NTNU – Trondheim
Norwegian University of
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A comparative study of energy certification systems for buildings

Jelena Milicevic

Master's Thesis
Submission date: April 2014
Supervisor: Vojislav Novakovic, EPT

Norwegian University of Science and Technology
Department of Energy and Process Engineering

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MASTER THESIS

for

Stud.techn. Jelena Milicevic

Spring 2013

A comparative study of energy certification systems for buildings

Sammenligning av ordninger for energisertifisering av bygninger

Background and objective

Buildings currently account for 40% of energy use in most countries, putting them among the largest end-use sectors. In order to reduce energy consumption in buildings, the European Parliament and the Council of the EU in 2002 adopted the Directive on energy performance of buildings (EPBD 2002/91/EC), and its recast in 2010 (EPBD 2010/31/EU). The objective of this Directive is to promote the improvement of the energy performance of buildings within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. One of the aims of WBC is joining the EU. For that purpose the Energy Community was established. As all WBC are signatories of the Energy Community Treaty, they are obliged to transpose the requirements of all energy related EU directives and regulation, including the EPBD.

Aim of this assignment is to analyse methodologies for building energy certification as one of means for promotion and improvement of energy efficiency in buildings in EU countries. A key activity will be to investigate the current state on energy certification of buildings in WBC, Norway, and some countries in Europe.

This assignment is realised as a part of the collaborative project "Sustainable Energy and Environment in Western Balkans" that aims to develop and establish five new internationally recognized MSc study programs for the field of "Sustainable Energy and Environment", one at each of the five collaborating universities in three different WB countries. The project is funded through the Norwegian Programme in Higher Education, Research and Development in the Western Balkans, Programme 3: Energy Sector (HERD Energy) for the period 2011-2013.

The following tasks are to be considered:

1) Literature study of the Directive on energy performance of buildings
2) Survey implementation of building energy certification in selected EU and non EU countries; e.g. Norway, Germany, Denmark, UK, Serbia, B&H, Croatia.

3) Analyse: legislation, standards, norms and technical regulations, calculation methodologies and tools (software), conditions and criteria for licensing, training programs for persons who perform energy audits and certification etc.
4) Establish few case buildings inside different building categories and compare energy certification calculation methodologies and tools (software) for these case buildings.

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Within 14 days of receiving the written text on the master thesis, the candidate shall submit a research plan for his project to the department.

When the thesis is evaluated, emphasis is put on processing of the results, and that they are presented in tabular and/or graphic form in a clear manner, and that they are analyzed carefully.

The thesis should be formulated as a research report with summary both in English and Norwegian, conclusion, literature references, table of contents etc. During the preparation of the text, the candidate should make an effort to produce a well-structured and easily readable report. In order to ease the evaluation of the thesis, it is important that the cross-references are correct. In the making of the report, strong emphasis should be placed on both a thorough discussion of the results and an orderly presentation.

The candidate is requested to initiate and keep close contact with his/her academic supervisor(s) throughout the working period. The candidate must follow the rules and regulations of NTNU as well as passive directions given by the Department of Energy and Process Engineering.

Risk assessment of the candidate's work shall be carried out according to the department's procedures. The risk assessment must be documented and included as part of the final report. Events related to the candidate's work adversely affecting the health, safety or security, must be documented and included as part of the final report. If the documentation on risk assessment represents a large number of pages, the full version is to be submitted electronically to the supervisor and an excerpt is included in the report.

Pursuant to "Regulations concerning the supplementary provisions to the technology study program/Master of Science" at NTNU §20, the Department reserves the permission to utilize all the results and data for teaching and research purposes as well as in future publications.

The final report is to be submitted digitally in DAIM. An executive summary of the thesis including title, student's name, supervisor's name, year, department name, and NTNU's logo and name, shall be submitted to the department as a separate pdf file. Based on an agreement with the supervisor, the final report and other material and documents may be given to the supervisor in digital format.

☐ Work to be done in lab (Water power lab, Fluids engineering lab, Thermal engineering lab)
☐ Field work

Department of Energy and Process Engineering, 17. September 2013

Olav Bolland
Department Head

Vojislav Novakovic
Academic Supervisor

Research Advisors: Prof. Branislav Zivkovic, University of Belgrade

Abstract

Due to the large amount of energy consumption in buildings and the biggest potential of energy and ecology savings, energy efficiency and sustainable construction represent the priorities of modern architecture and energetics today.
This paper shows a comparative analysis of energy certification of residential object in realistic environments with the aim of enhancing their energy efficiencies. Subjects of the analysis were two buildings - one in Norway (Oslo), and the other in Serbia (Belgrade). The buildings differ in: climate conditions, size, type of construction, heating systems, etc.
The calculation of yearly required heating and cooling energies was performed in German CASAnova software. The methodology is shown hereinafter.
Both buildings in this work, according to the calculated yearly heating energy consumption are classified as energy grade C.
In both objects it is possible to elevate the energy grade by remediation.

This assignment is realized as a part of the collaborative project "Sustainable Energy and Environment in Western Balkans" that aims to develop and establish five new internationally recognized MSc study programs for the field of "Sustainable Energy and Environment", one at each of the five collaborating universities in three different WB countries. The project is funded through the Norwegian Programme in Higher Education, Research and Development in the Western Balkans, Programme 3: Energy Sector (HERD Energy) for the period 2011-2014.

