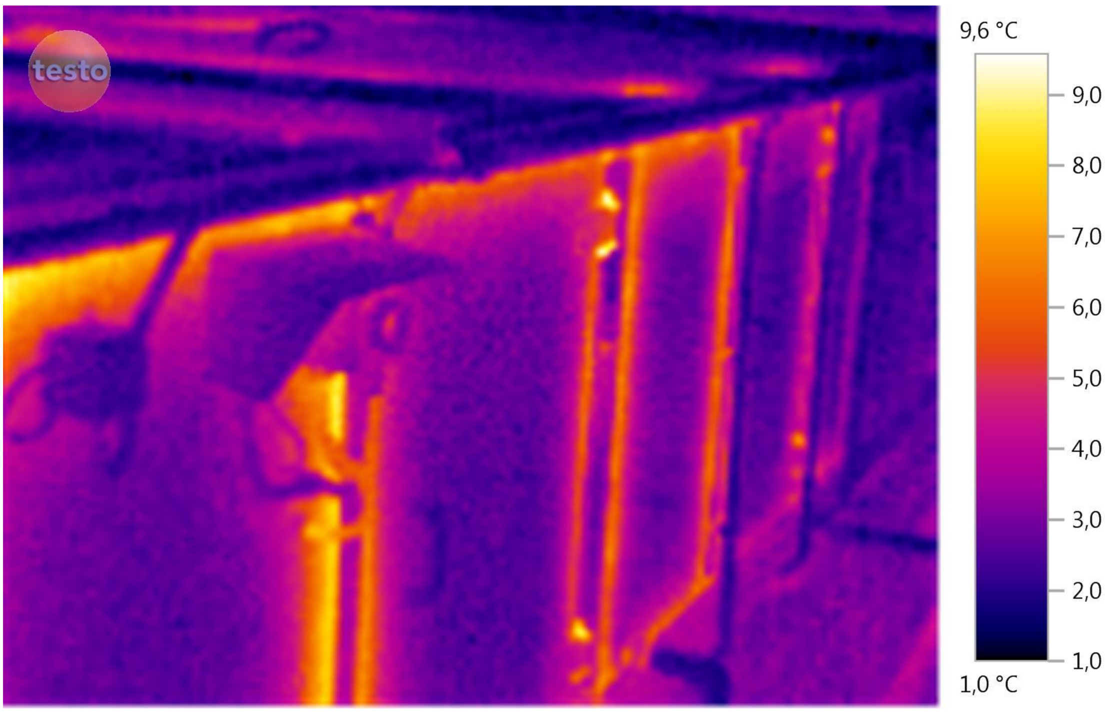
The highest risk is during the startup of the system, when the exhaust air is still cold and the recovery system is not able to pre-heat the inlet flow, which remains cold and can freeze on the warm surface of the exchange battery.
This is why electric resistance or hot water flow rates are used to defrost the exchange batteries in the cooling and ventilation systems; these maintenance operations are scheduled and take time, with a specific consumption given by the electricity absorbed by the electric motor of the pump used in the process.
In our building pumps are used to supply hot water to defrost the batteries. The total energy consumption for auxiliary systems can now be expressed by:

$$E_{LT,pumps} = P_{e,fü} \cdot Z_{LT} + P_{e,hü} \cdot n_{hü} + P_{e,vent} \cdot n_{df} \qquad kWh/a$$

Eq. 3.19

Where $P_{e,fü}$ and $P_{e,hü}$ are the electric power (W) absorbed by the pumps for the ventilation system, for heating and cooling, while $P_{e,vent}$ is the power of the pumps used to defrost the exchange batteries in the AHU.
These powers are multiplied for their operation time, which corresponds to the heating season provided by the degree days curve for the heating, to the cooling season, calculated as well with the degree days curve, for cooling and a number of hours $n_{df}$ provided by standard for frost protection.

We have now completed the calculus for the HVAC system energy consumption.



## 3.6 Primary Energy consumption for Cooling

The regulation establishes to calculate the risk of summer overheating, and therefore the necessity to install a cooling system, by assessing a balance temperature difference:

$$\Delta t_{bny\acute{a}r} = \frac{Q_{sdny\acute{a}r} + A_N q_b}{\sum AU + \sum l\psi + 0{,}35 n_{ny\acute{a}r} V} \qquad [K]$$

Eq. 3.20

In the formula the numerator represents the positive incoming thermal gains, while the denominator provides the losses through the envelope, thermal bridges and the ventilation system.
The $\sum AU$ is only referred to the external walls above the ground and the roof, since basement floors are not living spaces, while the internal gains $q_b$ take in account all the upper floors and the server room in the basement. The ventilation losses are considered only in the spaces where it is possible an effective air change, and so only the 0,1,2 and 3 floor volumes are taken into account.

The value for the air change volume $n_{nyár}$ is given by standard depending on how the air change is accomplished. Indeed, if many façades allow the air circulation the summer overheating will be prevented, with a lower value for the balance $\Delta t_{bnyár}$ and, consequently, a lower inside-outside air daily temperature difference. If the windows or doors are attending only one façade, as it happens in our case since only on the south façade we have openable windows and doors, the value is 3.
It is immediate to understand that if this ratio, expressed as temperature difference, is low, so it will be the overheating inside the building, with a situation where the solar and internal gains are balanced by the transmission and ventilation losses, the net heat flow will be very low and the internal temperature will remain at the comfort set-point of 26 °C. As this $\Delta t_{bnyár}$ rises, the internal and solar gains will affect the internal temperature, increasing its value with discomfort situations that require an intervention of the cooling system. The regulation decided to set an upper limit to the $\Delta t_{bnyár}$depending on the thermal mass of the building: for heavy buildings, if

$$\Delta t_{bnyár} < 3$$

there is no risk of summer overheating, otherwise a cooling system has to be designed.

In our building the value for $\Delta t_{bnyár}$is higher of 3, that is why a cooling system was designed.
The cooling demand of our building is satisfied by the Life Sciences Laboratory Building, that supplies the cold exchange batteries in the AHU for the A/C system. The chilled water is produced by a package air-condensing machine Power Ciat LX 3400 Z HPS located on the roof of the building, and carried by water pipes to the cold circuit of our library.
There are also two split conditioners installed, respectively, in a server room in the basement and in a same one on the third floor, to cool down servers there located. These machines have their own circuit, with air condenser units placed on the roof. Considering that our building is a library, and not a technological building or a research centre where server room are usually used, it has been decided not to take in account these devices in the cooling energy consumption. It cannot be assessed, indeed, that a public educational building like the one under analysis generally needs server rooms; thus, they are not necessary and no procedure allows us to calculate their percentage in the total cooling demand.
This is a simplification that doesn't affect larger the cooling consumption value, considering the low power of the two split machines; their energy consumption could be estimated by an energy audit with a measured rating, but let's recall we are dealing with an energy certification using a calculated approach and so we are authorized to ignore it.

The primary energy consumption for cooling is:

$$E_{hü} = \frac{Q_{hü} \cdot \sum \alpha_h \cdot C_h \cdot e_{hü}}{A_N} \qquad [kWh/m^2a]$$

Eq. 3.21

First it has to be calculated the heat that has to be removed from the cooling machines, that is:

$$Q_{hü} = \frac{24}{1000} \cdot n_{hü} \cdot \left(\sum A_N q_b + Q_{sdnyár}\right) \qquad [kWh/a]$$

Eq. 3.22

Let's proceed with order, since we only know the value of $A_N q_b$ so far. Firstly, it has to be determined the solar gain entering in the building through the glazed elements, that is:

$$Q_{sdnyár} = \sum A_{Ü} I_{nyár} g_{nyár} \qquad [W]$$

Eq. 3.23

Like the solar gain during winter season, there are appropriate values for the irradiance $I_{nyár}$ depending on the orientation of the facades:

| | North | South | East | West |
|---|---|---|---|---|
| $I_{nyár}$ | 85 | 150 | 150 | 150 |

The glazed facades are already known from the early step, while the transmittance $g_{nyár}$ now has to take in account the shading elements, which are present on the south façade that has wire netting covertures on 1/3 of the windows surface.
We can now proceed by calculating the effective duration of heating season $n_{hü}$, which depends on the daily average external temperature $t_{e,közepes}$.

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $t_{e,közepes}$ | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| $n_{hü}$ | 110 | 95 | 80 | 66 | 52 | 38 | 25 | 15 | 8 | 5 | 3 | 1 |

The external daily-average temperature $t_{e,közepes}$ is lower than the internal temperature, and depends on the balance temperature difference $\Delta t_{bnyár}$ already calculated:

$$t_{e,közepes} = 26 - \Delta t_{bnyár}$$

Eq. 3.24

The cooling is required when the internal temperature exceeds the set-point 26 °C which represents the comfort conditions; by assessing $t_{e,közepes}$ we can go in our climatic curve and properly assess the duration of cooling season. The values are resumed in the table above where we can find $n_{hü}$ , and then finally calculate $Q_{hü}$.

Back to the primary energy consumption, we still have to set a proper value for $C_h$, which represents the inverse of the seasonal energy efficiency of the cooling machines used:

$$C_h = \frac{1}{EER}$$

Eq. 3.25

All the cooling load is covered by an air-cooled condensation package unit located on the roof of the adjacent building: this machine produces chilled water that supplies the cold batteries in the AHU.

The EER value is reported, as always, in a table of the Regulation depending on the type of machine, in our case package air unit. This package machine uses screw compressor, that require electricity as energy source, and so the transformation factor $e_{hü}$ is again 2,5.

Now we know every single term and the primary energy consumption for cooling can be evaluated.

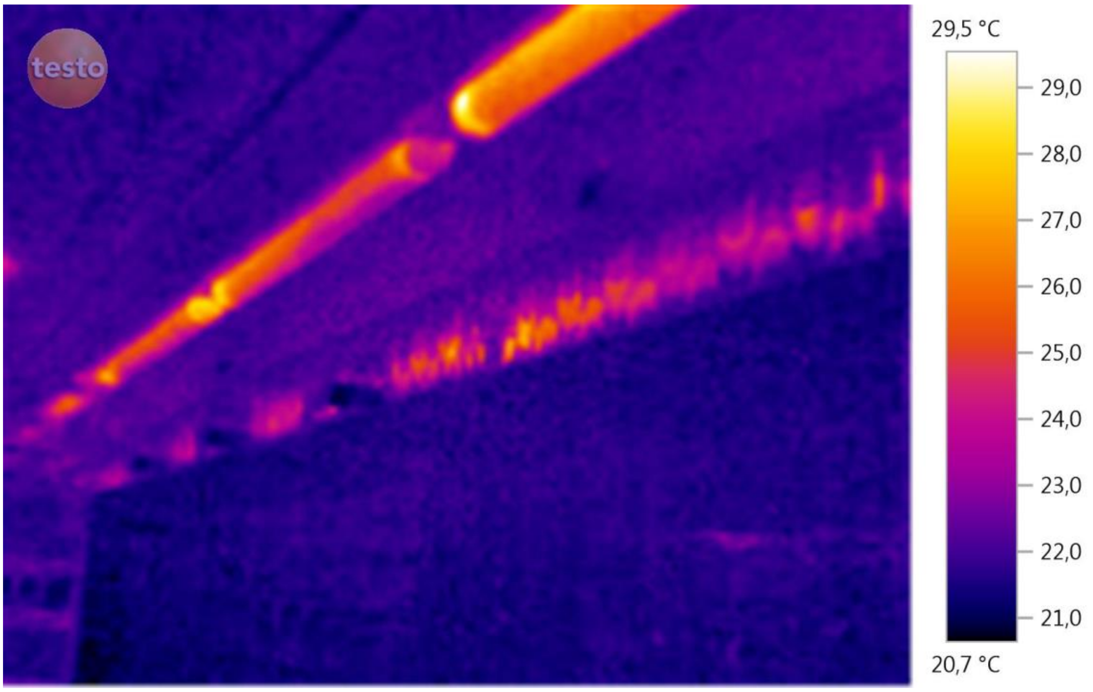
## 3.7 Primary Energy consumption for Lighting

The primary energy consumption for lighting is quite difficult to assess, requiring electrical competence that are usually out of the mechanical field. The normative helps us in this way, by providing a specific energy consumption for buildings $E_{vil,n}$ depending on their destination of use. As always the categories are three, residential, educational and office building.

$$E_{vil} = E_{vil,n}\, e_{vil} \upsilon \qquad [kWh/m^2a]$$

Eq. 3.26

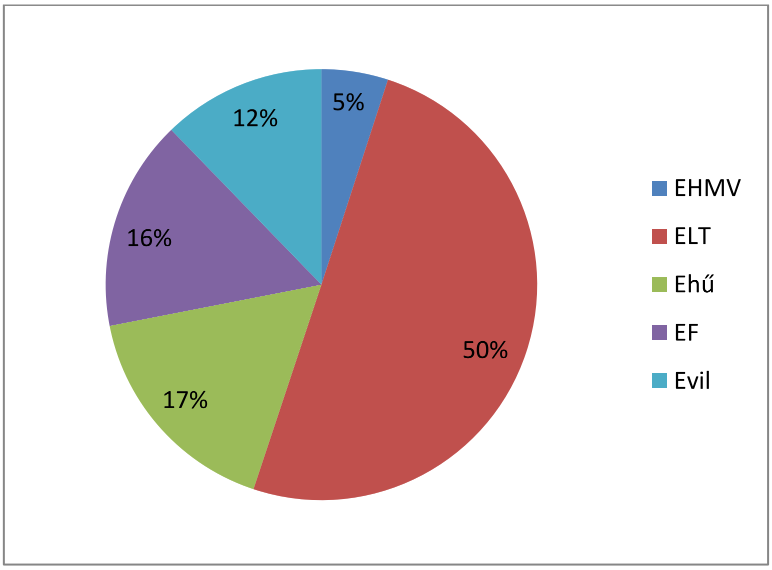
By knowing $E_{vil,n}$, considering that lighting is produced with electricity, its transformation factor $e_{vil}$ as usual equal to 2,5, we just have to use a correction factor $\upsilon$ that takes in account the usage of motion sensors and natural lighting, that reduce lighting needs.
The primary energy is now assessed, and it can be seen how it is the simplest term in the scenery.



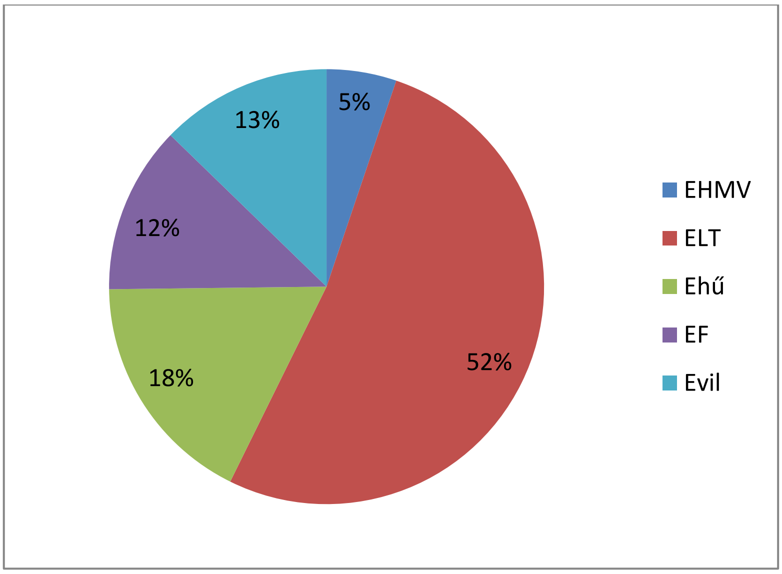

It is time to summarize the results obtained for primary energy consumption, divided as said at the beginning whether or not the direct solar gains are taken in account.

| | Solar gains not considered | Solar gains considered |
|---|---|---|
| $E_f$ | 24,86 | 18,81 |
| $E_{HMV}$ | 7,85 | 7,85 |
| $E_{LT}$ | 78,75 | 78,75 |
| $E_{hü}$ | 26,46 | 26,46 |
| $E_{vil}$ | 19,25 | 19,25 |
| $\sum E_i$ | 157,16 kWh/m$^2$a | 151,12 kWh/m$^2$a |

The diagrams below give a visual idea of the different share, and influences, of each factor in the primary energy consumption mix.




Without solar gains




With solar gains

It can be seen that the solar factor affects only the heating consumption, by changing the value of specific heat losses q, and therefore the energy demand $Q_F$, $q_f$ and finally $E_f$.
At this point the total *EP* would be compared to the requirement value $EP_{requir}$ provided by the regulation, depending on the shape factor and building category (see figure 2.3).

$$EP = \frac{EP_{calculated}}{EP_{requirement}} \cdot 100$$

Eq. 3.27

The 3.27 will give a numeric value that is used to assess the energy category for the building.

Unfortunately our building does not belong to any of the three existing categories, therefore no requirement value for the primary energy can be assessed. At this point the Regulations gives a guideline to acquire a requirement value for the primary energy consumption, so that it will be possible to establish an energy category for the building.

It is mentioned the presence of an anti-fire system for the two basement floors using HFC inert gas system. In case of fire the system is activated by a nitrogen tank sensor that blows out in the space the gas, stored as liquid phase, in the cylinders; the gas reacts with the oxygen damping down the combustion reaction and suffocating the fire by reaching very quick a high concentration in the volume and being a huge obstacle for the oxygen, and the flames, propagation.

## 3.8 Requirement building

The Life Sciences library that we propose to certificate, as repeated several times, does not fit into one of the three building category provided by the Hungarian normative for energy certification, because it is a mixed-use building with Galerià Cafè, offices, basement library, computer and reading rooms. At this point the Regulation suggests to create a fictive building that will be used as reference for the primary energy consumption: this new building has the same architectural characteristics of the existing one, same net floor area, heated volume and shape factor.
The power plant, though, will be different: we need a requirement to refer to, and so this fictive building will use heating, DHW and ventilation systems with fixed characteristics.
Once we will have its $EP_{requirement}$ it will be possible to compare it to the $EP$ calculated through the Regulation and the ratio between the two total primary energy consumption will give us the energy label.

The calculation follows the same path seen before, by applying three levels for the requirement building: our new building has, once again, to fulfil the limits imposed to, respectively, U-value of building elements, specific heat losses $q_m$ and specific primary energy $E_{tot}$.
From hereafter we will proceed quite fast since all the steps have already been discussed and explained previously.
The normative establishes some boundary conditions to “create” the fictive building, assigning specific values for some parameters of the calculations considering the most common and utilized service systems, based on surveys on building stock in Hungary and its technologic level.

Since the first level has to be satisfied, our fictive building will have opaque and glazed structures with U-value exactly equal to the uppermost admissible value given by the normative: in this way the first level is fulfilled and we can quickly go on.

On second step, since the architectural plan is the same, this new building will have the same net floor areas, same envelope surfaces and heated volume. It is then possible to calculate all the transmission losses through opaque and glazed elements, and then apply the correction factor to the U-value due to the thermal bridges. It’s so possible the calculus of the specific heat losses q, with and without taking in account the solar gains. It can be seen that the fictive building meets the requirement $q_m$, that is the same for the real building since the shape factor doesn’t change.

After this first part quite fast, it is time to analyse the primary energy, which will require more time and attention.

## 3.9 Primary energy for the fictive building

The normative as seen before establishes to valuate separately each contribute for the primary energy, heating, DHW, ventilation, cooling and lighting.

The heating analysis requires to determine in advance the specific heat energy demand $q_f$, so as seen before we have to calculate the $Q_F$ in three steps.

$$Q_F = 72V(q + 0{,}35n)\sigma - 4{,}4A_N q_b \qquad [kWh/a]$$

$Eq.$ 3.28

In the formula $q$, $V$, $n$ and $A_N$ are the same, the term different is now the specific internal gain $q_b$.
Instead of taking a standard value provided by tables, it is decided to evaluate more deeply the contributes of the production of sensible heat inside the building.
The sources of sensible heat existing are two, people and computer, but since we are creating a general standard close to the real building situation, the internal gain produced by computer are not taken in account. The computer, indeed, can be changed by number and characteristics during the lifetime of the building, with unpredictable effects on the internal gains.
It was estimated a number of occupants for each living zones, cafeteria, with customers and employees, offices and library, with opportune frequencies related to the different destination of use of the spaces. The normative gives values for the amount of sensible heat produced by people, depending on the activity attended, and so it is possible to calculate the total sensible internal gain.

$$Q_{int} = \sum_{spaces} N_{people} \cdot \Phi_{sensible} \qquad [W]$$

Eq. 3.29

$$q_{b,real} = \frac{Q_{int}}{A_N} \qquad [W/m^2]$$

Eq. 3.30

We have now a more accurate value for the internal gains $q_{b,real}$.
It follows with immediate calculation (see 3.1) $Q_F$.

In the second step calculation, as seen before, we calculate a balance temperature difference $\Delta t_b$ exactly similar in the procedure to the one carried out for the existing building, only with different value. Thanks to this $\Delta t_b$, $H$ and $Z_F$ are calculated, and so the second and third calculation are ready to be accomplished, providing the two values for the heat energy demand.

$$Q_F = HV\left[q + 0{,}35 n_{inf}\frac{Z_F - Z_{LT}}{Z_F}\right]\sigma + 0{,}35 n_{LT} V\left(t_i - \overline{t_{bef}}\right) Z_{LT} - Z_F A_N q_b \qquad \left[\frac{kWh}{a}\right]$$

$$Eq.\ 3.31$$

These two new values, with and without solar gains accounted, procure two new specific heat energies for winter season, which are:

$$q_f = \frac{Q_F}{A_N} = 30{,}39 \qquad [kWh/m^2a]$$

$$q_{f,solar} = 19{,}70 \qquad [kWh/m^2a]$$

The specific primary energy for heating is:

$$E_f = \left(q_f + q_{f,h} + q_{f,v} + q_{f,t}\right) \cdot \sum\left(C_k \cdot \alpha_k \cdot e_f\right) + \left(E_{FSz} + E_{FT} + q_{k,v}\right) e_v \qquad \left[\frac{kWh}{m^2a}\right]$$

$$Eq.\ 3.32$$

It is now considered that all the heat is produced uniquely by a low-temperature boiler, supplied by natural gas and without using heat storage. This is a requirement decided by the Hungarian regulation based on an average survey of the existing heating systems.
It becomes, in this way, a standard that takes in account the real energy situation of the country, and considers the most widespread heating system in the building stock.
This requirement will set new values for the electricity consumption of the boiler $q_{k,v}$, its efficiency $C_k$ and energy transformation factor $e_f$, now equal to 1, all given by tables in the normative.
From hereafter we will not justify every time why such conditions about the system equipment, efficiencies etc.. are taken as standard: they are always decision issued by the Regulation considering an average situation, sustained by energy analysis on the national building stock, for service systems in Hungary. The control of the heating circuit is demanded to thermostatic valve installed on the terminals, typically radiators, with a set-point Δt of intervention of 2 K; this will change $q_{f,h}$while $q_{f,v}$ is the same since the radiators are considered working with the same temperature difference 70-55 °C and the boiler is located outside of the heated space, in the cellar. All the circulation pumps of the hydraulic circuits are variable speed models, with a inverter electric engine, and so they absorb the same amount of energy $E_{FSz}$ .

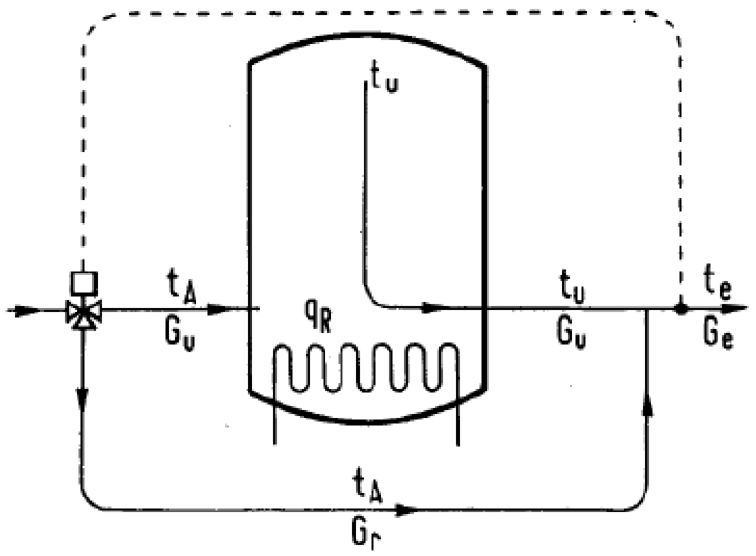
The primary energy for heating can now be assessed, referring to the new conditions of the fictive building.

The primary energy required to produce domestic hot water is:

$$E_{HMV} = q_{HMV}(1+\frac{q_{HMV,v}}{100}+\frac{q_{HMV,t}}{100}) \cdot \sum(C_k \alpha_k e_{HMV}) + (E_C + E_K)e_v \qquad [kWh/m^2a]$$

$$Eq. 3.33$$

In this case the specific consumption $q_{HMV}$ will be considered with a more accurate procedure, by taking in account all the users of the building that require hot water. The assessment of the daily need of liter of hot water for a mixed-use building is extremely difficult and quite uncertain, considering that all the normative provide daily values for fixed categories of buildings, as houses, offices, shops, hotels, exc. It was decided, as suggested by the standard regulation, to design an accumulation system with indirect heating through a serpentine exchanger that warms the cold water coming from the pipeline in a storage tank. The hot water, produced at 60 °C, is mixed with a cold flow rate at the design temperature of 10 °C and provided to the users at the standard temperature of 40 °C.




Referring to UNI 9182 it is possible to assess a daily need of hot water per person, based on the type of users: in our case the users are a bar, offices with private toilets and public toilets for students and visitors of the library. These hot water consumptions are referred to the standard temperature of 40 °C, which means that the storage tank will have to contain an amount of liters at 60 °C which will be less than the requirement, and it is given by a heat volume balance system:

$$\begin{cases} V_{40°} \cdot 40 = V_{10°} \cdot 10 + V_{60°} \cdot 60 \\ V_{40°} = V_{60°} + V_{10°} \end{cases}$$

Considering that is known the consumption $V_{40°}$ the system can be easily solved, and the daily consumption of liter $V_{60°}$ is known. Now it is possible to calculate the energy required to produce this amount of liter, given by the expression:

$$Q_{DHW} = \rho \cdot c_w \cdot V_{40°} \cdot (t_b - t_f) \cdot N_G \qquad [kWh/a]$$

$$Eq. 3.34$$

The supply temperature $t_b$ is 60 °C, and the number of days $N_G$ is established considering the opening timetable of the library, about 300 days per year. This energy demand will be provided by the same low-temperature boiler fuelled with natural gas. The ratio between $Q_{DHW}$and the net floor area will give us $q_{HMV}$. All the heat losses, back in the primary energy formula, are the same considering that the storage tank is placed outside the heated volume and the circulation pumps are the same, with also the same electric consumption $E_C$. The energy is provided only by a natural gas boiler, and so the transformation factor is different.
Now we can establish the DHW primary energy for the fictive building.

Going on with the calculation, it is time to check how the HVAC systems are designed and how much they consume. Let us remind that:

$$E_{LT} = \{[Q_{LT,n}(1 + f_{LT,sz}) + Q_{LT,v}]C_k e_{LT} + (E_{VENT} + E_{LT,s})e_v\}\frac{1}{A_N} \qquad [kWh/m^2a]$$

Eq. 3.35

The regulations establishes to analyse the existing ventilation system with its facilities.
All the three existing Air Handling Units are supplied with hot water produced with the low temperature boiler, and so $C_k$ and $e_{LT}$ will be different, and equals to the heating and DHW situation.

$$Q_{LT,n} = 0{,}35 V n_{LT}(1 - \eta_r) Z_{LT}(\bar{t}_{bef} - 4) \qquad kWh$$

Eq. 3.36

The heat energy requirement $Q_{LT,n}$ considers the same heat recovery system, with heat pipes exchangers, and the same value for $\bar{t}_{bef}$ given by a volume-weighted average.
The percentage $f_{LT,sz}$ of heat losses due to air infiltration in the duct joint is the same, while a different standard is set up for the transmission losses in the air ducts.
It is established to use air ducts with a 20 cm thickness insulation, so for circular channels the U-value $U_{kör}$ will be calculated from tables by interpolation depending on the real air speed, 3 m/s and the diameter of the duct. The transmittance $U_{nsz}$ for rectangular ducts will be the same for all the ducts, depending only on the air speed. The geometrical data for the air ducts, the inlet design temperature and the factor $f_v$ are the same, and so all the losses $Q_{LT,v}$ for the three air handling units can be calculated.

The supply and expulsion ventilators are considered with the same air flow rates, same static pressure difference and real efficiency given by the manufacturer catalogue. The auxiliary systems are considered in the same way. The calculation steps are omitted to avoid repetition.
Now the ventilation consumption $E_{LT}$ can be calculated.

The primary energy for cooling requires to calculate, as seen before in Eq. 3.20, 3.21, 3.22

$$E_{hü} = \frac{Q_{hü} \cdot \sum \alpha_h \cdot C_h \cdot e_{hü}}{A_N} \qquad [kWh/m^2a]$$

and

$$Q_{hü} = \frac{24}{1000} \cdot n_{hü} \cdot \left(\sum A_N q_b + Q_{sdnyár}\right) \qquad [kWh/m^2a]$$

The cooling systems are now considered in their real situation, with their seasonal energy efficiency ratio given by producer catalogue. The internal gains are the same calculated before with a more accurate way, while the solar gains $Q_{sdnyár}$ are the same considering the same glazed areas and same value for solar transmittance and summer irradiation.
The summer balance temperature difference

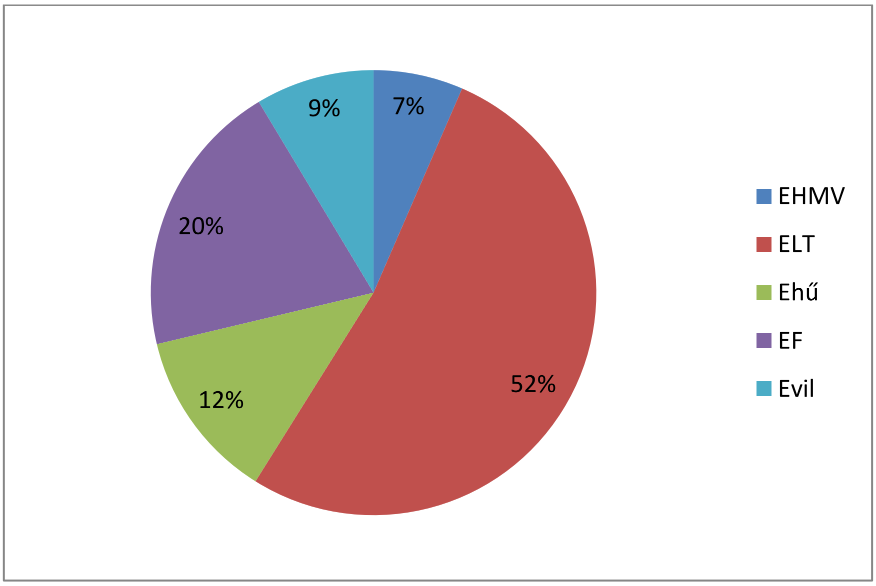
$$\Delta t_{bnyár} = \frac{Q_{sdnyár} + A_N q_b}{\sum AU + \sum l\psi + 0{,}35 n_{nyár} V} \qquad [K]$$

will now be different because of the different values for envelope transmission losses $AU$ and different internal gains amount $A_N q_b$, . therefore the length of summer cooling season $n_{hü}$ will not be the same. Its value is yet higher than 3, requiring the utilization of a cooling system With a new value for $Q_{hü}$ and by using the real EER for the package machine on Life Sciences building we can properly assess $E_{hü}$.

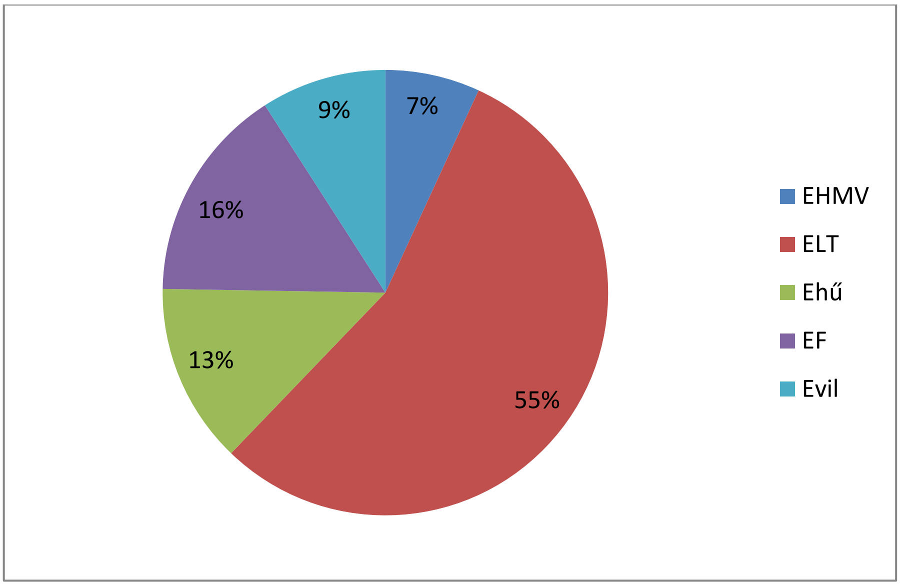
The last contribute in the primary energy mix is the lighting consumption: it was not possible acquire real data about the electrical devices consumption, which are standard neon lamps to light the library spaces and reading lamps for library desk and offices. For this reason it has been used the same procedure given by normative, using a standard value for office building. (see Eq. 3.25)

Now we can put together all the shares and have our total primary energy consumption, represented as before in the above diagrams for the two situations, with and without direct solar gains account.

It can be observed that this new requirement building has a global higher consumption for primary energy; the percentage of heating is now higher, while cooling is lower and the other services are almost the same influence. The net primary energy for ventilation is much higher, and this means that our building has a better efficiency of the ventilation system than the average standard provided by the Regulation.




Without solar gains




With solar gains

| | **Solar gains not considered** | **Solar gains considered** |
|---|---|---|
| $E_f$ | 41,20 | 29,60 |
| $E_{HMV}$ | 29,83 | 29,83 |
| $E_{LT}$ | 113,61 | 113,61 |
| $E_{hü}$ | 25,37 | 116,12 |
| $E_{vil}$ | 19,25 | 19,25 |
| $\sum E_i$ | 229,28 | 217,67 |

## 3.10 Energy Category

At this point we have accomplished two calculations that allow us to create an Energy Performance Certification following the Hungarian Regulation. The energy category of the building is the most visible and immediate result of the EPC, and it can be assigned by comparing the primary energy consumption of the existing and the fictive building.

The energy categories in Hungary are the following:

| Label | EP | Level of Energy Efficiency |
|---|---|---|
| A+ | < 55 | Highly energy-efficient |
| A | 56 - 75 | Efficient |
| B | 76 - 95 | Better than requirement |
| C | 96 - 100 | Adequate to requirement |
| D | 101 - 120 | Close to the requirement |
| E | 121 - 150 | Better than average |
| F | 151 - 190 | Average |
| G | 191 - 250 | Close to average |
| H | 251 - 340 | Weak |
| I | 341 < | Poor |

The ratio:

$$EP = \frac{EP_{ex.build.}}{EP_{requ.build.}} \cdot 100$$

represents the EP which will be used to issue the energy category.

In our case the ratio are two, whether or not taking in account the solar influence.

| | Solar gains considered | Without solar gains |
|---|---|---|
| **$EP/EP_{requirement}$** | 70,318 | 71,39 |
| **Category** | **A** | **A** |

It can be seen that in both cases our building has a A category, which means an efficient energy label. In this case the situation is very good, and finding effective energy saving measures seemed quite difficult; anyway an energy analysis was conducted on the building system to find some possible weak points. The result are reported in the next paragraph.

## 3.11 Recommendations

The energy saving measures that can be suggested are several, but they have to face the existing situation of the current building, and be feasible in terms of realization and installation.
For old housing, as it happens in most European Eastern Countries where buildings were constructed before 1990, it is always suggested to replace the windows with modern double glazed coated elements, to add an insulation layer in the facades and in the roof and to apply new sealings to reduce ventilation losses. We will not discuss further these refurbishment options as our library has already a modern envelope that doesn't need these improvements.
We have to analyse more in-depth the building structure to find possible energy saving measures.