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1. INTRODUCTION

1.1 Forms of Energy

All usable energy originates from the three basic sources of energy: the energy of the Sun, the energy from the Earth, and the energy of gravity.

The Energy of the Sun

Although only a small portion of the Sun's energy reaches the surface of the Earth, the amount of it that actually reaches the Earth in a year's time is bigger than all the energy contained in the world's reserves of oil and coal. The energy of Sun's radiation is on Earth transformed into other forms of energy through processes of photosynthesis, evaporation and fluid flow.

The Energy from the Earth

It is the result of the heat of the Earth's core being conducted from the inside towards the surface. The energy from the Earth is most commonly used as the heat from hot springs and as a source of heat required for the operation of heat pumps.

The Energy of Gravity

It is the result of gravitational forces between the Sun, the Moon and the Earth.

Natural forms of the energy can be directly harnessed or can be converted into useful forms, most commonly mechanical and thermal energy, using transformation devices. In this case we can distinguish primary, secondary, final and useful energies.

Primary energy is considered to be the energy contained in the energy source (the carrier of energy, such as the chemical energy of the fuel). Secondary energy is acquired by energy transformation from primary energy and it represents the primary energy subtracted by conversion losses (e.g. electric energy produced by fuel combustion in thermal power plants). Final energy is the energy that reaches the end user (secondary energy subtracted by preparation and transmission losses). Useful energy is the energy used for satisfying the needs of the end users (final energy subtracted by the user's conversion losses).

1.2 Thermal balance of buildings

When setting a building's thermal balance the thermal sheathing, which separates the heated area from the environment (air and ground) and the non-heated rooms of the building (loft and/or basement area), is considered to be the border of the system.

For the winter mode of a building's usage it is necessary to consider the following:

- Windows and glazed surfaces – thermally most sensitive parts of the thermal sheathing, influencing ventilation and transmission losses;
- Useful heat gains from the Sun and indoor sources are taken into account;
- The heating system should only compensate for momentary thermal losses during the whole heating season, through proper regulation of the thermal performance;
- The heat source should be efficient.

The heat necessary to be delivered to a building for final consumption increases because of technical losses (in production, transformation and distribution), while on the other hand, it decreases due to useful thermal gains from the indoor sources, from the Sun's radiation that enters the heated rooms and the possible use of waste water (the return of the heat back to the heated area).

The calculation of the flows of energy is made for a specified area, i.e. zone (e.g. a flat, a building, etc.).

The order of the calculations of necessary energy is reverse to the energy flow direction.

The calculation process can be broken down into several steps:

1. The heat necessary to be brought to or taken away from the area in order to realize a desired state is calculated first;
2. The energy required for the operation of the heating energy delivery thermal system is calculated then;
3. the losses that occur in the heating system originate from: production (transforming the chemical energy of the fuel into heat and the dissipation of heat from the boiler into the surroundings), distribution (heat dissipation into the surroundings during heat fluid transport to the heaters), storing (heat dissipation into the surroundings from hot water storing tanks) and losses from heat exchange in the heated area itself;
4. Finally, the amount of primary energy is determined using conversion factors depending on the energy source.

Heat loss data is an input parameter for thermal systems' balance.
Some of the occurring losses can be used in the system itself, such as the return of waste heat in recuperative/regenerative air heaters or the use of waste heat of a cooling device's condensation. In addition to that, heat losses can be used in the building itself, such as the heat losses in heating fluid distribution pipelines that go through the heated area in the facility. However, a part of the losses that occur in the system cannot be used.

1.3 Energy consumption parameters

The parameters most influential to the consumption of energy of a building's thermal systems (heating, ventilation and air conditioning systems) can be classified into five groups:
1. Climate factors, which are determined by the location of the building;
2. Thermal sheathing and the geometry of the building;
3. Characteristics of the HVAC system, sources of energy and the levels of automatic regulation;
4. The mode of building and technical systems usage;
5. Expenses of operation, i.e. the prices of fuel and energy.

Climate factors, such as the annual range of air temperature and humidity, insolation and added radiation of the Sun, the amount of wind, etc. are characteristics of the building's location. During the design of the building and its technical systems it is necessary to be familiar with the region's climate characteristics that serve as input data for the calculations.

When it comes to the HVAC systems, input data required are: data on the thermal sheathing (engineering elements' heat penetration coefficients, doors' and windows' sealing capacity), winter and summer outer projected temperatures, length of heating and cooling periods, amount of wind in the area, location and orientation of the building, etc.

Buildings of the same purpose which are located in notably different climates are also significantly different in architecture, materials used and engineering solutions in their systems.

Thermal sheathing, the geometry of the building, its exposure to the Sun and winds directly affect its energy requirements. With better thermal insulation and doors' and windows' sealing, and smaller form factor, drops the requirement for the installed power of the heating system. Windows' good sealing capacity can significantly reduce ventilation heat losses. The size of the windows and the usage of daylight influences indoor lighting, electric power consumption and heat gains from indoor sources. Methods of protecting from the Sun's radiation during the summer can lower the thermal load of the building as well as the installed capacity of the cooling device. The layout of the rooms, atrium and gallery areas can have a significant effect when naturally ventilating the building.
By carefully choosing the HVAC system, the source of energy supply and the levels of automatic regulation it is possible to make big energy savings in these systems throughout the year.