As designer it was considered the possibility of heat pumps: these machines are very incentivised in the housing market, receiving a lot of attention for their low carbon footprint, energy environment free and high efficiency. However, we must keep in mind that a heat pump does not produce energy, but it's only a vector that transfers energy from a cold heat source to a warm one in winter, vice versa in summer. This process is an inverse thermodynamic cycle that requires a compressor to overtake the pressure difference between the two levels; for a typical air/air or air/water heat pump the compressor is working with an electrical engine, which means that the heat pump consumes electricity, a very valuable form of energy. The convenience in the usage of a heat pump lies in the better efficiency compared to a traditional boiler, but since our building uses district heating the balance equation is expressed by:

$$COP \cdot \eta_{el} = \eta_{DH}$$

Eq. 3.37

where $\eta_{el}$ is the efficiency of the national electric grid, which can be assessed around 36-40 % considering a standard thermoelectric production, while $\eta_{DH}$is the efficiency of the district heating, that we have previously seen be equal to 99% as a standard assumed value in Hungary.
This means that the minimum COP to reach the breakeven point is around 2.75.
The latest generation of air/air heat pumps has COP in nominal conditions (air external temperature of 7 °C) around 4, and it doesn't decrease tremendously during winter season in percentage, staying always superior to 3. The design of a possible system should be oriented towards an air/water heat pump, considering the existing distribution system: all the offices, that represent almost half of the building spaces, have radiators and fain coils, terminals supplied by the hydraulic circuit. The ground floor is almost completely heated by radiant floor panels, that use water as well as heat transfer fluid. . This solution, as seen so far, would be justified by an energy efficiency point of view, representing a more virtuous way to produce heat during winter season without using district heating, that consumes fossil fuels in his power chain. But let's look more carefully the consequences of this choice by focusing on the expression of primary energy for heating (Eq.3.1), since this is the only parameter affected by this design change.
When using a heat pump to satisfy the heating demand the only term that changes is the efficiency of the energy source used. If we consider to keep the existing cogeneration gas motor to ensure hot water in case of emergency and combine it with an air/water heat pump that supplies 80 % of the heating demand, the efficiency mix will be:

$$\sum (C_k \cdot \alpha_k \cdot e_f) = C_{k,HP} \cdot 0{,}8 \cdot e_{el} + C_{k,DH} \cdot 0{,}2 \cdot e_{gazmotor} = 0{,}885$$

Eq. 3.38

It can be seen that this value is higher than the existing one for the district heating, which is:

$$\sum (C_k \cdot \alpha_k \cdot e_f) = C_{k,DH}(0{,}8 * e_{gas} + 0{,}2 \cdot e_{gazmotor}) = 0{,}719$$

Eq. 3.39

This quick comparison shows up a lack in our previous enthusiastic response towards a heat pump use; indeed, these kind of machines use electricity, which has a high primary energy transformation factor that cancels the positive effect of its higher efficiency.
This means that the primary energy consumption for heating with a heat pump is higher, and no benefits are provided with this energy measure. Of course it could be argued that the real efficiency of district heating is not so high, and this comparison would be reversed in favour of heat pump, but these argumentations are useless considering that these values are provided by the existing regulation of the Hungarian Government, which is the only organ allowed to acknowledge an energy certification.
The implementation of heat pumps would be sustainable by changing their energy source, first of all by using ground heat with geothermal heat pumps. This further option was taken in consideration, but it is not feasible because of the particular location of the library, that is placed inside a reserved

area called “Nagyerdő”. In this area no boring operations are allowed, to protect the environment and preserve the integrity of the surrounding forest; thus, no ground probe can be installed, and no power plant for a GHP can be realized.
The utilisation of PV panels could be interesting, but since the electricity consumption is really low its saving contribute would not be relevant.
If we look carefully to the primary energy consumption of the existing building, the highest shares belong to cooling, ventilation and DHW production.
Here we can focus and find out some solutions to improve the EE, which are:

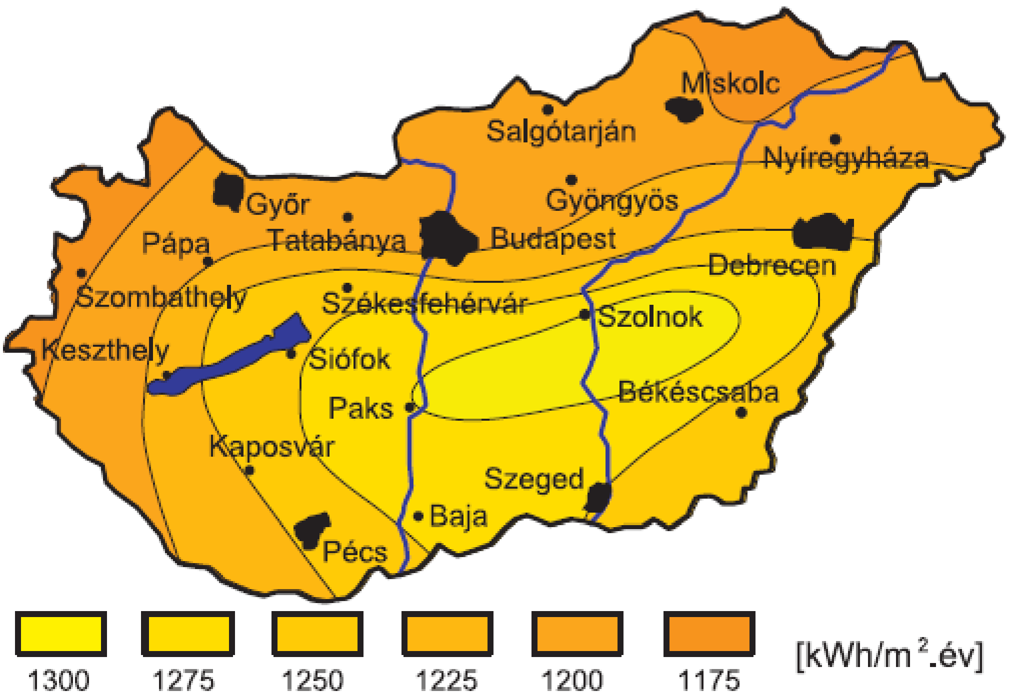
- Installation of solar thermal panel to produce DHW
- Installation of heat recoveries for the AHU with higher efficiency
- Installation of cooling machine with higher EER to substitute the existing one

These solutions are the most feasible and they can be effectively realized without major renovations that would cause several problems to all the power plants, first of all the hydraulic circuits, plumbing system, air ducts and all the control devices. Each one of the three solutions is analysed with a preliminary design and, on second hand, a short cost effective analysis that can justify or not its sustainability for a possible investment. It is important to underline that each solution proposal will affect our building energy performance in the first calculation, by lowering its EP; thus, the ratio $EP/EP_{requir.}$ will be lower, with a lower energy consumption that can lead, eventually, to a change of category.

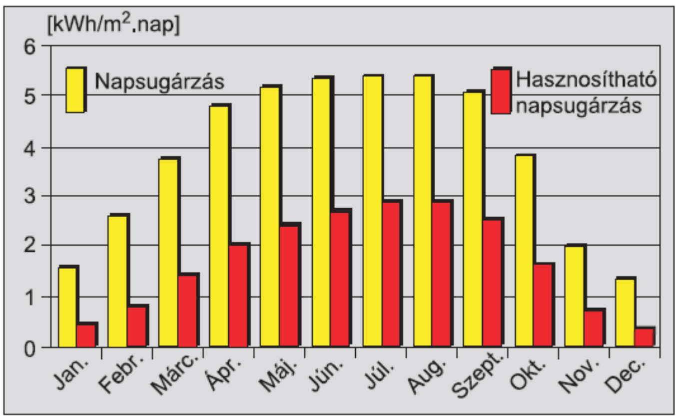
## 3.11.1 Solar thermal system

The installation of solar collectors to produce hot water for domestic use is a practice widely applied in the residential sector for single houses, considering the high consumptions and the possibility to install panels on the roof. In the tertiary sector it is not common, because of the complicated architecture, i.e. shops located in city centre, and the low value for hot water consumption. Our building has not a high hot water daily consumption, but on the roof there is a free area directly exposed to south that is perfect for solar collector system.
That’s why it is proposed a solar power plant with flat plate collectors, the simplest, cheapest and most common technology, supplying a storage tank by a hydraulic circuits with circulation pump, water pipes, regulation valves and sensors to integrate the solar with the district heating, so that when the collectors are not able to warm up the water the district heating will provide the production of DHW.
It will not be given a theoretical introduction to the solar energy and its implementation in the building sector, and neither a technical presentation of the state of solar collectors and all the design details that has to be considered in the preliminary stage and during the realization of the project.

The aim of the certification is only to give a general overview about the energy measure, with a cost effective analysis attached: the owner of the building, whenever deciding to apply the investment, will have to charge an engineer or technical expert that will plan all the system in its details.




As seen above, Hungary has a good yearly solar irradiance: this incoming energy can be quantified as daily energy on the histogram above, where it can be seen how only a percentage of this energy can be used for hot water production, because of the thermal losses in the collector, for transmission, irradiation and convection, and in the hydraulic circuit.




51. ábra
Hasznosítható napsugárzás melegvízkészítés esetén

The average value used by designer to determine the amount of area required to the solar collector are, respectively for summer and winter:

$$Q_{k,nyár} \cong 2.8\ kWh/m^2day \qquad \text{summer season}$$

$$Q_{k,tel} \cong 1.1\ kWh/m^2day \qquad \text{winter season}$$

The renewable energies, especially the solar, have intrinsic characteristics that create problems in the design of energy systems: e.g. , the solar energy, , has its highest availability during summer, when it is more difficult its usage since no heating is required. On the other hand, during winter season, it is more weak, while the demand for heat reaches its highest value.
This is not something that can be changed or avoided: the surplus hot water produced during summer can be used in absorption cooling machines, but it is a complicated solution that does not find concrete applications in tertiary sector, especially in our case since there is no space available to install absorption machine, that are very bulky and heavy.
We are now considering only the DHW production, that does not change in relevant way during the year. Since it has to be guaranteed during all year the supply of hot water, solar systems should always be designed to avoid energy waste during summer. The required collector area will so be calculated with the summer useful heat energy value; during winter, because of the lower energy available, the DHW demand will be integrated with the existing district heating power plant.

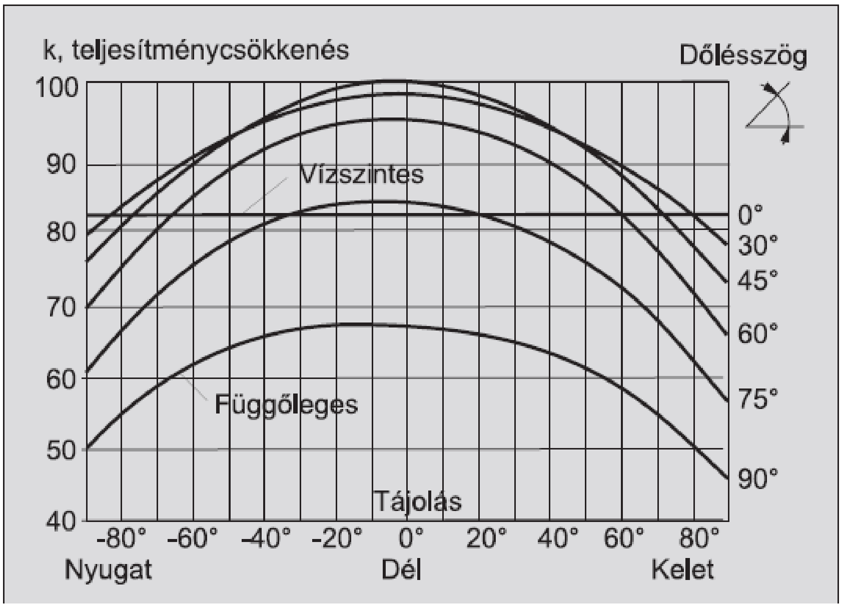
We are designing totally free and with no restrictions, so we decide to use the free roof area exposed to south, and we increase the efficiency of the collector by placing the panels with an orientation angle that maximize the solar direct radiation during all the year, which was proved be equal to 45 °C.
In this way we can calculate the required area for the collectors, given by:

$$A_{collector} = \frac{Q_{HMV}}{k \cdot Q_{k,nyár}} \qquad [m^2]$$

Eq. 3.40

The parameter $k$ , depending on the orientation of the panels, is equal to 1. The yearly demand of energy for domestic hot water has been calculated previously (Eq. 3.34), and so the net area for collector can be assessed.
The storage tank is the second very important element in the solar circuit: its size should be determined to guarantee the daily consumption of hot water. The hot water tank will use a heat exchanger supplied by solar hot water to warm up the cold water from the aqueduct: this water flow at 60 °C will be mixed with cold water at 10 °C and distributed to the users.
It is mentioned that a complete design project should consider the expansion vessel dimensioning, the hydraulic supply circuit of panels, the joint between two next panels and the structural frame to protect and sustain panels, bearing their weight and the stresses caused by wind and rain.

It is decided, based on experience and common practice, that the solar system will provide 70 % of the yearly energy demand for hot water, the remaining 30 % is provided by district heating.
This first solution will save primary energy from district heating, with a lower value of $E_{HMV}$.




52. ábra
Teljesítménycsökkenés a dőlés és tájolás függvényében

The primary energy saving expressed with the new EP achievable is:

$$EP_{saved} = EP - EP_{DHW\ solar} = 6{,}036\ kWh/m^2a$$

Eq. 3.41

where EP is the primary energy consumption of our current building calculated with the Regulation procedure and $EP_{DHW\ solar}$ the consumption with the solar panels system. This value will be multiplied for the net floor area to have the energy saving; then, we have to properly refer this primary energy to the source of energy used in our building, which is district heating.
We will step back and use the same energy transformation factor:

$$kWh_{D.H.} = EP_{saved} \cdot A_N \cdot \frac{1}{(0{,}8 \cdot e_{D.H.} + 0{,}2 \cdot e_{gaz})}$$

Eq. 3.42

We have now to translate this energy saving in economic benefit: the cost for district heating in Hungary is 13,68 Ft/kWh. Therefore, the money saving is:

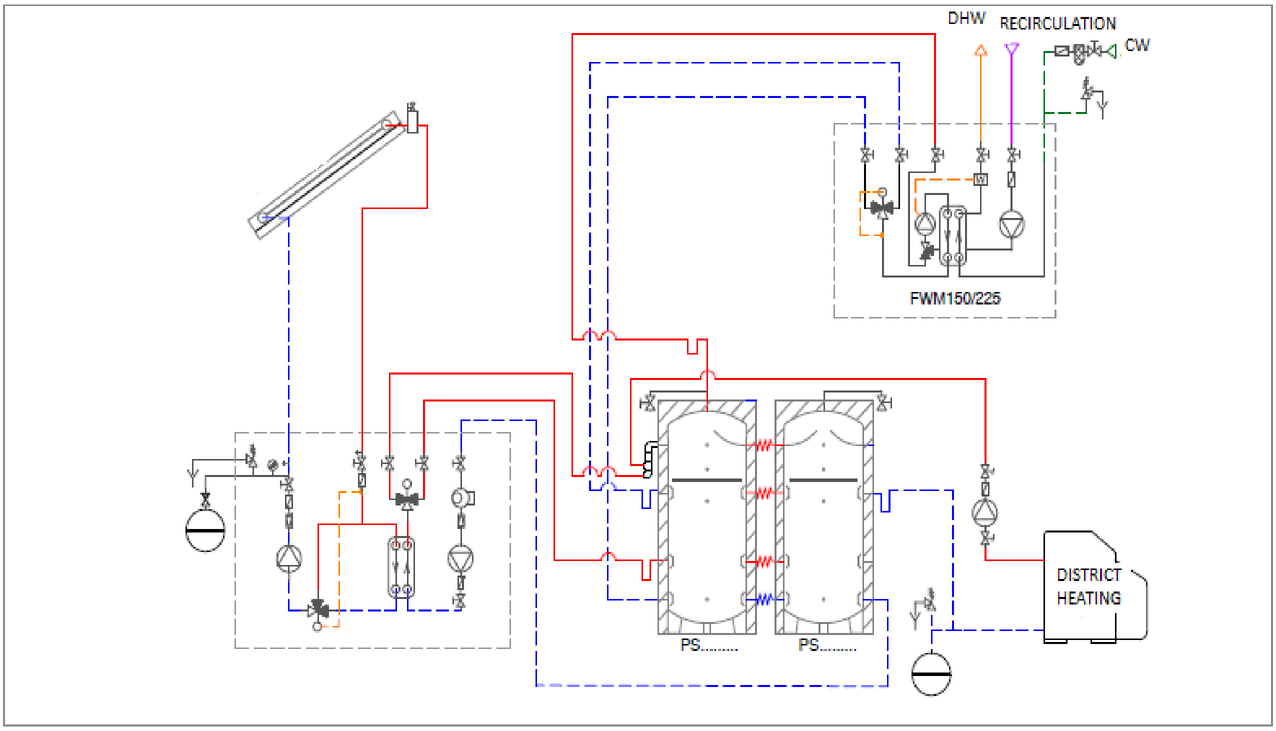
$$\$ = 13{,}68 \cdot\ kWh_{D.H.} \qquad Ft/year$$

Eq. 3.43

The cost-effectiveness analysis now requires to compare the money saving with the cost of investment, with an evaluation of the payback time. It is difficult to find a solar system with flat plate collectors for DHW for a non-residential building already assembled and provided by a manufacturer. The design should be ad-hoc for the specific case, and would require a more detailed analysis that is not necessary for the certification.

Considering in a simpler view the cost per m$^2$ of solar collectors, equal to 400 kFt/m$^2$, a storage puffer designed on the daily consumption of DHW, cost of auxiliary systems (pump, valves, expansion vessel, structuring frame), cost of installations and start-up of the system, the total amount of the investment can be estimated around 15 million Ft.

With a simple economic analysis, considering a financial subsidy that covers 50 % of the initial cost and the amount of savings fixed during the years, the payback time can be estimated equal to 18 years. It follows that this solution is not really convenient in cost effectiveness terms, especially considering that the target consumer is a private investor that usually needs a quick return of its investment in the short period.




Here above is reported an example of the hydraulic scheme of a solar thermal system; it can be seen how plate exchanger have been used, thanks to their high efficiency and compactness.

The hot water is stored in two tanks connected in series; this disposition is used when the users demand is not concentrated with peak times, as for residential units, but spread out during the day, as for offices. In this way the water can be stored and kept warm during all the day, and the tanks

guarantee the daily demand of DHW if during the next day the solar is not able to satisfy the demand (rainy or cloudy weather).
The system is integrated with a serpentine supplied by district heating (or a condensation boiler) put on the top of the tank to respect the thermal stratification that heats up the water whenever the solar panels are not able to.
The energy savings lies in the reduced time of intervention of the district heating (or traditional boiler) to produce the domestic hot water, which means a saving of natural gas, that is used as fuel for the gas turbine in the CHP power plant.

### 3.11.2. Recovery system for ventilation

The second proposal poses its attention on the ventilation consumption: if we analyse the terms in the primary energy expression it is immediate to observe that $Q_{LT,n}$ has the major influence.
This consumption is quite high because of the real poor efficiency of the heat recovery system: we can intervene here, by replacing the existing heat pipes with a device having better efficiency.
It is proposed to utilize cross-flow heat exchanger as heat recovery, with the same kind of heat transfer from exhaust to supply air stream in the air handling unit. Unlike other types of exchanger, i.e. rotary heat exchanger, this exchanger does not transfer humidity and there is no risk of short-circuiting the airstreams.

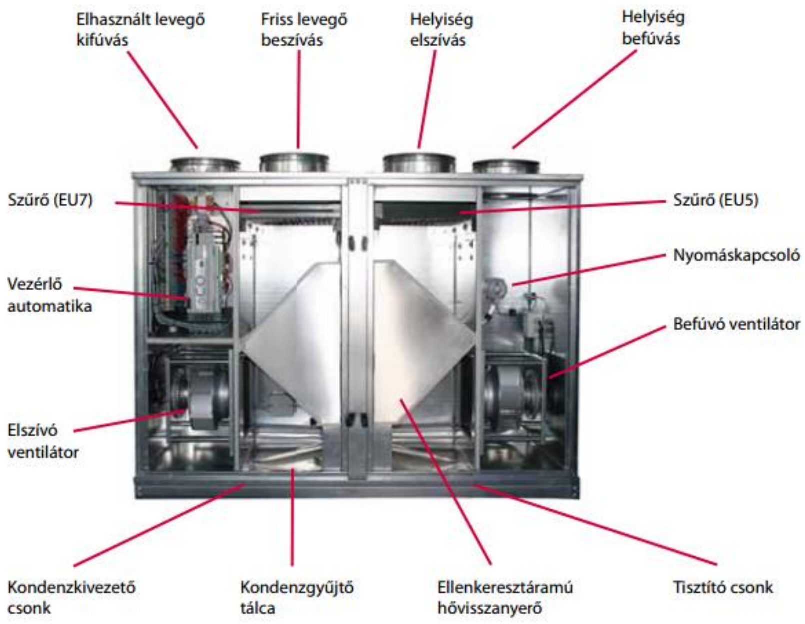
These heat exchangers are made of thin metal panels, normally aluminum; the heat is transferred via the panels. A traditional cross-flow heat exchanger has a square cross-section, with thermal efficiency of 40–65%; a counter-flow or dual cross-flow heat exchanger can be used if greater thermal efficiencies are required, as it happens in the building sector, reaching up to 75–85 %.

This device has to be integrated in the air handling unit upstream the exchange batteries pack and the power plant is not affected in a significant way, since it is placed before the warm exchange battery as the existing heat pipes.
The saving with this solution is really high:

$$EP_{saving} = 32{,}46\ kWh/m^2a$$

Eq. 3.44

Since the ventilation system uses district heating the energy saved has to be transformed in kWh with the energy transformation factor of district heating, as shown in the previous case for solar collectors.




The money saving is calculated as well and reported above.

$$kWh_{saved} = EP_{saving} \cdot A_N \cdot \frac{1}{e_{D.H.}} = 148689{,}37 \frac{kWh_{DH}}{year} = 2380706\ Ft/year$$

Eq. 3.45

The cost of investment, considering three cross-flow recovery system, one for each AHU, provided by Rosenberg Hungary KFT, same company that supplied the AHU, with air flow rate of 10000 $m^3/h$ and seasonal efficiency of 82 % by catalogue is around 2475000 Ft.

With a return investment analysis, considering once again a subsidy of 50 %, the payback time can easily be assessed equal to one year. This value is extremely interesting, and the situation is even better if we notice that the EP of our building now is 55,68, which means an A+ category.

The better energy category is not achieved if we consider the calculation with the solar account for the thermal losses $q_m$: this result is interesting, proving that direct solar gains can really affect in significant way the energy certification by changing the building label.

### 3.11.3 Cooling system

The last proposal to increase the energy efficiency considers the substitution of the existing air cooled condenser chiller with a water cooled chiller by the same manufacturer Ciat.
The difference, as immediately appears, lies in the use of water instead of air as cooling fluid in the condenser unit of the chiller. In this case the condenser will benefit of the greater heat capacity of water, reducing its exchange surface and its size, and also lowering the electricity consumption considering no fan unit are required, only circulation pumps that consume less energy than ventilators. This development allows a reduction in energy needs by more than 15% , and, additionally, a significantly reduced noise levels. but requires the installation of a cooling tower that regenerates the water used in the condenser. Furthermore, the machine has to be located inside the mechanical room: those units are designed to be installed inside the building to be protected against freezing temperatures and inclement weather. This means a complication for our building, considering that the mechanical room is currently not able to host such machine; a feasible solution has to be found by the designer.
The necessity to use one or more evaporator towers can be properly satisfied without major complications, considering the free area available on the roof of our building. One further positive aspect is the change of the refrigerant fluid, which is now R134A, in other words an ozone-friendly with a zero value of Ozone Depletion Potential. Also the GWP (Global Warming Potential) is lower than R407C currently used in the existing chiller; this means having a cooling unit that respond to the most stringent specifications for environmental protection, i.e. the European regulation EN 60-204 and EN 378-2 .
This proposal, based on the concept that we are discussing only a preliminary design, will not give a definitive solution to find a proper placement for the new chiller. The purpose of the recommendation is just to suggest a way to increase the energy efficiency, and this is possible considering the value of EER for the chiller, equal to 4.77, much higher than the current 2,55.
In this case the new EP, and therefore the EP saving, would be:

$$EP_{saved} = EP - EP_{water-cooled\ chiller} = 9{,}65\ kWh/m^2a$$

Eq. 3.46

This means, after the usual conversion of primary energy to electrical energy, and considering a price for electricity for a big consumer of 40 Ft/kWh, a money saving that can be calculated with:

$$\$ = EP_{saved} \cdot A_N \cdot \frac{1}{e_v} \cdot 40 \quad [Ft/year]$$

Eq. 3.47

We can now create a chart to resume the three solutions proposed, where we can combine them together and see what results are achievable by their implementation.
Each of the three measure is numbered, 1 for solar heating, 2 for recovery system and 3 for cooling.

| Case | $EP_{saving}$ | New category | Primary energy saving ($kWh_p/m^2a$) | Money saving (Ft/year) | Payback Time |
|---|---|---|---|---|---|
| 1 | 6,03 | A | 23112,75 | 443920 | 18 years |
| 2 | 32,46 | A+ | 124305,74 | 2387506 | 1 year |
| 3 | 10,42 | A | 39915,09 | 638642 | 22 years |
| 1+2 | 38,61 | A+ | 147882,84 | 2831426 | 1 year |
| 1+3 | 16,58 | A | 63493,29 | 1082562 | 20 years |
| 2+3 | 43 | A+ | 164686,40 | 3026148 | 1 year |
| 1+2+3 | 49,03 | A+ | 187799,03 | 3470068 | 1 year |

In case of making the calculations by taking in account the direct solar gains the results are:

| Case | $EP_{saving}$ | New category | Primary energy saving ($kWh_p/m^2a$) | Money saving (Ft/year) | Payback Time |
|---|---|---|---|---|---|
| 1 | 6,03 | A | 23112,75 | 443920 | 12 years |
| 2 | 32,46 | A | 124305,74 | 2387506 | 1 year |
| 3 | 10,42 | A | 39915,09 | 638642 | 22 years |
| 1+2 | 38,49 | A+ | 147418,49 | 2831426 | 1 year |
| 1+3 | 15,23 | A+ | 63027,84 | 1082562 | 18 years |
| 2+3 | 42,88 | A+ | 164220,83 | 3026148 | 1 year |
| 1+2+3 | 48,91 | A+ | 184372,62 | 3470068 | 1 year |

The further combinations 1+2, 1+3, ecc. will have higher investment costs, but also better EP and eventually better energy category.
In this way it is possible for the building owners to decide whether or not accept the investment and, in case of positive response, which investment fits best their demands and their financial resources
The payback time has been calculated considering a financial subsidy that covers 50 % of the initial investment cost.
It follows now that the most realistic and immediate solution is the second, by changing the heat recovery system with cross-flow exchanger.
The energy category of the building, indeed, is already very high, and this means that the possible saving measures are limited or, as we have seen, not convenient with intolerable investment costs.
The two solutions with solar thermal flat plate panels and new water-cooled chiller are quite difficult to sustain for a private investor in the short period, with a payback time around twenty years, even if we consider a financial subsidy that covers 50 % of the initial cost provided by the National Energy Program.

Our building, however, is a public building owned by the University of Debrecen: this means that all its costs, energy bills, employee salaries, maintenance and management are covered by the Hungarian State.
It follows that the government is the first one that takes advantage of the increased efficiency of a public building, with consequent lower public expenses for its management and maintenance. That’s why, for public buildings, the renovation project, whenever accepted and proved the existence of energy savings and higher energy efficiency of the solution proposed, is fully covered by the Government subsidy.
It is reported, for the attention of the reader, that currently the building is managed by a private company which has won a 3 year auction contract amounting to about 1 million Ft. Therefore, it is a matter of fact that a reduction in these costs is supported and well accepted by the State.
The economic analysis in this case is not necessary, and the investment is certainly approved in all the three cases, with a lower energy consumption and less energy costs.

For private buildings, on the other hand, the government subsidies are lower, as said before, covering maximum 50 % of the investment; in these cases it is not convenient for the State an improvement in the efficiency and energy performance of the building. The private owners will have lower energy bills, which means less profits for the energy companies and less profits also for the government, that has always a share in the energy market.
The second solution, anyway, is still the first-choice proposal, thanks to its quick installation and high primary energy, and money, savings.
Particular attention must be paid for the possible obstructions and obstacles during the substitution of the recovery system: heat pipes currently operating have their own dimensions, far cry from cross-flow exchanger. Therefore the designer has to check the plan of the AHU to be sure of a proper and successful installation “in-situ” of the cross-flow exchanger.

Water-cooled chiller Hydro Ciat 3050 BX XPS

## 3.12 Observations

During the design phase the glazed element by Gastaldello should have been located on the south façade, instead than on the north where the solar irradiation contribute is the lowest.
In this way the direct solar gains would be maximized with a positive effect on the thermal losses, which would be lower, and the length of heating season that would reduce as well. On the other hand this would require a higher cooling load in summer, but the energy saving during winter season, that is much longer than summer one, would justify this solution.
In the preliminary design of the building the architecture should always consider the orientation of the façade so that the solar gain can be successfully used to reduce the heating consumption, especially for climatic conditions quite cold as in Hungary.

It is interesting to observe what would happen if we consider our building as “educational” or “office” real estate.
The requirement for primary energy consumption, provided by the standard, would be, respectively:

Educational: $EP_{requirement} = 92\ kWh/m^2a$

Office: $EP_{requirement} = 138\ kWh/m^2a$

And, most interesting, the energy category now would be, with and without solar gains accounted:

| | Solar gains | Without solar gains |
|---|---|---|
| Educational building | F | F |
| Office building | D | D |

This is a huge difference considering that the energy category determined creating a fictive building according to the regulation was A, and the highest achievable category was even A+.
We are facing a particular situation where the building does not fit in one of the three categories, and this is a weak point that can generate pretentious energy rating with labels that do not reflect the real energy performance of the building.

The primary energy savings obtained with the three proposals are the same, but the new achievable category are now lower, as it can be seen in the table below:

| | Educational | Office | Payback time |
|---|---|---|---|
| 1 | F | D | 12 years |
| 2 | E | B | 1 year |
| 3 | F | D | 22 years |
| 1+2 | E | B | 1 year |
| 1+3 | F | D | 18 years |
| 2+3 | E | B | 1 year |
| 1+2+3 | D | B | 1 year |

It can be seen that the requirement for educational building is stricter, and the consequent energy performance is lower. Anyway, in both cases, our first extremely good response, with an A category calculated by following the regulation disposal, has been twisted and deeply changed by considering our building as belonging to one of the three categories arranged by the Hungarian standard.
The positive impact of the second measure with the new ventilation recovery system is once again the most effective, producing an immediate change of category; in this new situation, though, the top category achievable are, respectively, D and B.
This side calculation, even though unnecessary and invalid to assess the energy category, has been reported to the reader’s attention to show how our building is not so efficient but has some weak points, first of all the high ventilation consumption, that can be improved.

The absence of requirement and, therefore, the necessity of creating one ad-hoc for the specific case, is always a delicate aspect to be dealt with: we will see how the Italian regulation, using a different standard, does not allow this awkward situation.
Nevertheless, it can be stated that our building meets the first two levels of requirement, with U-values and specific losses $q_m$ in the limit imposed by the Regulation.
The primary energy analysis is a further aspect that is not mandatory in our case, but that has been made to find out possible saving measure that can reduce energy consumption and improve the efficiency. This is a clear example of how an EPC can hit the consumer target, with cost effective proposal that can be accepted without hesitation by building owners. The implementation of these measure creates jobs opportunities for people of the building sector, and at the same time every renovation project or new building designed with particular attention to its energy performance it’s a little step towards the reduction of energy in the building stock.

# CHAPTER 4

## Energy analysis of the existing building with the Italian Regulation

At this point it is a matter of interest to make an energy analysis of our University Library with the Italian regulation, to find out the common points and the differences, and assess a new energy label to this existing building. As said before, Italy adopts a calculated rating based on the technical regulation UNI TS 11300 part I, II, III and IV.
We will, thus, analyse our property as if it is located in a climatic zone similar to Hungary, which is zone F in the city of Cuneo with 3012 degree days , and proceed in our calculations using the software STIMA developed by Watts Industries. It is an example of the several commercial software used in the housing sector to properly assess thermal performance and energy consumption for buildings during winter and summer season.

## 4.1 Building structure and transmittances

The software STIMA allows to create all the building structure that actively participate in the heat exchange; it follows that external walls, basement floor laid on the soil and the roof were created in the program, with their U-value and opaque surface. All the glazing elements can be inserted, and this allows to calculate the transmission losses through the envelope $H_{T:}$

$$H_{T,global} = H_{T\ i,e} + H_{T\ i,ground} + H_{T\ i,j} + H_{t\ i,u} \qquad [W/K]$$

Eq. 4.1

The first term:

$$H_{T\ i,e} = \sum_{envelope,i} U_i \cdot A_i \qquad W/K$$

Eq. 4.2

requires to calculate all the transmittance $U_i$ of the building elements, glazed and opaque, that separate the heated and unheated spaces: these calculations were already done previously, the only differences are new values for heat transfer coefficient $\alpha_{glob}$ that can be found in Appendix.
The U-value of opaque elements are corrected with a factor that takes in account the thermal bridges, as seen before in the Hungarian procedure.

The program allows to calculate the exact transmittance for doors and windows, depending on the net glazed area $A_g$ and frame area $A_f$ of the element, the U-values $U_g$ and $U_f$ for frame and glass, which depends on the materials and technology used for glass and concrete frame and eventual shading elements. The thermal bridge along the frame is also taken in account.
The correct value for $U_w$ is:

$$U_W = \frac{U_g \cdot A_g + U_f \cdot A_f + l_g \cdot \Psi_g}{A_g + A_f} \qquad W/m^2K$$

Eq. 4.3

It follows a proper value for heat transmission losses between inside heated spaces and outside ambient $H_{T\ i,e}$ through all opaque and glazed elements.

The second term of 4.1. allows to calculate the heat losses between the heated space and the ground: its value depends on the structure of the ground floor, i.e. its thermal resistance $R_g$, and on how it is placed, if directly in contact with the soil or if it is underground.
In our case the basement floor is placed under the level of the ground, at a depth of 6 meters, therefore:

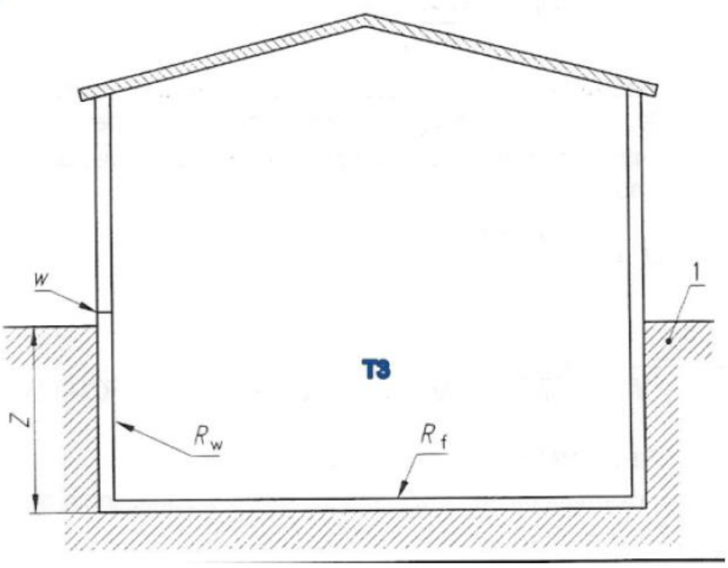
$$H_{T\ i,g} = \left(U_f \cdot A_f + z \cdot P_w \cdot U_w\right) \qquad W/K$$

Eq. 4.4

where $U_f$ and $A_f$ are transmittance and net area of the basement floor -02, z is the depth in meters, $P_w$ the perimeter of and $U_w$ the transmittance of buried external walls. It is very similar to the calculation suggested by the Hungarian regulation

3.2.4.5.4 Pavimento interrato

T3



The last two terms $H_{T\,i,j}$and $H_{t\,i,u}$ are, respectively, thermal losses between heated space and neighbouring spaces at different temperature and losses between heated and unheated spaces, and are equal to zero.
The procedure to properly calculate these terms is reported in the UNI-TS prospect in Appendix for the attention of the reader. Now we know the global transmission losses $H_{T,global}$ , it is time to assess the ventilation losses due to the air change of the heated volumes.

$$H_V = \sum_{spaces,i} \dot{V}_{n,i} \cdot \rho_a \cdot c_a \qquad W/K$$

Eq. 4.5

$$V_{n,i} = V \cdot n \qquad m^3/h$$

Eq. 4.6

The ventilation is necessary to ensure hygiene and comfort in all the heated spaces, but it causes thermal losses due to the inside-outside temperature difference of the air flow rates.
With the 4.6 it is possible to assess the air flow rate $\dot{V}_{n,i}$ required to have an adequate air change: the value n for the air change rate is given as a standard value for residential buildings, or is calculated as an average with:

$$n = \frac{(\dot{V}_{op} \cdot n_s \cdot A_N)}{V} \qquad [h^{-1}]$$

Eq. 4.7

$\dot{V}_{op}$ is the minimum air flow rate to guarantee an adequate air change, provided by normative, while $n_s$ is the density of people per m$^2$.
We can now calculate the energy requirement for heating, given by:

$$E_H = 0{,}024 \cdot GG \cdot (H_T + H_V) \qquad kWh/a$$

Eq. 4.8

This requirement is not a net value, because it doesn't consider all the positive contributes of the internal and solar gains. Therefore, we have to calculate first the internal gains:

$$Q_i = N_G \cdot A_l \cdot \alpha \cdot F_{oc} \cdot 10^{-3} \qquad kWh/a$$

Eq. 4.9

$N_G$ is the number of days of heating season, $A_l$ is the net floor area, α is the specific value for sensible heat gain, expressed in W/m$^2$, i.e. $q_b$ in the Hungarian procedure, $F_{oc}$ is a parameter expressing the average number of occupation of the building per day given by UNI 15833.
The sensible heat gains provided by the solar radiation are distinguished in: solar gains through glazed elements, opaque facades and non-conditioned spaces hit by the sun, e.g. greenhouses.
The incoming energy for every month provided by solar radiation on the transparent surfaces is given by:

$$Q_s = N \sum_j \overline{H}_{s,j} (\sum_i A_{L,i} \cdot F_T \cdot g \cdot F_S) \cdot 0.85 + Q_{s,s} \qquad [kWh]$$

Eq. 4.10

In 4.10 N is the number of days of the considered month, $\overline{H}_{s,j}$ is the global daily average solar irradiation during the month considered for every exposition (N, N-E, exc.), expressed in kWh/m$^2$ and reported in Appendix. Every transparent surface is considered with its gross area $A_L$ , correction factor $F_T$ considering the ratio glass/frame of the window, solar transmittance g of the glass and shading factor $F_S$ given by:

$$F_S = F_h \cdot F_o \cdot F_f$$

Eq. 4.11

The three terms of equation 4.11 are: $F_h$ is the partial shading factor due to external obstructions, such as neighbour buildings, trees or other major structure, $F_o$ and $F_f$ are partial shading factor linked to horizontal and vertical lug wrenches, like balconies or other architectural elements that shadow the building. Each of these coefficients can be calculated depending on geometrical data of the obstacle. For our library on the west façade the monument represents an obstacle to the sun rays, with $F_o$ due to its horizontal roof linked to the library roof and $F_f$ because of the concrete façade; therefore the opaque and glazed elements on this façade will have a lower value for the direct solar gains. Going back to 4.10, all the direct solar gains are reduced with a factor 0,85 that consider the inclination of solar rays to the surface hit by the sun.
The solar gains through opaque elements can be assessed using the following expression:

$$Q_{se} = N \sum_j \overline{H}_{s,j} (\sum_i \alpha_i A_{L,i} \cdot F_h \cdot F_{ER,i} \cdot \frac{U_i}{h_e}) \cdot 0{,}85 \qquad [kWh]$$

Eq. 4.12

In the equation above the new terms are, respectively, $\alpha_i$ , that is an average absorption factor of the opaque surface, depending on the colour of the wall, while $F_{ER,i}$ is a reduction factor considering the part of infrared radiation that is transferred to the sky that is conventionally equal to 1 because the radiation given to the sky volt is considered as an extra heat flow that increases the transmission exchange. $U_i$ is the transmittance of the opaque element, and $h_e$ is the superficial heat transfer coefficient, expressed in $W/m^2K$. It is calculated by the inverse of superficial thermal resistance $R_e$, that is given by UNI EN ISO 6946-A with a calculus depending on average monthly temperature and wind speed. If we sum all the monthly solar gains for glazed and opaque elements we have the total solar contribute in kWh during the heating season.
Now that we have assessed all the solar gains we can calculate the net heating requirement for our building: the boundary conditions are a set point internal temperature of 20 °C and a continuous operating mode for heating working 24 hours per day:

$$Q_{NH} = (0{,}024 \cdot N_{GG} \cdot (H_T + H_V) - f_x(Q_i + Q_s) \qquad kWh/a$$

Eq. 4.13

It is considered that not all of the free gains can be effectively used during heating season, thus they are reduced with a utilization factor $f_x$; this factor depends on the ratio gains/losses and on a time constant $\tau_H$ given by the climatic zone.