In complex and large buildings with big investment values variant solutions are often considered, with multidisciplinary teams working on them. These teams consist of architects, mechanical and electrical engineers. So that the building have, during its lifespan, satisfactory energy performance it is necessary to regularly and properly maintain it and its systems. If there is no regular maintenance, and the functionality of the systems isn't completely disturbed, irrational consumption of energy will occur almost always.
When designing new systems, and more often when reconstructing existing systems, an integral part of the procedure is conducting a techno-economic analysis, i.e. examining the investment and operation expenses throughout the project's lifespan. However, the price of energy and fuel cannot always be precisely predicted on a long-term basis. If there is a disparity of the prices on the market irrational energy consumption will occur. A user's basic motivation is the price of heating and air conditioning. An extreme example is the amount of lump-sum heating charges in buildings that are part of remote heating control systems. A fixed monthly heating cost isn't conditioned by the energy consumed; therefore the users will to rationally use energy available is non-existent. The same applies to the office buildings in which the user doesn't pay the expenses, but does the owner. Low price of one type of fuel will provide for irrational consumption because it's cheaper than enforcing the energy-saving measures.

2. The Directive on the energy performance of buildings

With the increase of the standard of living increases the consumption of heating and cooling energy. Due to the large amount of energy consumption in buildings and the biggest potential of energy and ecology savings, energy efficiency and sustainable construction represent the priorities of modern architecture and energetics today. This is an area with the biggest potential for reducing the total consumption of energy since it is estimated that buildings use up to one third of the total produced energy. For a facility to be energy efficient it is necessary that, along with the implementation of new technologies and the introduction of high-quality materials and systems, thermal savings and energy savings in general be provided. The most common weak spots that can affect energy efficiency are:

- Energy loss through the roof
- Energy loss through windows- outer walls insulation
- Energy loss through basement ceiling and floor
- Energy loss through the heating system
- Losses caused by impractical ventilation

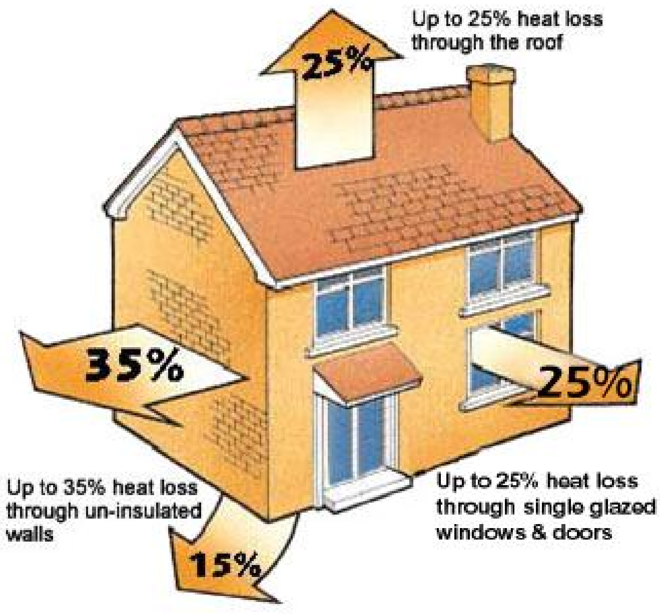


Figure 2-1: Heat losses

The advancement of energy efficiency in building construction is of extraordinary importance since the most rational and, on a long-term basis, most cost-effective solution for energy saving is investing in energy efficiency of buildings, i.e. thermal insulation materials and the usage of renewable sources, through which a building's value is increased and the quick regain of the invested finances is provided.

By introducing The Directive on Energy Performance of Buildings (EPBD – 2002/91/EC), the EU aimed to reduce the amount of energy being used in buildings, i.e. to determine the economic value of energy preservation.

The percentage of buildings' consumption of the total produced energy constantly increases. Therefore the purpose of the directive is to make a systematic approach in evaluating energy performance of a facility and, based on that, issue a document with the evaluation on energy consumption. This document will be of importance whenever a facility is being sold, rented, built or is undergoing major works, such as renovation.

The aim of the directive, as far as market changes are concerned, is that the tenants of a building, when moving in, receive a certificate on the energy performance of the building. State administration buildings, with a surface area of over 500m2 will be obliged to display the certificate showing their building's energy performance.

The directive states that it should be possible to, in a reasonable time frame, regain the costs invested into the renovation, in relation to the expected technology life-cycle investment through the accumulated energy savings.

The energy efficiency of a building is usually rated from A to G, with A the highest, and G the lowest category of a building's energy efficiency.

Apart from the efficiency rating for the whole building, the directive states a test of heating and air conditioning systems. The test should include an evaluation of the efficiency of the system and the estimation of the size of the system in relation to the requirement for heating and cooling in the building. When designing new building it is important to consider the engineering, ecological, and economic viability of alternative energy supply systems, such as renewable energy sources.