$$f_x = \frac{1-\gamma_H^{a_H}}{1-\gamma_H^{a_H+1}} \qquad if\ \gamma_H > 0\ and\ \gamma_H \neq 1$$

$$f_x = \frac{a_H}{a_H+1} \qquad if\ \gamma_H = 1$$

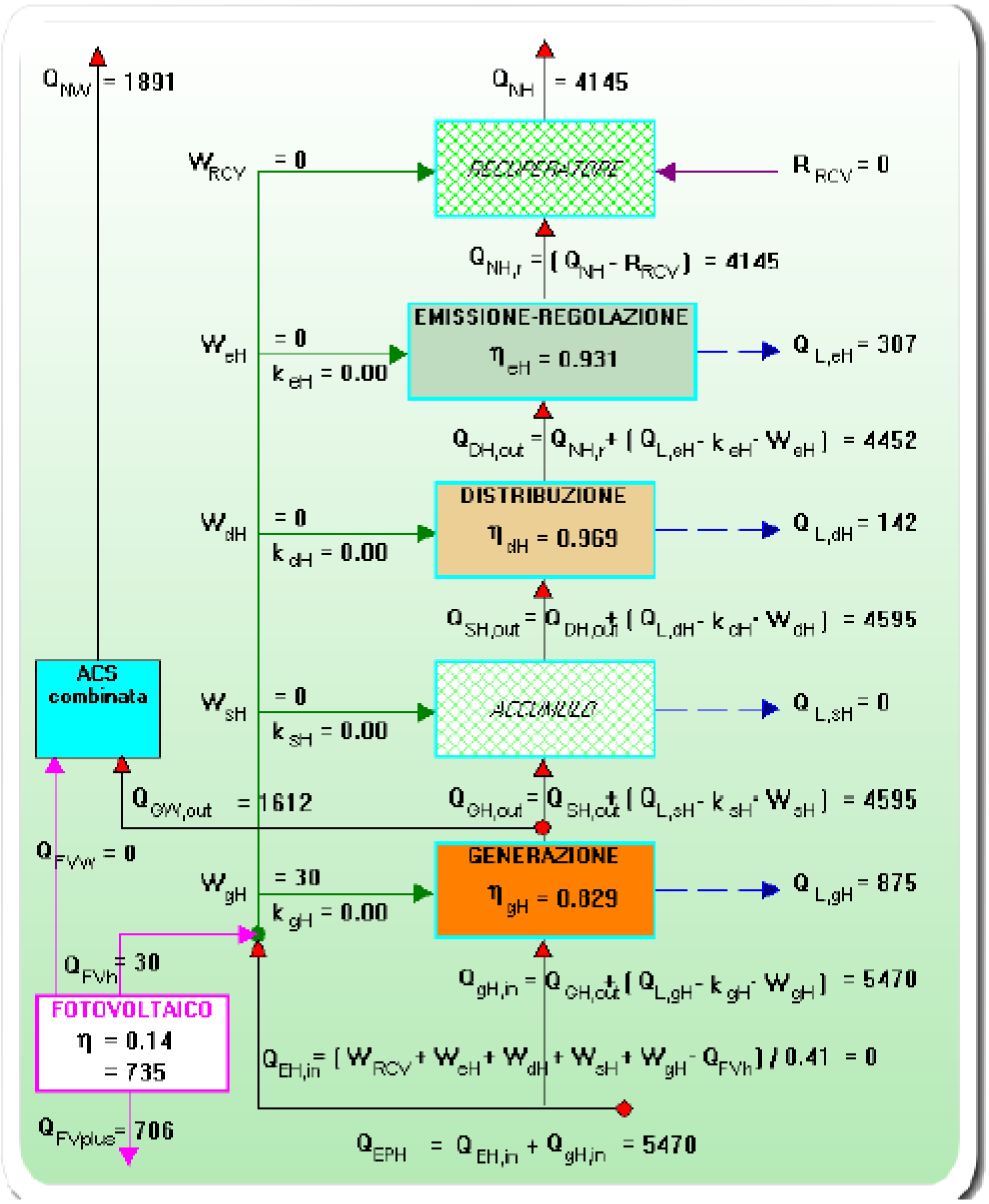
$$\gamma_H = \frac{Q_{gH}}{Q_{lH}} \qquad a_H = 1 + \frac{\tau_H}{15}$$

Eq. 4.14

We will see in the next paragraph the meaning of the quantity $Q_{gH}$ and $Q_{lH}$.
The program does the calculus for every month, considering how all the thermal parameters, external temperature, utilization factor, exc. change during the time.
We have now accomplished the calculation of net heating energy requirement, similar to the $Q_F$ previously obtained with Hungarian regulation. If we remember correctly the Hungarian procedure had three steps for its calculation of heating requirement, with a deeper analysis which considers also the contribute of air conditioning system in the heating system, see Eq. 3.10. The numeric result we have obtained now for $Q_{NH}$is quite similar to the first step result of $Q_F$.
We can now proceed with the primary energy consumption calculation.

## 4.2 Primary energy need

Our building needs primary energy to maintain comfort conditions during the heating season: we can easily understand how the Italian regulation proceeds to assess primary energy consumption by launching the calculus with our software. The scheme used is the following:




The input data is $Q_{NH}$: starting from our energy requirement it is considered how the energy is effectively distributed and produced throughout the emission, distribution and generation subsystems. Every system has its efficiency, that can be calculated with Prospect and tables provided by the normative, therefore the final requirement for heating will be higher. It has also to be considered the electricity used during the process, with a global consumption that is converted in primary energy through a conversion factor generally equal to 0.41.

In the final step the sum of heating and electric need will give us the primary energy consumption:

$$Q_{EPH} = Q_{EH,in} + Q_{gH,in} \qquad [kWh_{ep}/a]$$

Eq. 4.15

The calculation proceeds step by step from the net heating energy need, that is our input, back forward to the generation core: first, it is considered the heat recovery system, with its efficiency and electric power consumption. It follows that the net heating requirement decreases, by:

$$Q_{NH,r} = Q_{NH} - \eta_R \cdot Q_V \qquad [kWh/a]$$

Eq. 4.16

In this way we can consider our heat pipe recovery system in the AHU, which has efficiency equal to 42%: we have also to include the electric power consumed by the auxiliary, which are ventilators supplying the A/C system, working at operating speed 17 hours per day.

$$W_{RCV} = \sum_i \dot{W}_{RCV} \cdot h_{RCV} \cdot N \qquad [kWh]$$

Eq. 4.17

N is the number of days of heating season, equal to 183 for climatic zone E, $\dot{W}_{RCV}$is the auxiliary power and $h_{RCV}$ the daily operation time in hours.
If we think to our energy itinerary, from production to the user, the final stage are the terminals; they can be considered as a subsystem that has to be managed to adapt and coordinate the energy produced to the users demand, that typically change during the day and the heating season depending on the climatic conditions and user behaviour. The terminals have also their own efficiency, depending on the way the heat is transferred to the space (convection, radiation, transmission), the fluid and the technology used. It is considered a global efficiency $\eta_{eH}$ given by the product of the emission efficiency and the control system efficiency.

$$\eta_{eH} = \eta_{eeH} \cdot \eta_{cH}$$

Eq. 4.18

Considering our building uses different kind of terminals (fan coils, radiators, ..) the emission efficiency is a weighted average of each terminals on the heated volumes. All the values for efficiency are given by standard tables and prospects. The terminals are managed with climatic logic and also possibility of control of the single heated space.

The thermal losses in this subsystem are given by:

$$Q_{L,eH} = \left(\frac{1}{\eta_{eH}} - 1\right) \cdot Q_{NH,r} \qquad [kWh]$$

Eq. 4.19

This means that our requirement $Q_{dH,out}$ will be higher, because it has to overtake these losses, and will be increased by a factor equal to $Q_{L,eH}$.
The electric consumption of the terminals and control system is expressed like 4.16, where the number of hours now is equal to the open time of the building, considering that the heating system is switched off during the night.
If we consider once again our energy path it is time to evaluate the distribution lines: our building has a centralized system with vertical pipelines to supply hot water and air ducts with insulation for the warm air, thus the efficiency can be assessed by standard tables and so the thermal losses:

$$Q_{L,dH} = \left(\frac{1}{\eta_{dH}} - 1\right) \cdot Q_{dH,out} \qquad [kWh/a]$$

Eq. 4.20

The electric consumption, once the power of auxiliary is inserted, is calculated by the program depending on the logical operation, that we have already cleared being intermittent.

After the distribution the program allows to calculate eventual thermal losses caused by a heat storage, given by:

$$Q_{l\,sH} = f_s \cdot t \cdot N \cdot 10^{-3} \qquad [kWh]$$

Eq. 4.21

Since our building has no heat storage this term is not considered.
We have now arrived to the last subsystem, that is the production unit: this is the central core of our building. It is possible to use database for generators (traditional, condensation and biomass boilers, heat pumps) and also district heating can be selected, with efficiency values automatically provided. It is also possible, in case of existing buildings, to insert manually the efficiency and energy consumption of the real generation system. It is also possible, as second option for existing buildings with boilers without information about its efficiency system, to calculate via-software the efficiency of the boiler filling in thermal losses of the chimney, supply return temperatures and other technical data.
As we know our building is supplied by district heating, thus we immediately select this option in the software, with an assessed efficiency of 100%. The thermal losses, in this way, are equal to zero as it can be seen by the equation:

$$Q_{L,gH} = \left(\frac{1}{\eta_{gH}} - 1\right) \cdot Q_{gH,out} \qquad [kWh]$$

Eq. 4.22

The electric consumption of auxiliary can be inserted as usual: the energy consumption is then calculated during the heating season.
We can now resume the global heating requirement, which is the energy "entering" in our building system upstream the users, and then running through the generation and distribution subsystems to the terminals and finally to the heated volume, that represents the last ring of the energy chain.

$$Q_{gH,in} = Q_{gH,out} + Q_{L,gH}$$

Eq. 4.23

In our case, considering an efficiency equal to 1, this term is equal to the energy supplied by the generation system, that is the net requirement $Q_{NH,r}$ increased step by step of the thermal losses in the subsystems.
On the other hand we have also the electric consumption, given by:

$$Q_{EH,in} = \frac{\left(\sum_i W_{i,H} - Q_{FVh}\right)}{0.41} \qquad [kWh]$$

Eq. 4.24

The first term takes in account the electric consumption of auxiliary in recovery system, terminals, distribution and generation systems, while $Q_{FVh}$ is the photovoltaic contribute, in our case not present. The energy consumption is converted into primary energy through a conversion factor equal to the efficiency of the national electric system.
The primary energy required to the building for heating then is:

$$Q_{EPH} = Q_{gH,in} + Q_{EH,in} \qquad [kWh/a]$$

Eq. 4.25

The energy performance is assessed by the ratio of primary energy and heated volume, considering the non-residential destination of use:

$$EP_{ci} = \frac{Q_{EPH}}{V} = 15.3 \qquad [\,kWh/m^3]$$

Eq. 4.26

The certification requires to calculate also the consumption for DHW as indicated in Part 2 of UNITS 11300: via software we can insert as input the daily requirement of hot water per person $Q'_W$, expressed in Wh/px/day. The program, depending on the destination of use of the building, calculates number of users and period of consumption during the year, with an energy requirement to produce DHW given by:

$$Q_{NW} = Q'_W \cdot F_{oc} \cdot n_s \cdot A_N \cdot N_{days} \qquad [\,kWh/a]$$

Eq. 4.27

As seen for heating requirement, this value is taken as input to go back forward and properly assess the primary energy required to guarantee exactly $Q'_W$ during all year. The hot water is supplied by terminals that have their own efficiency, assessed by standard, exactly as in heating calculation.
The second subsystem is the distribution, which as we know has a recirculation line to respond quickly to the users demand. Then there is the storage system: as we know the hot water produced is sent to a storage tank, placed in the service room. The last station is the generation system: the program allows to link the DHW production with the heating system, as it happens in our case considering DH provides both the services. It follows the efficiency of production is once again equal to 1 without any losses. The energy requirement is increased at any step by the thermal losses, as well as the electric consumption (the calculations are omitted).
The software allows to insert eventual solar thermal system $Q_{ST}$ and photovoltaic devices $Q_{FV}$, whenever they are used.
The consumption for how water is:

$$Q_{EPW} = Q_{gW,in} + \sum_i (W_{i,W} - Q_{FV})/0{,}41 - Q_{ST} \qquad [\,kWh/a]$$

Eq. 4.28

The EP for hot water is calculated as usual with the ratio:

$$EP_W = {}^{Q_{EPW}}/_{V} = 2.7 \qquad [kWh/m^3]$$

Eq. 4.29

This value is compared to the requirement, set by the regulation.

The cooling is evaluated as standard by the software with the first method proposed by UNITS, by calculating the $EP_{inv}$ equal to the primary energy required to maintain the comfort conditions inside the building during the hot season. This value $E_c$ is compared to the requirement $E_{cL}$ and the ratio gives the energy label.

It is now possible to calculate:

$$EP_{glob} = EP_{ci} + EP_W = 18 \qquad [kWh/m^3]$$

Eq. 4.30

## 4.3 Energy classification and recommendations

The ministerial Decree DPR 59/09 art.4 imposes a list of controls that we are going to show on the building structure and energy performance for every Qualified Expert whenever issuing a EPC.

The first check is about $EP_{ci}$, and as seen in the chart below our building does not meet the requirement with a heating consumption higher than the requirement $EP_{ciL}$ .
The requirement $EP_{cil}$ is given as usual by standard depending on the number of degree days and the shape factor, and we can then calculate the energy rating:

| $EP_{ciL}$ | $EP_{ci}$ | $\left(\frac{EP_{ci} - EP_{ciL}}{EP_{ciL}}\right)\%$ | Category |
|---|---|---|---|
| 15.3 | 17.3 | +13% | **D** |

The production of DHW is considered with a specific $EP_w$ expressed in $kWh/m^3$; the requirement are not specified for non-residential buildings, thus they are proportioned on the values given for residential buildings. The result is an A category.

Thereafter the summer cooling consumption $EP_{e,inv}$ has to respect the requirement $EP_{e,inv.limite}$ imposed by the technical specifications (see Table 3 in Appendix), and in this case our building has a level II of performance with an $EP_{e,inv}$ shown below lower than the requirement.

$$E_c = 5.8 \frac{kWh}{m^3} < E_{cL} \Rightarrow \quad Level\ II$$

The controls go on by evaluating the transmittance U of all building elements, opaque and glazed; every structure has to meet the requirements, depending on climatic zone and period of construction of the building. The requirement is satisfied for all structures of our library.

A further control is arranged for humidity and temperature on the internal and external surfaces of all structural elements, to prevent the possibility of condensation.

This is a very important aspect to be controlled, especially for buildings with a lot of thermal bridges and without an acceptable ventilation rate; internal condensation can bring to corrosion of metallic structures, mold and damages to the exterior walls.
That is why air condensation, on inner or outer layer, is not accepted: the internal condensation has to be controlled with a maximum admissible value for the amount of vapor condensed within the walls that is equal to the quantity that can re-evaporate during the hot season.
The humidity and temperature conditions in our building, thanks to the A/C system and to the big volumes that guarantee an adequate air change, are always under control during the year, without any superficial condensation; there are, however, two external walls, $F_{k4}$ and $F_{k6}$ have problems with internal condensation over the limit.

During the month with maximum sunstroke, if our building is placed in a locality with a month-average value of irradiance on horizontal surface $I_{m,s} \geq 290$ W/m$^2$ , then:

- All opaque vertical surfaces must have a superficial mass (calculated according to Attachment A of DLG 192/05) $m_s > 230$ kg/m$^2$;
- All opaque horizontal and sloping surfaces must have an average periodic transmittance value $Y_{IE} < 0{,}20$ W/m$^2$K .

These requirement are set up to maintain the inner temperature during summer period in a fixed range of the set-point (26°C) without huge variations caused by a bad thermal inertia of the envelope that can lead to discomfort. The decree gives indication to help the designer reducing the cooling load, by using shading elements for all the glazing surfaces to shield the building and reduce the incoming heat flow during summer. It is also suggested to use the natural ventilation to ensure the air change, by using the internal volume in a way that doesn't require mechanical ventilation. Whenever this is not feasible a ventilation system has to be adopted: it is required the adoption of a heat recovery system when the air flow rate and operation time exceeds specific requirement values (see Appendix).

It is also required to cover 50 % of the domestic hot water energy demand with renewable energies: this part of the decree will be adjusted and completed with technical details, prescriptions and application terms in the future regulation updates.

The global efficiency during heating season has to fulfill a requirement based on the installed power of the heat generator:

$$\eta_{glob} = \eta_{eeH} \cdot \eta_{cH} \cdot \eta_{dH} \cdot \eta_{gH}$$

$$\eta_{glob} \leq (75 + 3\log P_N)\% \qquad P_N < 1000\ kW$$

$$\eta_{glob} \geq 84\% \qquad P_N \geq 1000\ kW$$

Eq. 4.31

The technical report that has to be presented to the municipality by the building constructor at the beginning of the work has to contain an energy diagnosis of the building, with particular attention for the possible saving measures and renovation proposal in case of retrofit for existing buildings.
The report has to present the energy savings achieved with correspondent return time of investments and the new energy category obtained after the implementation of the intervention, with particular attention for plant design whenever $P_N$ > 100 kW.

The designer can use the software (in our case STIMA) at the end of the energy analysis to write down the technical report with a complete description of all the building data, architecture, mechanical systems, specifications adopted, regulations followed and then proposal to increase the energy efficiency and energy category. The software has three pre-set models, one for new buildings, one for renovation projects and one in case of substitution of the heat boiler for existing buildings.
It is also possible via-software to print the EPC: in Italy there are two possibilities, as seen in the previous chapter, AQE or ACE. These certificates follow the national energy guidelines and represent a valid document to be attached in the selling contract for building's owner. The ACE for our library is reported in Appendix.

The recommendations to save primary energy are the same three ones already discussed, but now only the first two ones are feasible because the software does not permit to calculate the cooling primary energy consumption.

The substitution of the heat recovery system allows a relevant saving for heating: it is immediate to evaluate this contribute in the calculation of the real net heat need $Q_{NH,r}$, with a higher value for the efficiency $\eta_R$ now up to 82% as given by catalogue of the cross-flow heat exchanger manufacturer.

The second measure with production of hot water by a solar thermal system affects the consumption $Q_{EPW}$ in 4.27. Now the term $Q_{ST}$ has to be considered: its value is calculated depending on the type of collectors, with efficiency and loss factors that have standard values or that can be inserted if provided by the producer catalogue. It is also considered the inclination and orientation of the panels, which is in our case is equal to the latitude of the location and pointed towards the South, so that the seasonal efficiency is maximized.
The energy savings in both cases must be converted from primary energy to heat considering district heating as energy carrier, with a transformation factor equal to 1.
The payback time of the solutions consider the same cost for the cross-flow heat exchanger and solar thermal system, but the energy costs are based on Italian energy prices and are slightly different. The return time is based on national subsidy provided by the Tax programme, with a contribute of 55 % to cover the initial investment.

Here above the recommendations are summarized:

| | New EP | Payback time |
|---|---|---|
| 1 (cross-flow heat exchanger) | $EP_{ci}$ = 11.4 C | 1 year |
| 2 (solar thermal) | $EP_w$ = 0.7 A | 8 years |
| 1+2 | $EP_{ci}$ = 11.4 C<br>$EP_w$ = 0.7 A | 3 years |

It can be seen that the best choice is also in this case the first one, with immediate high money savings, quick return time of investment and a label C that meets the minimum requirement for new buildings.

These saving measures are only theoretical, considering that the building is located in Hungary and the intervention, whenever accepted by the building owner, would be made according to Hungarian standards. They are reported to the reader's attention to complete the energy analysis and to show how, no matter what regulation has been used, energy savings are always achievable.

## 4.4 Comparison between Hungarian and Italian energy analysis

Now that we have completed two different energy analysis, both using technical specifications based on European Directive, we can find out the differences and analogies.