The Directive was introduced in order to affect future construction of residential and office facilities in Europe. The aim is to reach a universal solution that requires a joint approach of all members of the EU. Such a solution would contribute to equalization of criteria in this area in all member states, so that the energy performance be transparent for future owners or users on the real estate market in Europe. To reach a joint approach a joint education program on this issue is required in Europe. With the aim of joint education, a project under the name of Europrosper has been started that deals with the methods of possible implementation of energy efficiency ratings.

For the needs of calculating the energy performance of buildings required methods have been determined that include the following thermal characteristics: thermal insulation, hermeticity, role of natural ventilation, implementation of passive solar systems, protection from the Sun's radiation, location and orientation of buildings.

The deadline for the implementation of the directive in EU member states was set on 04.01.2006. However, due to the lacks of standards and human resource potential in this area to support the implementation of the directive, the deadline had been delayed to the end of 2009, when the directive became an active part of the construction legislation in EU member states.

On 10.05.2010 EPBD 2002/91/EC was replaced and supplemented by The Directive EPBD 2010/31/EU.

The new directive introduced more strict obligations:

- limits on CO_2 emission
- new public domain requirements
- final consumption reduction by 20%
- increase of the share of renewable sources in total energy production to 20% by the end of 2020.

*the so-called Principle 20-20-20: reducing greenhouse gasses emission by 20%, reducing energy consumption by 20% and increasing the share of renewable sources in total production to 20%.

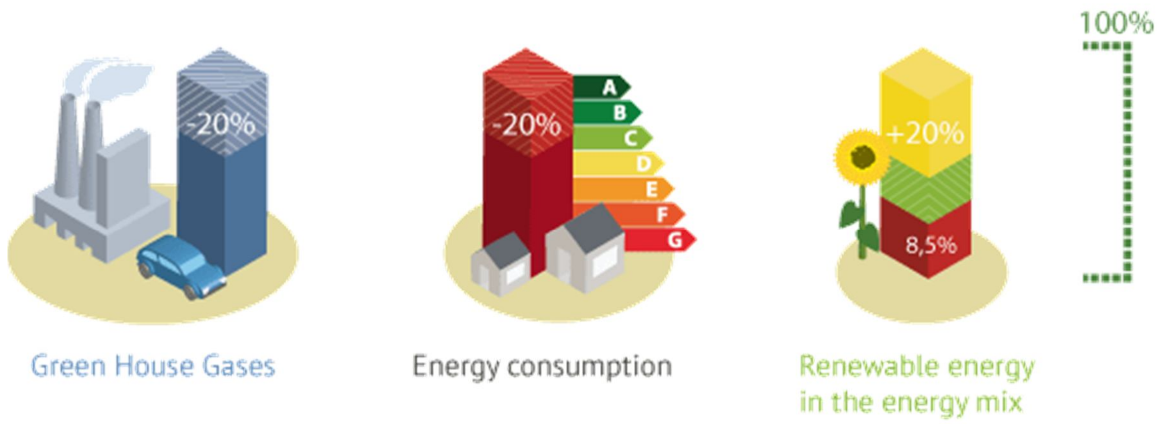


Figure 2-2: The objectives of the energy policy in the EU to 2020.

EPBD 2010/31/EU proscribed the requirements on:

a) A general framework for the methodology of the integrated calculation of energy efficiency of new buildings and independent usable units;
b) Application of minimum requirements on energy efficiency of new buildings and independent usable units;
c) Application of minimum requirements on energy efficiency of:
    -existing buildings, independent units and parts of a building that undergo major reconstruction,
    - Elements that make a building's sheathing and have a great impact on energy efficiency that undergo repairs,
    -technical systems of buildings being installed, replaced or modernized
d) National plans for the increase of the number of buildings with energy consumption near zero;
e) Energy certification of buildings or independent usable units;
f) Regular inspections of heating and air conditioning systems of buildings and
g) Independent inspections of energy certificates and inspection reports.

ESCO is and energy service company, that, through its operation, increases energy efficiency of facilities, technical process and service, while accepting the risk for the services provided, and charging its services completely or partially from the savings gained by implemented measures.
Energy service – a service, technology, control system, device or other commodities implemented in any part of the process of energy usage, which is provided based on a contract and which, in normal operating methods, leads to the increase of energy efficiency, i.e. saving of energy, which can then be tested.

With regards to the fact that buildings consume a third of the world's total produced energy and that thermal systems represent the biggest consumers of energy in buildings, it is of crucial importance that the analysis of those systems is done properly, with the aim of saving energy.
The consumption of energy in buildings should be reduced to a minimum so that the comfort conditions aren't disturbed, i.e. during the whole year it is necessary to maintain the thermal parameters of the inner environment, the quality of the air, the required level of lighting and the sufficient amount of sanitary hot water. A building's technical systems that fulfill the comfort conditions are energy consumers.

With the aim of improving energy efficiency, different saving measures are implemented, paying attention to financial expenses of implemented measures.
During the analysis of the implementation of energy efficiency improvement measures it is necessary to follow a certain pattern:

- A group of measures for improving the performance of the building;
- The measures for reducing heat losses in the production and distribution of heat;
- a group of measures that include the replacement of devices and equipment for heating, air conditioning, preparing sanitary hot water or lighting systems, all of those along with the introduction of the regulation of the systems' operation.