First of all the Italian normative takes in account once for all the soar gains in the assessment of net heat requirement $Q_{NH}$, without any ambiguous points that can lead, as seen in the Hungarian case, to different energy category for the same building.
The early steps in the energy calculation are the same, by assessing net area and volume and all the losing surfaces, opaque and glazed, and their U-value.
The first difference is in the determination of the length of heating season, that influences the requirement for primary energy. The Hungarian specifications is focused more on the thermal characteristics of the building, using a balance point difference $\Delta t_b$ that takes in account its real behaviour depending on the insulation of the envelope, ventilation rate and internal gains.
The Italian case, on the other hand, is more focused on the geographical location using standard periods for heating season depending on the climatic zone; different localities in the same zone can have different degree days, with a heating requirement that may vary significantly.

The second difference can be found in the internal gains, that are estimated in a more accurate way through the Italian calculation, by assessing a frequency rate for people inside the building, depending on its destination of use, and a period of occupancy during the day.

Let's look now the requirement for heating; as we have seen the Hungarian directive firstly calculates specific thermal losses q expressed in $W/m^3K$ , and in this computation takes in account, whether or not, the solar gains. This means, looking to the equation of $Q_F$, that solar gains are fully considered in their value in the heating energy need, without any reduction factor.
Besides this, in the third-step calculation for $Q_F$ also the thermal losses caused by Air conditioning are considered, with a difference between inlet air flow and real internal temperature.
In the Italian procedure the thermal losses are calculated with the parameter $H_T$, and all the free gains, both internal and solar, are considered as heat flows that reduce the demand of heating with a utilization factor $f_x$ , as seen in equation 4.13 for $Q_{NH}$. The ventilation losses $H_V$ do not take in account the presence of an air conditioning system; as seen in 4.5 only the minimum requirement for air change has to be respected.
It is possible, anyway, to use an average value for the air change rate n considering the real presence of people and layout of the building as seen in 4.6, with an increase of ventilation losses that reflects more the real energy consumption. This choice reflects the first two step calculation for $Q_F$ (see 3.7, 3.8) when we used an average value for ACR n; with the third step the Hungarian procedure allows the designer to split the heat gain between standard heating systems (boilers, district heating, heat pumps) and air conditioning system. In case of building with big volumes that require a high demand of ventilation to guarantee the air change, such as our library, the designer can decide to use the AHU also to heat up the spaces, covering part of the heat demand with air conditioning.

The Hungarian specifications has set up a specific calculus for primary energy consumption for HVAC systems $E_{LT}$: all the losses through the air ducts are considered and as well the electric energy required by ventilators and auxiliary systems. This is a huge difference that reflects a weak point of Italian procedure, especially for building served with primary air system like our library where A/C and ventilation heavily affect the global consumption of primary energy.
Anyway it is possible to take in account the thermal losses in air ducts and electric energy consumed by ventilators considering them in the power consumption of auxiliary machines in the recovery system and in the losses of the distribution subsystem, as we have done with our software. The numeric results are almost the same.

No controls are required on humidity in the Hungarian regulation: all the calculation to control surface condensation and humidity condition within walls (Glaser diagrams) by the plan designer or architect during the early phase of the project.
If it is required an energy audit instead of a certification these calculations would be are performed to check the presence of mould, corrosion of sealings, walls and plaster, especially if the building has a lot of thermal bridges and an inadequate air change rate.

Another important difference is the presence of primary energy calculation for cooling and lighting, required as mandatory in the Hungarian EPC, in addition to heating and DHW.
These two calculations, most of all the cooling one, are very important to quantify the performance of a building: as we have repeated several times the demand of cooling, especially for residential sector, is becoming more and more relevant, and an energy certificate cannot omit a technical report and energy rating on this matter.
It is not required at present, even though it has been introduced a methodology in the last UNI-TS Part III, the calculation for primary energy consumption for cooling in the Italian procedure; it is only calculated a specific energy requirement $EP_{inv}$ which does not consider how the cooling load is handled, with its power plant, machines and auxiliary.
In the case of existing buildings of tertiary sector, or for open space ambient as airport, museums, auditorium, halls, exc.. the cooling demand can be significantly high, even more than heating in particular warm climatic conditions, and its energy consumption has to be considered in the certification.

We have anyway to report a positive aspect of the Italian regulation: the requirement for energy performance EP are separated in two big groups, one for residential and one for non-residential buildings. In this way all the mixed-use buildings, as the one under discussion, belong to the second group and have a unique and fixed requirement.

As we have reported previously this does not happen for the Hungarian certification, where the intention of the energy board editing the normative was to create three categories for building depending on their destination of use. This choice on one hand promotes a more accurate analysis with specific requirement that vary depending on the use of the building, but on the other hand creates problems for mixed-use buildings that do not fit exactly in these three classes and that actually do not have a requirement.

As we have underlined, whenever it is needed to create a requirement “ad hoc” the certification becomes misleading, with responses that do not reflect the real energy performance of the building.

The final recommendation to increase the EE of the building are more limited with the Italian procedure considering that cooling machines and lighting are not contributing to the global energy consumption. This means, whenever the building has already an efficient envelope, sealings, windows, heating and DHW production system, no saving measure can be suggested even though there are possible solutions that could be implemented on cooling or A/C power plant.

It follows that the Hungarian EPC, at the moment, is more complete and accurate by assessing all the forms of energy actually used in the building.

The analysis through the Italian software was more precise, thanks to the big database for walls and glazed structure, climatic data for all localities with degree days, temperature and R.H. profile for every month, occupation times depending on the type of building and more sub-menu that give access to technical details and allow to evaluate properly the efficiency of existing heat generator. However this detailed analysis can be made as well with Hungarian softwares for energy certifications (e.g. WinWatt) , that are available on the market. It was a decision of the writer not to use them, considering that all the calculations could be handled even without it thanks to the detailed tables and informations already provided by the Hungarian regulation.

The reduction of energy demand thanks to renewable energies is suggested and can be calculated in both the procedures; in the Hungarian case ( see XI page 18411of Regulation), as we have seen for the solar thermal system, this means a change in the energy factor *e* depending on which RES is used.
The Italian calculation is more accurate because it is based on UNITS 11300 Part 4, a specification released on June 2012 especially focused on RES and their implementation on building system to reduce the energy demand for heating and DHW. It is taken in account the contribute of all the latest renewable energies, such as thermal and PV solar, biomass, geothermal, eolic and hydroelectric to produce electricity or as energy source for heat pumps.

Here below are summed up the main differences between the Hungarian and Italian procedure to issue an EPC for a mixed-use building as the one under discussion.

| Italian Procedure | Hungarian Procedure |
|---|---|
| RES taken in account with detailed specifications (UNI TS 11300 Part 4). CHP system design, DH and heat pump energy analysis. | Absence of standard requirement for building out of category, necessity to create a fictive building with “ad hoc” requirement. Absence of generalization for similar buildings. |
| Solar gains always considered in heat demand | EPC contains primary energy consumption for A/C systems, cooling and lighting, with ad hoc calculations attached in the Regulation. Energy performance rating more accurate and complete. No control on air comfort, R.H., surface and external condensation during the certification, calculation made before during early design phase. No requirement for global efficiency of service systems. |
| Simple and effective division between residential and non-residential for building requirement | |
| Every Region has developed its own certification procedure, with standard and peculiarities that do not allow a national generalization of EPC. | |
| Energy demand for DHW based on UNI 9182 with detailed calculation for daily consumption | Energy requirement more precise, tailor-made to building’s destination of use. |

To complete our report we will compare the results obtained through the Hungarian and Italian calculation in the same table; the specific consumption is measured in kWh/m$^2$, therefore the Italian results have been converted from kWh/m$^3$.

| $kWh/m^2a$ | Hungary | Italy |
|---|---|---|
| $EP_{heating}$ | 18.81 | 55.58 |
| $EP_{ventilation}$ | 78.75 | - |
| $EP_{DHW}$ | 7.85 | 8.67 |
| $EP_{cooling}$ | 26.46 | 18.63 |
| $EP_{lighting}$ | 19.25 | - |
| $EP_{glob}$ | 151.12 | 64.25 |
| Global Category | **A** | **D** |
| Global Category with office building requirement | **D** | **D** |
| Category DHW | **-** | **A** |
| Category cooling | **-** | **II- Good** |

We have to keep in mind that the Hungarian global EP is higher because it also takes in account cooling and lighting needs and calculates more precisely A/C systems consumption.

The Italian EP global considers only heating, which includes also infiltration and ventilation, and hot water production. The Italian certification has a specific category for DHW , unlike Hungarian that includes it in the global EP.

Also the cooling evaluation is different: the Italian procedure considers only the energy required to maintain comfort conditions inside the building  and balance the solar gains, while the Hungarian calculates the primary energy effectively used and needed in the cooling power plant.

However it can be seen that in both cases the DHW and cooling consumption is very similar, while heating is different because of the different contributes. The global category is higher with the Hungarian procedure, but as we have reported this is only caused by the absence of requirement for mixed-use buildings. If we consider the library as office building we can see it has the same category D obtained through the Italian way.

This is very interesting and it means that both the procedures are well-structured because they are both based on accurate studies of thermodynamics, energy transmission and service systems.
This is why they assess in a similar way the energy consumption and efficiency of the library we have analysed, even though they use different specifications.
The two procedures are both referring to EPBD, thus this means that the EU Directive is effectively a powerful mean to analyse the housing sector and find saving measure to reduce its energy need and its impact on the environment.

# CONCLUSIONS

> "Buildings are at the core of the European Union's prosperity. They are important to achieve the EU's energy savings targets and to combat climate change whilst contributing to energy security.
> An enormous unrealised energy-saving potential lies dormant in buildings. In untapping that potential, not only more energy efficient buildings, but also better living conditions, financial benefits and sustainable jobs can be provided for Europe's citizens. "
>
> Dr. Péter Szaló, Deputy Secretary of State of Spatial Planning and Construction

In these few words lies all the importance of EPBD, as a unique way to gather all EU member states and to cooperate and work together for a better, sustainable and environment-friendly future.
The Energy Certification of buildings has immediate benefits that do not make it just another confused political document but an effective guideline to find new ways for saving energy overcoming market barriers with economic benefits for everybody.

Nowadays in the EU every designer and technician who wants to work in the housing sector has to use his professional skills, creativity and intelligence being aware of the European Directive and its implementation in the specific country he is employed in.
In this new context all the lifecycle of a building has to be designed following a sustainable manufacturing, constructing and use phase, with a reduction of primary energy consumption, a lower impact on the environment and climate change ($CO_2$ emissions), that lead to economic savings and better living conditions for building occupants.
In this sense the scientific research can help a lot, as the building sector affects multiple fields of interest, among the others service system, air comfort, acoustics, architecture, electricity, lighting, applied physics, renewable energies, new materials and construction techniques.
This new scenario will be possible if the EPBD will spread all over the housing sector, from the designer to the building owners, and this is why the first chapters were dedicated to introduce and explain the European energy guideline and the technical regulation for Hungary and Italy.

As we have shown by using both Hungarian and Italian procedures, the Energy Certification is able to assess correctly all the factors playing a role during the lifetime of a building. Furthermore, the designer or in general the qualified expert issuing the EPC can find and then propose to the building owners solutions to improve energy efficiency and reduce maintenance and use costs.
This is the core of the EPC, as we have seen in the Certification made for the University library of Debrecen, and benefits can be obtained even if the project is referring to a different technical

specifications. As we have seen with Italian and Hungarian cases, the result do not vary in a significant way, because we are dealing with regulations based on scientific studies of energy use in buildings. Most of the time the diversification is caused by different legislation, standards and requirement that change even within the same country, as seen for Italy.

Anyway EPC, although it's the most visible part of the EPBD, is still a "work in progress", with technical specifications that need to be continuously updated, language and legislation barriers to overcome and weak points that have to be fixed, as we have seen in the comparison between the Hungarian and Italian procedure.

The first step for EU member states is the full and proper adoption of EPBD, with an effective implementation that oversees regionals specifications, especially for countries with a very diversified legislation like Italy, through nationally tailored adjustments. Only in this way every project will not need to be updated and modified depending on the legislation of the country or region where it is built, and comparisons among European states will be made easily.

A part of the job has been done, but there is still a long way to go, as it can be seen in all the discussions between the EU countries on how to implement the respective articles of the EPBD recast. A broad range of topics, including, among others, software programs, qualification requirements for auditors and quality assurance of certificates, modalities of transferring and storing energy performance certificates, publishing of certificates and adaptation of the certificate to new requirements (especially concerning the nearly zero-energy buildings requirement and the cost-optimum methodology), layout and information included in the certificate, acceptance of the certificate in the real estate sector, and use of certificate data for monitoring processes has yet to be discussed to reach common results generally accepted and valid for everybody.

More surveys and studies are needed to assess correctly the influence of EPC on the market value of buildings and its impact on employment, and at the same time state administration have to offer subsidies on the basis of energy certification to motivate project developers to apply increasingly more efficient technologies.

Continued efforts are and will be needed across the board to reap the full benefits that lie inside this Directive, especially to slim and clarify the energy guideline and make them simpler to understand for every citizen who wants to issue an EPC for his property.

We hope that during our energy report even a lay reader was able to follow the general guideline, and at the end of the work he can realize what the designer has found out during his calculations and how it is possible to improve the efficiency of a the building and reduce its use costs.

The commercial softwares, as the one it has been used, can help the public to get along with Energy Certification with a direct and immediate impact that does not require particular scientific knowledge and technical competences.

The retrofit and refurbishment of buildings in this sense is the sector with the most unexpressed potential that can guarantee jobs and energy savings for a lot of countries, especially the ones with an old and quite inefficient housing stock as Hungary that needs severe renovations to meet the requirements set by the EPBD.

Hopefully in an immediate future whenever entering in an estate agency we will not only look to the price, net area, location and design of a building but also to its energy category, and this will become a decisive factor influencing the buyer's decisions.
New energy policies, with the support of stakeholders, universities and research institutes, have to be published to support and enforce the EPBD into achieving the ambitious goal for all new buildings constructed in Europe to become nearly-zero energy buildings by 2020.

The EPC can become an incisive mean for every citizen of the European Union to enhance the conditions of their private houses and for governments to renovate their public ownership, achieving results that can be actually perceived during the use phase of the building with money saving and better living conditions (visual, acoustic and thermal comfort).
Besides this, every time a building's tenant or owner issues an EPC he will find out and discover more about energy performance, efficiency and energy costs; thus, he will change his way of thinking and he will be more aware of what is and how energy can be saved.

This is not something that happens every day, and that's why we all should start to think in a different way every time we look to a building; probably we will not see just some bricks, concrete walls and glass melt together, but we will discover an energy core that needs to unleash its full potential.

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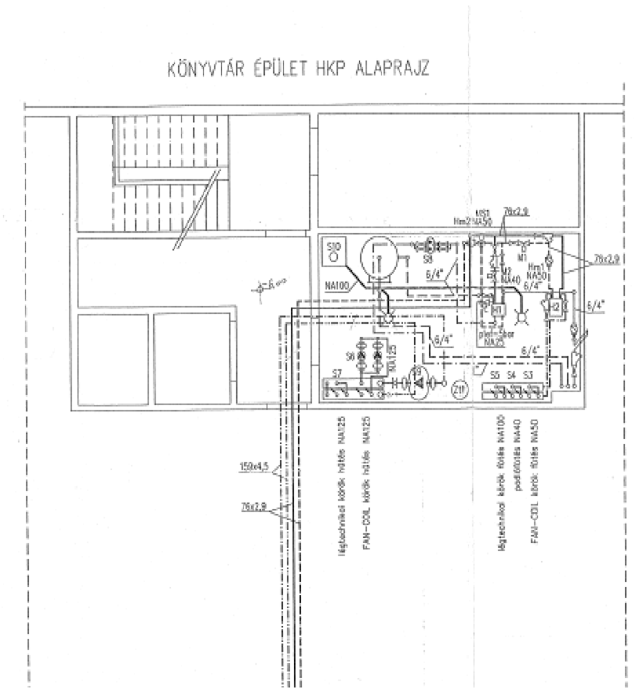
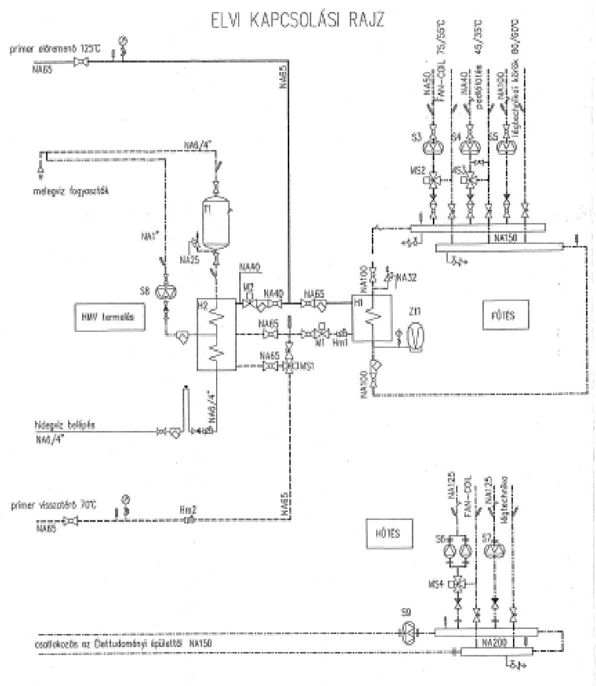
# APPENDIX

We will report here only the tables and technical details that cannot be found in the Hungarian and Italian specifications to accomplish the calculation of an EPC.

All the architecture and building service system data are contained in the plans provided by Dr. Kálmar Ferenc and, for obvious copyright reason, cannot be here attached.

A lot of information were also taken from manufacturer catalogues that can be found on the website link attached.



# HUNGARIAN CALCULATION

The total thermal transfer coefficient used in the Hungarian procedure are the following:

| | $\alpha_e$ W/m$^2$K | $1/\alpha_e$ m$^2$K/W | $\alpha_i$ W/m$^2$K | $1/\alpha_i$ m$^2$K/W |
|---|---|---|---|---|
| Vertical walls | 24 | 0.0416 | 8 | 0.125 |
| Floor on the soil | 8 | 0.125 | 6 | 0.166 |
| Basement floor | 6 | 0.166 | 6 | 0.166 |
| Flat roof | 10 | 0.10 | 10 | 0.10 |
| Mansard | 12 | 0.083 | 10 | 0.10 |
| Balconies | 24 | 0.0416 | 10 | 0.10 |

These are the corrective coefficient $\chi$ used to take in account the thermal bridge losses in the U-value of building elements.

| Határoló szerkezetek | | | A hőhidak hatását kifejező korrekciós tényező $\chi$ |
|---|---|---|---|
| Külső falak [1)] | külső oldali, vagy szerkezeten belüli megszakítatlan hőszigeteléssel | gyengén hőhidas | 0,15 |
| | | közepesen hőhidas | 0,20 |
| | | erősen hőhidas | 0,30 |
| | egyéb külső falak | gyengén hőhidas | 0,25 |
| | | közepesen hőhidas | 0,30 |
| | | erősen hőhidas | 0,40 |
| Lapostetők [2)] | | gyengén hőhidas | 0,10 |
| | | közepesen hőhidas | 0,15 |
| | | erősen hőhidas | 0,20 |
| Beépített tetőteret határoló szerkezetek [3)] | | gyengén hőhidas | 0,10 |
| | | közepesen hőhidas | 0,15 |
| | | erősen hőhidas | 0,20 |
| Padlásfödémek [4)] | | | 0,10 |
| Árkádfödémek [4)] | | | 0,10 |
| Pincefödémek [4)] | szerkezeten belüli hőszigeteléssel | | 0,20 |
| | alsó oldali hőszigeteléssel | | 0,10 |
| Fűtött és fűtetlen terek közötti falak, fűtött pincetereket határoló, külső oldalon hőszigetelt falak | | | 0,05 |

The value depends on the ratio length of thermal bridge\total opaque façade, and the three range are given in the table below.

| Határoló szerkezetek | A hőhidak hosszának fajlagos mennyisége (fm/m$^2$) | | |
|---|---|---|---|
| | Határoló szerkezet besorolása | | |
| | gyengén hőhidas | közepesen hőhidas | erősen hőhidas |
| Külső falak | < 0,8 | 0,8 – 1,0 | > 1,0 |
| Lapostetők | < 0,2 | 0,2 – 0,3 | > 0,3 |
| Beépített tetőtereket határoló szerkezetek | < 0,4 | 0,4 – 0,5 | > 0,5 |

In the calculation of heating consumption we report the value for $C_k$ , which depends on the net floor area, technology of the boiler and its location, inside or outside the heated space. The table contains also the values for the electrical consumption of the boiler $q_{k,v}$ .