Application of every individual measure depends on the purpose of the building and the current state of the building. It is important to consider every implemented measure or a group of measures, with the aim of achieving a satisfactory period of the investment's repayment.

3. Implementation of the building energy certification

3.1 Norway

The Directive on Energy Certification of Buildings was completely changed in Norway in 2010. Norwegian standard for calculating energy efficiency of buildings is
NS 3031 and was made from EN 15603.
According to the regulations, all new buildings should be at the level of passive houses until 2015 and nearly zero-energy buildings until 2020.
Norwegian construction regulations have two options for fulfilling the requirements:
- limiting specific energy for different types of buildings,
- The other option analyses different components of a building's sheathing, technical installations and solutions.

Since 1 January 2013 all new buildings must be verified by an independent expert. The control is more extensive in case of larger residential and non-residential buildings than in case of family houses.
Regulations do not allow using fossil fuel boilers for covering the basic load. A building of area larger than 500m2 is designed in such manner so that at least 60% of its water and space heating requirements are fulfilled by energy that is neither electric nor fossil fuel. The requirement for buildings of area smaller than 500m2 is 40%.
Exceptions are apartments of area smaller than 50m2, apartments that fulfil the passive houses criterion according to NS 3700, and buildings where this requirement is practically impossible to fulfil due to local conditions.
The Law on Energy Certification has been in power since 1 January 2010, and it was reviewed on 1 July 2010. Main change is the design of the label that should show two dimensions: Energy characteristics and the inclusion of renewable energy sources in heating systems.
Another revision came in power on 1 January 2012, and it allows buyers that do not receive the energy certificate to ask for expert certification at the expense of the seller of the real estate.

The regulation does not make a distinction between publicly and privately owned buildings, every apartment should obtain an energy certificate and every public building of area larger than 1000m2, only the public building is obliged to publicly display its certificate.
As the result of the implementation of the Directive into the Norwegian legislation there are more than 300 000 issued energy efficiency certificates, in the period of three years.
Energy certificate is a legal document made during energy certification, and the part of the energy certificate such as the energy label can be used as its short version.

Contents of the Energy Certificate:

1) Personal Information (address, name of the owner, name of the person or organisation responsible for the certification, and name of the person that registered the information),

2) Energy Label

Is the result of a two-dimensional calculation.

Firstly, the vertical axis, the energy grade (A to G), represents the calculated delivery energy requirement.

Secondly, the horizontal axis, the heating grade, represents the extent to which the heating of space and water can be realised using renewable energy sources. Heating grades are marked by colours, of which red marks heating based on fossil fuels or electric energy, while green marks predominantly using renewable energy sources.

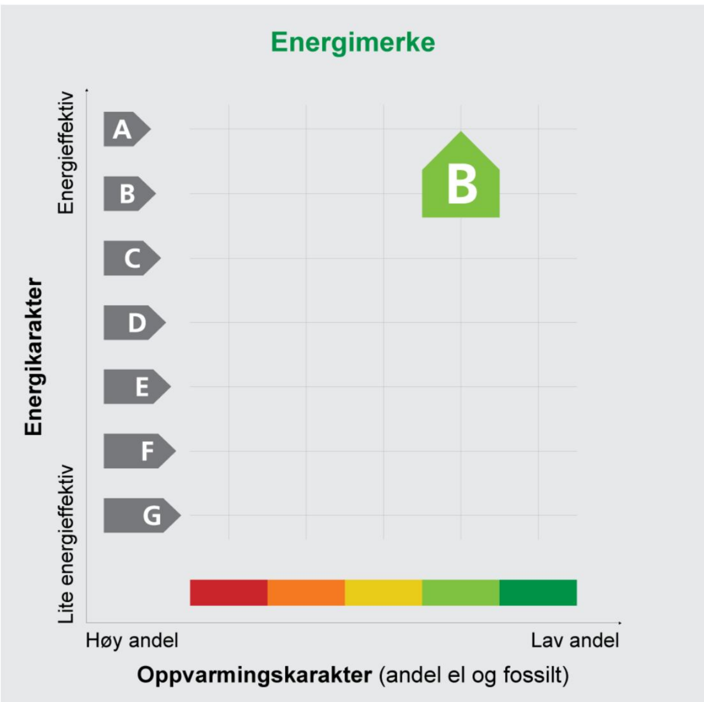


Figure 3-1: Norwegian Energy Label

3) Measured Energy Consumption

This information is obligatory for non-residential buildings, while in residential buildings it is only encouraged. It is shown at the bottom of the front page and it represents average consumption of energy per energy carrier in the previous three years.

4) User Influence,

general advice to the user on energy-saving energy use

5) Recommendations for Enhancing Energy Efficiency

6) Central Input Data

Can be found on page 3 of the certificate and most of them are gathered from the owner (type of building, year of construction, etc.)

7) Information and Help

Are located on the last page of the certificate and are determined by Norwegian authorities.

A high level of technical competences is required for the certification of both the new and existing buildings.

Bachelor degree in education and two years of relevant experience are required for non-residential buildings, while for new buildings the certificate can be issued only by a person of the same degree of competence which is required for designing.

For existing apartments there is a system of self-registration which provides the owner with a faster and cheaper registration, with the aim of enhancing energy efficiency.

The owner gives the input data to the energy efficiency system (room area, year of construction, etc.), the system searches for the corresponding typical parameters needed for the calculation and produces a complete certificate.

Validity of the energy certificate is 10 years.

3.2 Serbia

By signing the contract with the energy community on the 25 October 2005 Serbia took the responsibility of introducing European Directives on energy consumption into the national legislation

With the Resolution of the Council of Ministers of the Energy Community from 18 December 2009 all signatories of the contract are required to introduce EPDB regulations into their national legislation until 30 June 2012.

Rulebook on Energy Efficiency came into power on 30 September 2009. It proscribes the requirements, the contents and the way of issuing energy certificates.

According to this rulebook, energy passport is a document containing the calculated values of energy consumption of a certain category of buildings, the energy grade, and the recommendations for improving the energy characteristics of a building.

Energy passport is issued by a business company or another legal entity fulfilling the required conditions.

Energy passport is required for: new buildings, and existing buildings undergoing reconstruction or adaptation. Categories of buildings for which the passport is issued are determined according to the predominant purpose defined by the regulation determining the energy characteristics of a building:

-residential buildings with one apartment,

-residential buildings with two or more apartment,

-management and office buildings,

-buildings designed for education and culture,

-buildings designed for health and social security,

-buildings designed for tourism and catering,

-buildings designed for sport and recreation,

-buildings designed for trade and services,

-buildings of mixed purpose,

-buildings for other purposes that consume energy.

National energy passport is different for residential and non-residential buildings, but both have five pages displaying the following information:

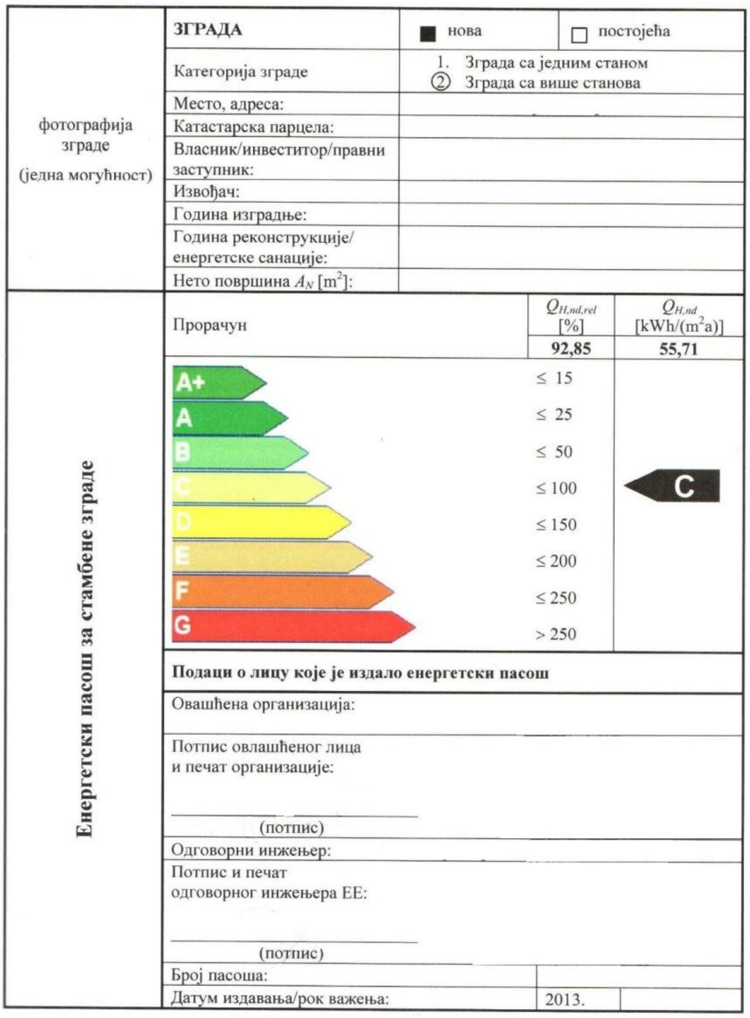
1) Page one - general information and information on energy grade;

2) Page two - information on air-conditioning, thermal systems, and elements of the thermal sheathing;

3) Page three - energy requirements, primary energy and measured energy consumption;

4) Page four - a proposal of measures for enhancing energy efficiency of the building and

5) Page five - explanation of used technical terminology.