VI.1. táblázat. A fűtött téren kívül elhelyezett kazánok teljesítménytényezői, $C_k$ és segédenergia igénye, $q_{k,v}$

| | Teljesítménytényezők $C_k$ [-] | | | |
|---|---|---|---|---|
| Alapterület $A_N$ [m$^2$] | Állandó hőmérsékletű kazán | Alacsony hőmérsékletű kazán | Kondenzációs kazán | Segédenergia $q_{k,v}$ [kWh/m$^2$/a] |
| 100 | 1,38 | 1,14 | 1,05 | 0,79 |
| 150 | 1,33 | 1,13 | 1,05 | 0,66 |
| 200 | 1,30 | 1,12 | 1,04 | 0,58 |
| 300 | 1,27 | 1,12 | 1,04 | 0,48 |
| 500 | 1,23 | 1,11 | 1,03 | 0,38 |
| 750 | 1,21 | 1,10 | 1,03 | 0,31 |
| 1000 | 1,20 | 1,10 | 1,02 | 0,27 |
| 1500 | 1,18 | 1,09 | 1,02 | 0,23 |
| 2500 | 1,16 | 1,09 | 1,02 | 0,18 |
| 5000 | 1,14 | 1,08 | 1,01 | 0,13 |
| 10000 | 1,13 | 1,08 | 1,01 | 0,09 |

VI.2. táblázat: A fűtött téren belül elhelyezett kazánok teljesítménytényezői, $C_k$ és segédenergia igénye, $q_{k,v}$

| | Teljesítménytényezők $C_k$ [-] | | | Segédenergia $q_{k,v}$ [kWh/m²/a] |
|---|---|---|---|---|
| Alapterület AN [m2] | Állandó hőmérsékletű kazán | Alacsony hőmérsékletű kazán | Kondenzációs kazán | |
| 100 | 1,30 | 1,08 | 1,01 | 0,79 |
| 150 | 1,24 | | | 0,66 |
| 200 | 1,21 | | | 0,58 |
| 300 | 1,18 | | | 0,48 |
| 500 | 1,15 | | | 0,38 |
| 750 | | | | 0,31 |
| 1000 | | | | 0,27 |
| 1500 | | | | 0,23 |
| 2500 | | | | 0,18 |
| 5000 | | | | 0,13 |
| 10000 | | | | 0,09 |

The tables below show the values for the heat losses in the terminals $q_{f,v}$ , depending as usual on the net floor area, supply/return temperature and location of the pipes inside or outside the heated spaces, the specific losses caused by the control systems $q_{f,h}$ and the electrical consumption of pumps in the hydraulic circuit $E_{FSz}$. (see Eq. 3.12)

| Alap-területig $A_N$ [m²] | A hőelosztás veszteségei $q_{f,v}$ [kWh/m²/a] Vízszintes elosztóvezetékek a fűtött téren kívül | | | |
|---|---|---|---|---|
| | 90/70°C | 70/55°C | 55/45°C | 35/28°C |
| 100 | 13,8 | 10,3 | 7,8 | 4,0 |
| 150 | 10,3 | 7,7 | 5,8 | 2,9 |
| 200 | 8,5 | 6,3 | 4,8 | 2,3 |
| 300 | 6,8 | 5,0 | 3,7 | 1,8 |
| 500 | 5,4 | 3,9 | 2,9 | 1,3 |
| > 500 | 4,6 | 3,4 | 2,5 | 1,1 |

| Alap-területig $A_N$ [m$^2$] | A hőelosztás veszteségei $q_{f,v}$ [kWh/m$^2$/a] Vízszintes elosztóvezetékek a fűtött téren belül | | | |
|---|---|---|---|---|
| | 90/70°C | 70/55°C | 55/45°C | 35/28°C |
| 100 | 4,1 | 2,9 | 2,1 | 0,7 |
| 150 | 3,6 | 2,5 | 1,8 | 0,6 |
| 200 | 3,3 | 2,3 | 1,6 | 0,6 |
| 300 | 3,0 | 2,1 | 1,5 | 0,5 |
| 500 | 2,8 | 2,0 | 1,4 | 0,5 |
| > 500 | 2,7 | 1,9 | 1,3 | 0,5 |

| Rendszer | Szabályozás | $q_{f,h}$ [kWh/m$^2$/a] | Megjegyzések |
|---|---|---|---|
| Vízfűtés Kétcsöves radiátoros és beágyazott fűtések | Szabályozás nélkül | 15,0 | |
| | Épület vagy rendeltetési egység egy központi szabályozóval (pl. szobatermosztáttal) | 9,6 | |
| | Termosztatikus szelepek és más arányos szabályozók 2 K arányossági sávval | 3,3 | |
| | 1 K arányossági sávval | 1,1 | |
| | Elektronikus szabályozó | 0,7 | Idő- és hőmérséklet szabályozás PI - vagy hasonló tulajdonsággal |
| | Elektronikus szabályozó optimalizálási funkcióval | 0,4 | Pl. ablaknyitás, jelenlét érzékelés funkciókkal kibővítve |
| Egycsöves fűtések | Épület vagy rendeltetési egység 1 központi szabályozóval (pl. szobatermosztáttal) | 9,6 | Pl. lakásonkénti vízszintes egycsöves rendszer |
| | Időjárásfüggő központi szabályozás helyiségenkénti szabályozás nélkül | 5,5 | Pl. panelépületek átfolyós vagy átkötő szakaszos rendszere |
| | Termosztatikus szelepekkel | 3,3 | |

VI.9. táblázat: Fajlagos villamos segédenergia igény [kWh/m$^2$/a] 20, 15, 10 és 7 K hőfoklépcső esetén, $E_{FSz}$

| Alap-területig $A_N$ [m$^2$] | Fordulatszám szabályozású szivattyú | | | | Állandó fordulatú szivattyú | | | |
|---|---|---|---|---|---|---|---|---|
| | Szabad fűtőfelületek | | | Beágyazott fűtőfelületek | Szabad fűtőfelületek | | | Beágyazott fűtőfelületek |
| | 20 K 90/70 °C | 15 K 70/55 °C | 10 K 55/45 °C | 7 K | 20 K 90/70 °C | 15 K 70/55 °C | 10 K 55/45 °C | 7 K |
| 100 | 1,69 | 1,85 | 1,98 | 3,52 | 2,02 | 2,22 | 2,38 | 4,22 |
| 150 | 1,12 | 1,24 | 1,35 | 2,40 | 1,42 | 1,56 | 1,71 | 3,03 |
| 200 | 0,86 | 0,95 | 1,06 | 1,88 | 1,11 | 1,24 | 1,38 | 2,44 |
| 300 | 0,61 | 0,68 | 0,78 | 1,39 | 0,81 | 0,91 | 1,04 | 1,85 |
| 500 | 0,42 | 0,48 | 0,57 | 1,01 | 0,57 | 0,65 | 0,78 | 1,38 |
| 750 | 0,33 | 0,38 | 0,47 | 0,83 | 0,45 | 0,52 | 0,64 | 1,14 |
| 1000 | 0,28 | 0,33 | 0,42 | 0,74 | 0,39 | 0,46 | 0,58 | 1,02 |
| 1500 | 0,23 | 0,28 | 0,37 | 0,65 | 0,33 | 0,39 | 0,51 | 0,90 |
| 2500 | 0,20 | 0,24 | 0,33 | 0,58 | 0,28 | 0,34 | 0,46 | 0,81 |
| 5000 | 0,17 | 0,22 | 0,30 | 0,53 | 0,24 | 0,30 | 0,42 | 0,74 |
| 10000 | 0,16 | 0,20 | 0,28 | 0,50 | 0,22 | 0,28 | 0,40 | 0,70 |

Going on with DHW consumption (Eq. 3.13), these tables down below contain all the values for $q_{HMV,v}$, $q_{HMV,t}$ and $E_C$.

VII.4. táblázat: A melegvíztárolás fajlagos vesztesége, $q_{HMV,t}$ (a tároló a fűtött légtéren belül)

| Alap-terü-letig $A_N$ [m$^2$] | A tárolás hőveszteségе a nettó melegvízkészítési hőigény százalékában | | | |
|---|---|---|---|---|
| | A tároló a fűtött légtéren belül | | | |
| | Indirekt fűtésű tároló | Csúcson kívüli árammal működő elektromos bojler | Nappali árammal működő elektromos bojler | Gázüzemű bojler |
| | % | % | % | % |
| 100 | 24 | 20 | 13 | 78 |
| 150 | 17 | 16 | 10 | 66 |
| 200 | 14 | 14 | 8 | 58 |
| 300 | 10 | 12 | 7 | 51 |
| 500 | 7 | 8 | 6 | 43 |
| > 500 | 5 | 6 | 5 | 35 |

VII.5. táblázat: A melegvíztárolás fajlagos vesztesége, $q_{HMV,t}$ (a tároló a fűtött légtéren kívül)

| Alap-terü-letig $A_N$ [m$^2$] | A tárolás hőveszteségе a nettó melegvízkészítési hőigény százalékában | | | |
|---|---|---|---|---|
| | A tároló a fűtött légtéren kívül | | | |
| | Indirekt fűtésű tároló | Csúcson kívüli árammal működő elektromos bojler | Nappali árammal működő elektromos bojler | Gázüzemű bojler |
| | % | % | % | % |
| 100 | 28 | 24 | 16 | 97 |
| 150 | 21 | 20 | 12 | 80 |
| 200 | 16 | 16 | 10 | 69 |
| 300 | 12 | 14 | 8 | 61 |
| 500 | 9 | 10 | 6 | 53 |
| 750 | 6 | 8 | 5 | 49 |
| 1000 | 5 | 8 | 4 | 46 |
| 1500 | 4 | 7 | 4 | 40 |
| 2500 | 4 | 6 | 3 | 32 |
| 5000 | 3 | 5 | 2 | 26 |
| 10000 | 2 | 4 | 2 | 22 |

## 4. A melegvíz elosztás veszteségei

VII.6. táblázat: A melegvíz elosztó és cirkulációs vezeték fajlagos energiaigénye, $q_{HMV,v}$

| Alap-területig $A_N$ [m$^2$] | Az elosztás hőveszteségе a nettó melegvíz készítési hőigény százalékában | | | |
|---|---|---|---|---|
| | Cirkulációval | | Cirkuláció nélkül | |
| | Elosztás a fűtött téren kívül | Elosztás a fűtött téren belül | Elosztás a fűtött téren kívül | Elosztás a fűtött téren belül |
| | % | % | % | % |
| 100 | 28 | 24 | 13 | 10 |
| 150 | 22 | 19 | | |
| 200 | 19 | 17 | | |
| 300 | 17 | 15 | | |
| 500 | 14 | 13 | | |
| 750 | 13 | 12 | | |
| > 750 | 13 | 12 | | |

5. A cirkulációs vezeték fajlagos segédenergia igénye

VII.7. táblázat. A cirkulációs vezeték fajlagos segédenergia igénye, $E_c$

| Alapterületig $A_N$ [$m^2$] | Fajlagos segédenergia igény [$kWh/m^2/a$] |
|---|---|
| 100 | 1,14 |
| 150 | 0,82 |
| 200 | 0,66 |
| 300 | 0,49 |
| 500 | 0,34 |
| 750 | 0,27 |
| 1000 | 0,22 |
| 1500 | 0,18 |
| 2500 | 0,14 |
| 5000 | 0,11 |
| > 5000 | 0,10 |

Now we provide the parameters to properly assess the ventilation and A/C consumption $E_{LT}$ (Eq. 3.14).

VIII.1. táblázat: Ventilátorok összhatásfoka, $\eta_{vent}$

| | Ventilátor térfogatárama $V_{LT}$ [$m^3/h$] | Ventilátor összhatásfoka $\eta_{vent}$ [-] |
|---|---|---|
| Nagy ventilátorok | $10.000 \leq V_{LT}$ | 0,70 |
| Közepes ventilátorok | $1.000 \leq V_{LT} < 10.000$ | 0,55 |
| Kis ventilátorok | $V_{LT} < 1.000$ | 0,40 |

VIII.2. táblázat: A teljesítmény és az igény illesztésének pontatlansága miatti veszteség a nettó hőigény százalékában, $f_{LT,sz}$

| Rendszer | Hőmérséklet szabályozás módja | $f_{LT,sz}$ % | Megjegyzés |
|---|---|---|---|
| 20 °C feletti befúvási hőmérséklet esetén | Helyiségenkénti szabályozás | 5 | Érvényes az egyes helyi (helyiségenkénti) és a központi kialakításokra, függetlenül a levegő melegítés módjától. |
| | Központi előszabályozással, helyiségenkénti szabályozás nélkül | 10 | |
| | Központi és helyiségenkénti szabályozás nélkül | 30 | |
| 20 °C alatti befúvási hőmérséklet esetén | | 0 | Pl.: hővisszanyerős rendszer utófűtő nélkül |

VIII.3. táblázat: Kör keresztmetszetű légcsatornák egységnyi hosszra vonatkoztatott hőátbocsátási tényezője $U_{kör}$ [W/mK] a csőátmérő, sebesség és hőszigetelés függvényében

| Cső átmérő $d$ [mm] | Szigetelés nélkül | | | 20 mm hőszigetelés | | | 50 mm hőszigetelés | | |
|---|---|---|---|---|---|---|---|---|---|
| | Áramlási sebesség $w_{lev}$ [m/s] | | | | | | | | |
| | 2 | 4 | 6 | 2 | 4 | 6 | 2 | 4 | 6 |
| 100 | 1,39 | 1,83 | 2,08 | 0,53 | 0,57 | 0,59 | 0,32 | 0,33 | 0,34 |
| 150 | 1,95 | 2,57 | 2,93 | 0,73 | 0,80 | 0,83 | 0,43 | 0,45 | 0,46 |
| 200 | 2,48 | 3,28 | 3,74 | 0,94 | 1,03 | 1,06 | 0,53 | 0,56 | 0,57 |
| 300 | 3,49 | 4,63 | 5,29 | 1,33 | 1,47 | 1,52 | 0,75 | 0,79 | 0,80 |
| 500 | 5,49 | 7,27 | 8,30 | 2,13 | 2,34 | 2,43 | 1,17 | 1,23 | 1,25 |
| 800 | 8,30 | 11,0 | 12,5 | 3,29 | 3,63 | 3,78 | 1,79 | 1,88 | 1,92 |
| 1000 | 10,1 | 13,4 | 15,3 | 4,05 | 4,48 | 4,66 | 2,20 | 2,32 | 2,37 |
| 1250 | 12,2 | 16,2 | 18,5 | 4,99 | 5,52 | 5,76 | 2,71 | 2,86 | 2,92 |
| 1600 | 15,2 | 20,1 | 23,0 | 6,29 | 6,97 | 7,28 | 3,42 | 3,61 | 3,69 |

VIII.4. táblázat: Négyszög keresztmetszetű légcsatornák belső felületre vonatkoztatott hőátbocsátási tényezője a sebesség és hőszigetelés függvényében, $U_{nsz}$ [W/m$^2$K]

| Áramlási sebesség $w_{lev}$ [m/s] | Szigetelés vastagsága [mm] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 80 | 100 |
| 1 | 2,60 | 1,60 | 1,16 | 0,91 | 0,75 | 0,64 | 0,55 | 0,44 | 0,36 |
| 2 | 3,69 | 1,95 | 1,33 | 1,01 | 0,82 | 0,68 | 0,69 | 0,46 | 0,38 |
| 3 | 4,40 | 2,12 | 1,41 | 1,05 | 0,84 | 0,70 | 0,60 | 0,47 | 0,39 |
| 4 | 4,90 | 2,23 | 1,45 | 1,08 | 0,86 | 0,72 | 0,61 | 0,48 | 0,39 |
| 5 | 5,29 | 2,30 | 1,48 | 1,10 | 0,87 | 0,72 | 0,62 | 0,48 | 0,39 |
| 6 | 5,60 | 2,36 | 1,51 | 1,11 | 0,88 | 0,73 | 0,62 | 0,48 | 0,39 |

A légcsatorna $f_v$ veszteségtényezője fűtött téren kívül haladó légcsatorna esetén $f_v = 1$, fűtött térben haladó vezetékeknél $f_v = 0{,}15$ értékkel számítható.

Here below we report the values $C_h$ for cooling machines (Eq. 3.21).

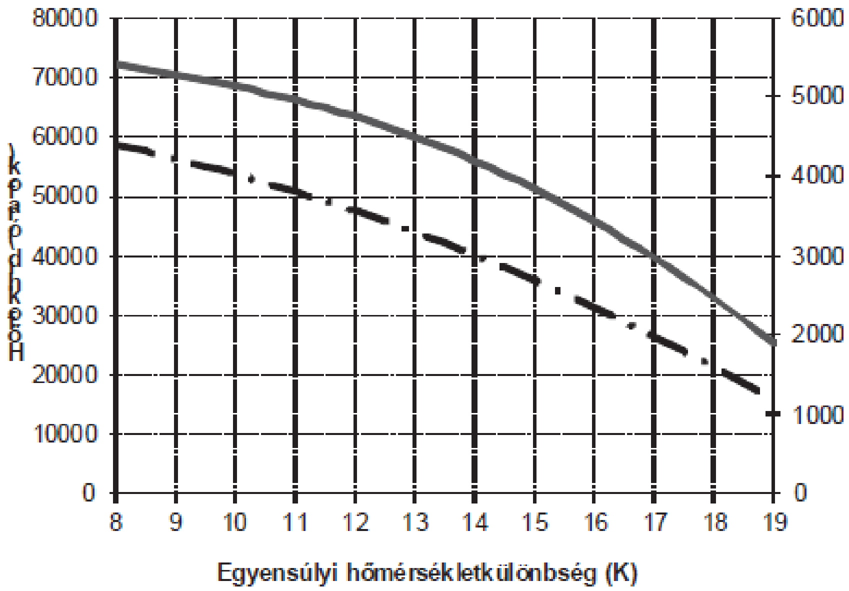
IX.1. táblázat: szezonális teljesítménytényező, EER és hűtési teljesítménytényező értékek, $C_h$

| Hűtőgép típusa | EER | $C_h$ |
|---|---|---|
| Kompresszoros léghűtés (split) | 2,5 | 0,40 |
| Léghűtéses kompakt és osztott kivitelű (távkondenzátoros) folyadékhűtő | 3,0 | 0,33 |
| Vízhűtéses folyadékhűtők (scroll kompresszor) | 4,3 | 0,23 |
| Vízhűtéses folyadékhűtők (csavar kompresszor) | 5,0 | 0,20 |
| Vízhűtéses folyadékhűtők (turbó kompresszor) | 7,0 | 0,14 |
| Talajhő/víz elektromos hőszivattyú | 5,0 | 0,20 |
| Fölgáz üzemű hőszivattyú, a gázmotor hulladékhője hasznosítva van | 1,7 | 0,58 |
| Fölgáz üzemű hőszivattyú, a gázmotor hulladékhője hasznosítva van | 1,4 | 0,71 |

It is also reported the climatic curve for heating degree days and length of heating season H and $Z_F$ depending on balance temperature difference $\Delta t_b$. (Eq. 3.9)

I.1. táblázat: Hőfokhíd és fűtési idény hossza 20 $^{O}$C belső hőmérséklet esetén az egyensúlyi hőmérsékletkülönbség függvényében

| Egyensúlyi hőmérséklet-különbség [K] | Hőfokhíd [hK] | Idény hossza [h] |
|---|---|---|
| ≤ 8,0 | 72000 | 4400 |
| 9,0 | 70325 | 4215 |
| 10,0 | 68400 | 4022 |
| 11,0 | 66124 | 3804 |
| 12,0 | 63405 | 3562 |
| 13,0 | 60010 | 3295 |
| 14,0 | 55938 | 3003 |
| 15,0 | 51191 | 2687 |
| 16,0 | 45766 | 2346 |
| 17,0 | 39666 | 1980 |
| 18,0 | 32889 | 1590 |
| 19,0 | 25436 | 1175 |




1. ábra: Hőfokhíd és fűtési idény hossza 20 $^{O}$C belső hőmérséklet esetén az egyensúlyi hőmérsékletkülönbség függvényében

These are the standard values for irradiation during winter and summer season $I_b$ and $I_{nyár}$ and the specific solar gains $Q_{TOT}$.