Енергетски пасош за стамбене зграде

фотографија зграде (једна могућност)

ЗГРАДА	■ нова	□ постојећа
Категорија зграде	1. Зграда са једним станом ② Зграда са више станова	
Место, адреса:		
Катастарска парцела:		
Власник/инвеститор/правни заступник:		
Извођач:		
Година изградње:		
Година реконструкције/ енергетске санације:		
Нето површина A_N [m²]:		

Прорачун	$Q_{H,nd,rel}$ [%]	$Q_{H,nd}$ [kWh/(m²a)]
	92,85	55,71
A+	≤ 15	
A	≤ 25	
B	≤ 50	
C	≤ 100	C
D	≤ 150	
E	≤ 200	
F	≤ 250	
G	> 250	

Подаци о лицу које је издало енергетски пасош

Овашћена организација:

Потпис овлашћеног лица и печат организације:

(потпис)

Одговорни инжењер:

Потпис и печат одговорног инжењера ЕЕ:

(потпис)

Број пасоша:

Датум издавања/рок важења: 2013.

Figure 3-2: The first page of Serbian energy passport

Energy passport contains information on a building's energy grade according to the calculated requirement for the final annual thermal energy. Buildings are classified into eight energy grades, from A+ (energetically most favourable) to G (energetically most unfavourable grade). Energy grade of new buildings must at least be C, while for existing buildings after reconstruction, energy grade must be at leas one higher than prior to it.
Energy grade is displayed graphically by an arrow on the first page of the energy passport,
Energy passport is issued for the whole building or one of its parts, if the building is defined as a building with more energy zones in the Rulebook.
Public buildings, with net area of over 250m2 are also obliged to be certified and publicly display the certificate.

3.3 Denmark

In the Danish Building regulations, the targets for the next tightening in 2015 are specified. Furthermore, a new building Class 2020 is introduced, i.e., the Danish NZEB definition. Even if the recast EPBD published in 2010 it still have for a goal continuous improvisations the methodology and certification. All of these improvements are based on the experience collected in past few years.
Energy performance requirements. Progress and current status, calculating for this part contains forecast for the tightening of the EP requirements in 2010 and 2015.
Format of national transposition and implementation of existing regulations. Low energy class 2015 and Building Class 2020 are low - energy classes which are the part of BR10 sets for the minimum energy requirements. All of this regards for the new buildings. A considering the existing buildings, it means applying replacement or reconstruction of components. But, the taken investments must be economically justified. That means that the payback must be less of the estimated 75% of life time taken investment.
Energy performance certificates. In Denmark there are EPC classes sorted by alphabet. From A which is high energy to G known as poor energy efficiency. DANAK-Danish accreditation agency, European accreditation agency under the European Accreditation Organisation are the Qualified experts.
Inspection requirements - HVAC systems. Denmark, they prefer at first the place economic incentives as stimulant for a regular and voluntary inspections of oil boilers, instead the mandatory inspections.

On every 5 years is regular inspection of AC system. All AC systems bigger than 5kW except some industrial and all devices who works more than 500 hours per year are part of inspection commission.

Fundamental strategy is comprehensive analysis of the existing building stock, including the energy saving potential, in a goal to reach most cost-effective interventions.

3.4 Germany

In 2011, German Federal Government makes decision to transform the energy system.

Energy performance requirements. For a new buildings was an mandatory to recover the heating and DHW. Chosen energy source was dictated variation ratio in share from 15%, e.g. in the case solar thermal water all to 50% in the case of geothermal heat.

In Germany, all energetic requirements must be repaid shorter than the lifetime of measured investment.2014 and 2016 are the years of step by step approach with the reduction of NZEB for 12,5% every year.

Residential buildings will be ranged with the tax between 50€ and 800€, because the ESO doesn't have an regulations for following costs insured for the energy certification. For new buildings, everything is described in regional law. Beside the law, experts are authorized to provide certificates for existing building. Responsibility for the enforcement of the regulation also takes the federal states. On the federal states is responsibility to control issuing of EPCs.

In every 10 year, all AC units with a thermal output of more than 12kW must undergo aninspection by specialist engineer.

Federal Government has presented an evaluation report on the current REHA. This report also gives some basic suggestions for an amendment of this law, probably due the next legislative period, beginning in October 2013.

3.5 United Kingdom

The implementation of the EPBD in England Wales is the responsibility of the Department for Communities and Local Government. Implementation in Northern Ireland and Scotland is the responsibility of devolved administrations, respectively: the Department of Finance and Personnel and the Scottish Building Standards Division.

On a demand of Local Authorities, Building Regulations outputs will be produced accredited EPC assessors. Similar is in the Northern Ireland where is the District Councils is that who has responsibility for the enforcement of Building Regulations requirements within their council boundaries. Local Authorities also in Scotland administer the Building Standards system with responsibility for granting permission for work to be done.

Under the SORs, Accreditation Schemes are mandated to undertake QA of the outputs produced by their accredited energy assessors. Government also carries out QA audits of the quality systems implemented by Accreditation Schemes and compliance with the SORs.

In UK, they considered and made conclusion to promote persuasion for the boilers, instead than insist on inspect regime, and continually wide programme of informations, grant schemes and regulation who will be historically followed.

EPBD was transposed by UK a jurisdiction who has adopted several different approaches for it.

3.6 Croatia

EPDB implementation in Croatia started in 2005. The implementation as well has for plan to be completed by the end of 2013 by trespassing through publication in Official Gazette No. 76/2077 who was based the legal basis for adoption of the implementation regulations regarding the application of the minimum EP, and 158/2008, who was based the legal basis for adoption of the implementation ordinances regarding the application of other requirements such is: obligation for issuing EPC, and for the inspection of HVAC systems, also regarding for establishing an independent control system. The energy standard NZEB includes continuous reductions of energy consumption, and keep of the minimum requirement for renewables.