I.3. táblázat: A napsugárzásra vonatkozó tervezési adatok

| A számítás célja | Tájolás | | |
|---|---|---|---|
| | É | D | K - N |
| Sugárzási energiahozam a fűtési idényre fajlagos hőveszteségtényező számításához $Q_{TOT}$ [kWh/m²/a] | 100 | 400 | 200 |
| Átlagintenzitás egyensúlyi hőmérsékletkülönbség számításához $I_b$ [W/m²] | 27 | 96 | 50 |
| Átlagintenzitás nyári túlmelegedés kockázatának számításához $I_{nyár}$ [W/m²] | 85 | 150 | 150 |

Az ÉK-ÉNY szektorban az északi tájolás adatai mérvadók.

Here we can find the table to calculate the number of days of cooling season $n_{hű}$ and the air change rate $n_{nyár}$ depending on the number of windows and aperture in the façade.

I.4. táblázat:A nyári félévben a középhőmérsékletek eloszlása

1.

| $t_{e,közepes}$ °C | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $n_{hű}$ | 110 | 95 | 80 | 66 | 52 | 38 | 25 | 15 | 8 | 5 | 3 | 1 |

## II. Légcsereszám tervezési adatok a nyári túlmelegedés kockázatának megítéléséhez

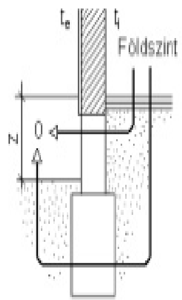
II.1. táblázat: Légcsereszám tervezési adatok a nyári túlmelegedés kockázatának megítéléséhez természetes szellőztetés esetén

| A légcsereszám tervezési értékei nyáron, természetes szellőztetéssel | | Nyitható nyílások | |
|---|---|---|---|
| | | egy homlokzaton | több homlokzaton |
| Éjszakai szellőztetés | nem lehetséges | 3 | 6 |
| | lehetséges | 5 | 9 |

Éjszakai szellőztetés esetében a nagyobb érték az alacsonyabb hőmérsékletű külső levegő kedvező előhűtő hatását fejezi ki.

In these two charts are shown the fictive heat transfer coefficient Ψ for external walls and basement floor, depending on the U-value of walls and on the thermal resistance of the floor in contact with the ground.

III.1. táblázat: A talajon fekvő padlók vonalmenti hőátbocsátási tényezői a kerület hosszegységére vonatkoztatva




| A padlószint és a talajszint közötti magasság-különbség z (m) | A padlószerkezet hővezetési ellenállása a kerület mentén legalább 1,5 m szélességű sávban[1) ] $R = \frac{d}{\lambda} (m^2K/W)$ | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Szigete-letlen | 0,20--0,35 | 0,40--0,55 | 0,60--0,75 | 0,80--1,00 | 1,05--1,50 | 1,55--2,00 | 2,05--3,00 | 3,05-4,00 | 4,05-5,00 | 5,05-6,00 | 6,05-7,00 |
| -6,00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -6,00...-4,05 | 0,20 | 0,20 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0,15 | 0 | 0 | 0 | 0 |
| -4,00...-2,55 | 0,40 | 0,40 | 0,35 | 0,35 | 0,35 | 0,35 | 0,30 | 0,30 | 0,10 | 0,10 | 0 | 0 |
| -2,50...-1,85 | 0,60 | 0,55 | 0,55 | 0,50 | 0,50 | 0,50 | 0,45 | 0,40 | 0,20 | 0,15 | 0,10 | 0 |
| -1,80...-1,25 | 0,80 | 0,70 | 0,70 | 0,65 | 0,60 | 0,60 | 0,55 | 0,45 | 0,30 | 0,22 | 0,177 | 0,13 |
| -1,20...-0,75 | 1,00 | 0,90 | 0,85 | 0,80 | 0,75 | 0,70 | 0,65 | 0,55 | 0,40 | 0,31 | 0,25 | 0,21 |
| -0,70...-0,45 | 1,20 | 1,05 | 1,00 | 0,95 | 0,90 | 0,80 | 0,75 | 0,65 | 0,50 | 0,40 | 0,33 | 0,29 |
| -0,40...-0,25 | 1,40 | 1,20 | 1,10 | 1,05 | 1,00 | 0,90 | 0,80 | 0,70 | 0,60 | 0,49 | 0,41 | 0,37 |
| -0,20...+0,20 | 1,75 | 1,45 | 1,35 | 1,25 | 1,15 | 1,05 | 0,95 | 0,85 | 0,70 | 0,58 | 0,50 | 0,45 |
| 0,25....0,40 | 2,10 | 1,70 | 1,55 | 1,45 | 1,30 | 1,20 | 1,05 | 0,95 | 0,75 | 0,62 | 0,53 | 0,48 |
| 0,45....1,00 | 2,35 | 1,90 | 1,70 | 1,55 | 1,45 | 1,30 | 1,15 | 1,00 | 0,80 | 0,66 | 0,56 | 0,51 |
| 1,05....1,50 | 2,55 | 2,05 | 1,85 | 1,70 | 1,55 | 1,40 | 1,25 | 1,10 | 0,95 | 0,70 | 0,60 | 0,55 |

[1)] A szigetelt sáv függőleges is lehet: a szigetelés a pincefalon vagy a lábazaton is elhelyezhető (a magasságkülönbség előjelének megfelelően). A vízszintes és függőleges helyzetű szigetelt sávok összegezett kiterített szélességének minimális szélessége 1,5m.

III.2. táblázat: A pincefalak vonalmenti hőátbocsátási tényezői a kerület hosszegységére vonatkoztatva

| A talajjal érintkező falszakasz magassága [m] | A falszerkezet hőátbocsátási tényezője | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0,30… 0,39 | 0,40… 0,49 | 0,50… 0,64 | 0,65… 0,79 | 0,80… 0,99 | 1,00… 1,19 | 1,20… 1,49 | 1,50… 1,79 | 1,80… 2,20 |
| …- 6,00 | 1,20 | 1,40 | 1,65 | 1,85 | 2,05 | 2,25 | 2,45 | 2,65 | 2,80 |
| - 6,00…- 5,05 | 1,10 | 1,30 | 1,50 | 1,70 | 1,90 | 2,05 | 2,25 | 2,45 | 2,65 |
| - 5,00…- 4,05 | 0,95 | 1,15 | 1,35 | 1,50 | 1,65 | 1,90 | 2,05 | 2,25 | 2,45 |
| - 4,05…- 3,05 | 0,85 | 1,00 | 1,15 | 1,30 | 1,45 | 1,65 | 1,85 | 2,00 | 2,20 |
| - 3,00…- 2,05 | 0,70 | 0,85 | 1,00 | 1,15 | 1,30 | 1,45 | 1,65 | 1,80 | 2,00 |
| - 2,00…- 1,55 | 0,55 | 0,70 | 0,85 | 1,00 | 1,15 | 1,30 | 1,45 | 1,65 | 1,80 |
| -1,50…- 1,05 | 0,45 | 0,60 | 0,70 | 0,85 | 1,00 | 1,10 | 1,25 | 1,40 | 1,55 |
| - 1,00…- 0,75 | 0,35 | 0,45 | 0,55 | 0,65 | 0,75 | 0,90 | 1,00 | 1,15 | 1,30 |
| - 0,70…- 0,45 | 0,30 | 0,35 | 0,40 | 0,50 | 0,60 | 0,65 | 0,80 | 0,90 | 1,05 |
| - 0,40…- 0,25 | 0,15 | 0,20 | 0,30 | 0,35 | 0,40 | 0,50 | 0,55 | 0,65 | 0,74 |
| - 0,40… | 0,10 | 0,10 | 0,15 | 0,20 | 0,25 | 0,30 | 0,35 | 0,45 | 0,45 |

These two tables contain a list of parameter used in several calculus, including the energy transformation factor depending on the energy source.

## IV. Épületekre vonatkozó tervezési adatok

IV.1. táblázat: Tervezési adatok

| Az épület rendeltetése | Légcsere-szám fűtési idényben $n$ [1/h] 1) | 2) | 3) | Használati melegvíz nettó hőenergia Igénye $q_{HMV}$ [kWh/m²/a ] | Világítás energia igénye $q_{vil}$ [kWh/m²/a] | Világítási energia Igény korrekciós szorzó $\upsilon$ 4) | Szakaszos üzem korrekciós szorzó $\sigma$ 5) | Belső hő-nyereség átlagos értéke $q_b$ [W/m²] |
|---|---|---|---|---|---|---|---|---|
| Lakóépületek 6) | 0,5 | | | 30 | (4) 9) | - | 0,9 | 5 |
| Irodaépületek 7) | 2 | 0,3 | 0,8 | 9 | 11 | 0,7 | 0,8 | 7 |
| Oktatási épületek 8) | 2,5 | 0,3 | 0,9 | 7 | 6 | 0,6 | 0,8 | 9 |

| Energia | $e$ |
|---|---|
| elektromos áram | 2, 50 |
| csúcson kívüli elektromos áram | 1,80 |
| földgáz | 1,00 |
| tüzelőolaj | 1,00 |
| szén | 1,00 |
| tüzifa, biomassza, pellet | 0,60 |
| megújuló (pl. napenergia) | 0,00 |

| Távfűtés esetén | | $e$ földgáz | $e$ biomassza |
|---|---|---|---|
| fűtőművi távfűtés* | | 1,26 | 076 |
| távfűtés kapcsolt energiatermelés* | kombinált ciklusú (ellennyomású) | 0,71 | 0,43 |
| | kombinált ciklusú (elvételes-kondenzációs) | 0,43 | 0,26 |
| | gőzkörfolyamatú (ellennyomású) | 0,87 | 0,52 |
| | gázmotor ( > 1 MWe) | 0,55 | 0,33 |
| | gázmotor ( ≤ 1 MWe) | 0,72 | 0,43 |
| | gázturbina hőhasznosítóval | 0,82 | 0,49 |

# ITALIAN CALCULATION

The transfer coefficient with Italian regulation are:

| | $\alpha_e$ W/m$^2$K | 1/ $\alpha_e$ m$^2$K/W | $\alpha_i$ W/m$^2$ K | 1/$\alpha_i$ m$^2$K/W |
|---|---|---|---|---|
| Vertical walls | 25 | 0.04 | 8 | 0.125 |
| Floor on the soil | 25 | 0.04 | 6 | 0.166 |
| Basement floor | 6 | 0.166 | 6 | 0.166 |
| Flat roof | 25 | 0.04 | 10 | 0.10 |

Summer $EP_e$:

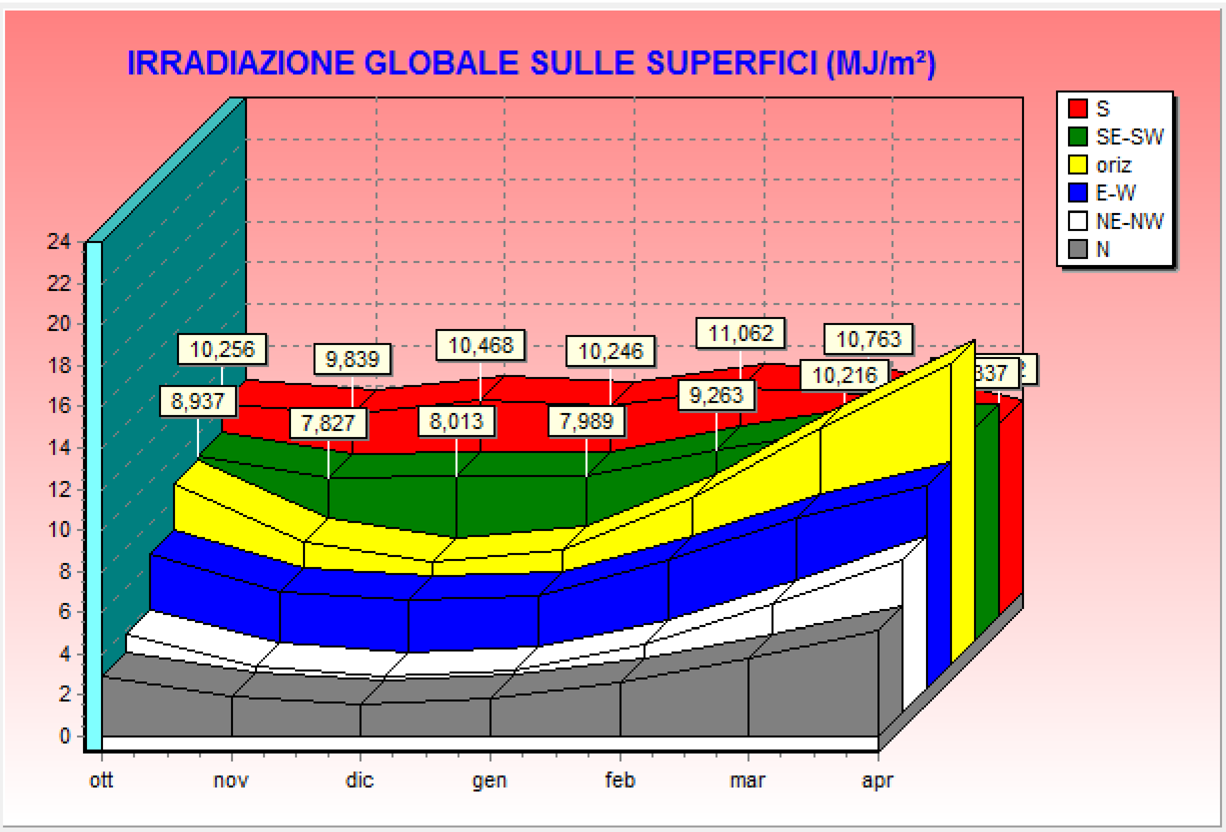
Coling performance is currently evaluated in the Italian certification by assessing an $EP_e$ for the envelope of the building that takes in account transmission losses, solar and internal gains but not the primary energy effectively used in the power plant.
It follows a range of classes for summer performance which are shown in the following table:

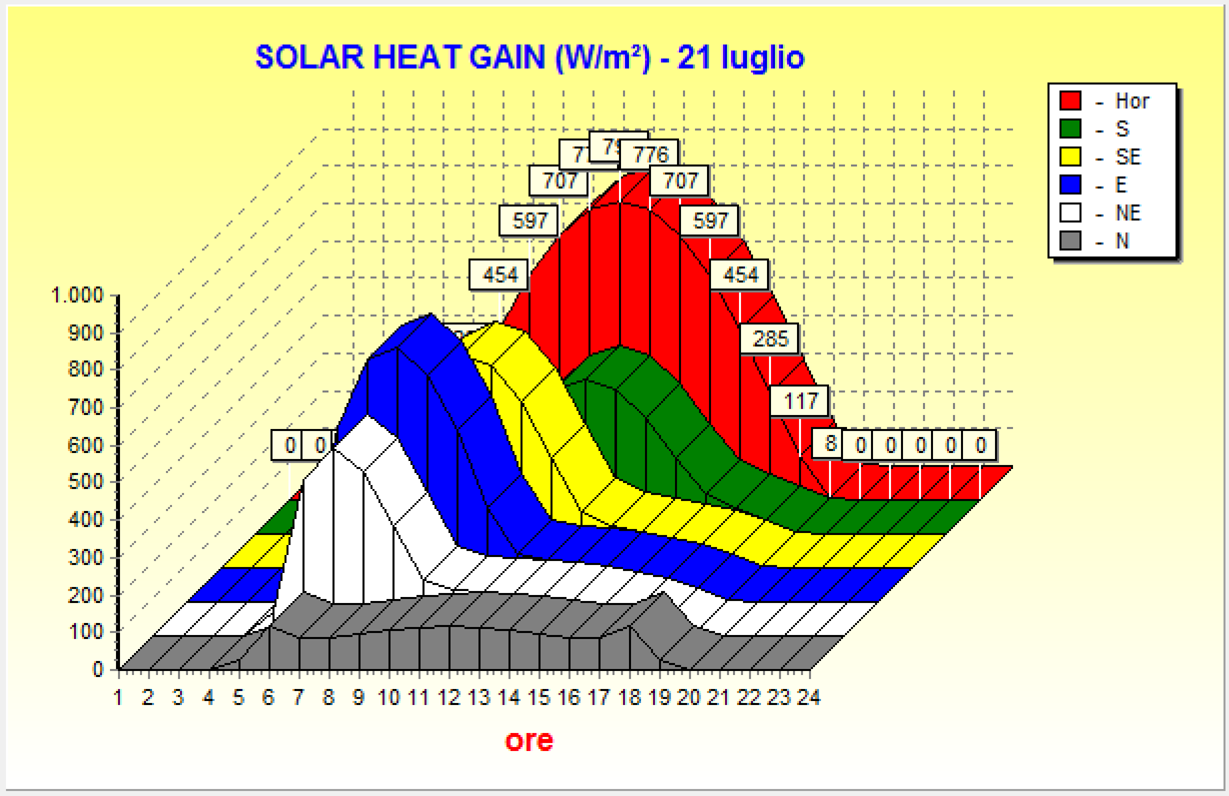
| EP e, thermal load (kWh/m$^2$ year) | Evaluation | Performance quality |
|---|---|---|
| EP e, thermal load < 10 | Optimal | I |
| EP e, thermal load < 20 | Good | II |
| EP e, thermal load < 30 | Medium | III |
| EP e, thermal load < 40 | Sufficient | IV |
| EP e, thermal load > 40 | Poor | V |

The evaluation can be also made with a dynamic approach, by assessing phase and shift of the heat gain. The correspondent categories are the following:

| Phase shift | Attenuation factor | Performance | Performance indicator |
|---|---|---|---|
| S>12 | Fa<0.15 | Excellent | I |
| 12≥S>10 | 0.15<Fa<0.30 | Good | II |
| 10≥S>8 | 0.30<Fa<0.40 | Average | III |
| 8≥S>6 | 0.40<Fa<0.60 | Sufficient | IV |
| 6≥S | 0.60<Fa | poor | V |

Here below the global irradiance during winter season and specific solar gains for the locality (Cuneo) used in the Italian certification.





SOLAR HEAT GAIN (W/m²) - 21 luglio
- Hor
- S
- SE
- E
- NE
- N
1.000
900
800
700
600
500
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
ore
0
0
454
597
707
776
707
597
454
285
117
8
0
0
0
0
0

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FACOLTA' DI INGEGNERIA

CORSO DI LAUREA MAGISTRALE IN INGEGNERIA MECCANICA

Dipartimento di Ingegneria Industriale

# ENERGY ANALYSIS AND RENOVATION PROPOSAL FOR A LIBRARY IN THE UNIVERSITY OF DEBRECEN

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ACADEMIC YEAR 2012/2013