Energy performance requirements. Progress and current status is displayed through 8 simple rules. Accompanying study of, technical, environmental and economic feasibility of alternative systems cogenerations systems, electricity supply is a must of Application for a building permit of existing building.

Format of national transposition and implementation of existing regulations. Responsibility takes approved engineer or approved architect for conducting surveillance an independent building during the construction work.

Energy performance certificates is firstly established for a use of new buildings, and after that comes old and used buildings who has been, rented, leased and at the end buildings for the public use.

Inspection requirements - HVAC systems. Short brief of this theme, main part at surveying and inspection of installations has M.Sc.M.E. Condition of those system is predicted to be checked on every 5 years.

The goal for reaching high results of energy efficiency for new and used buildings is that to improve as many as possible implementations and measures on that field efficiency.

4. Software for calculations of energy consumption in buildings

Software used for the calculation, and required for energy certification of buildings in the chosen countries, is the German programme **CASAnova**.
CASAnova is an educational software for the calculation of the heating and cooling demand of buildings.

The calculation of heating demand is based on the European norm EN 832. CASAnova uses building shapes of rectangular form for which in a monthly balance transmission and ventilation losses as well as solar and internal gains are calculated. Heating demand is the difference between energy losses and energy gains of the building.

4.1 Method of calculation in CASAnova software

The heating demand of a building:

$$Q_H=V_T+V_L-\eta\cdot(G_S+G_I)$$

With

Q_H:	heat energy demand
V_T:	transmission losses
V_L:	ventilation losses
η:	utilization factor
G_S:	solar gains
G_I:	internal gains

The calculation of the cooling demand, the heating, cooling and zero-energy hours as well as the maximum heating load is done with the help of a one-zone-model.

CASAnova calculates the utilization factor η according to the European Standard EN 832 for the monthly calculation method:

$$\eta = \begin{cases} \dfrac{1-x^{a}}{1-x^{a+1}} & for \quad x \neq 1 \\ \dfrac{a}{a+1} & for \quad x = 1 \end{cases}$$

With

η: utilization factor

$x = \dfrac{G_S + G_I}{V_T + V_L}$ ratio of heat gains to losses

$a = a_0 + \dfrac{\tau}{\tau_0}$

a_0 = 1 (according to EN 832)

τ_0 = 16 h (according to EN 832)

τ: time constant due to thermal inertia

4.1.1 Solar gains

The solar gains entering the building through the windows per time interval are:

$$G_S = \sum_{all\ windows} g_F \cdot (1 - r_F) \cdot A_F \cdot H_F$$

With

G_S: solar gains

g_F: g-value of glazing

r_F: frame ratio of window

A_F: surface area of window

H_F: solar radiation on window surface

The solar gains effected by the radiation on the outside walls result from

$$G_{W,S} = \sum_{walls} \frac{U_W}{\alpha_a} \cdot A_W \cdot H_{W,S}$$

With:

$G_{W,S}$:	solar gains through the walls in kWh
$H_{W,S}$:	solar radiation on the wall surface in kWh/m^2
A_W:	outside wall area in m^2
α_a:	exterior surface heat transfer coefficient, 20 W/(m^2 K)
U_W:	U value of the wall in W/(m^2 K)

4.1.2 Internal gains

The expected internal gains resulting from devices and persons are determined from the heated floor area:

$$G_I = A_{hfa}$$

With

G_I:	internal gains
A_{hfa}:	heated floor area
q_{int}:	specific internal gains (assumption: 25 kWh/(m^2 a), about 2.85 W/m^2)

4.1.3 Transmission losses

$$V_T = \sum_{all\,walls} U_W \cdot \mathrm{A}_W \cdot (T_S - T_\mathrm{A}) \cdot \Delta t + \sum_{all\,windows} U_F \cdot \mathrm{A}_F \cdot (T_S - T_\mathrm{A}) \cdot \Delta t$$
$$+ k_B \cdot U_B \cdot \mathrm{A}_B \cdot (T_S - T_\mathrm{A}) \cdot \Delta t + k_D \cdot U_D \cdot \mathrm{A}_D \cdot (T_S - T_\mathrm{A}) \cdot \Delta t$$

With

V_T:	transmission losses
U_W, U_F:	heat transfer coefficients of walls and windows
U_B:	heat transfer coefficient of ground floor (against unheated cellar or ground)
U_D:	heat transfer coefficient of roof resp. uppermost ceiling
A_W, A_F:	surface area of walls and windows
A_B:	surface area of ground floor
A_D:	surface area of uppermost ceiling resp. roof
T_S:	indoor air temperature
T_A:	ambient temperature (weather / climatic data)
k_B:	Correction of U-value of the ground floor
k_D:	Correction of U-value of the roof resp. the uppermost ceiling
Δt:	calculation period

4.1.4 Ventilation losses

Supplementary to transmission losses a building has losses due to ventilation - warm inside air is replaced by colder ambient air. The ventilation losses are:

$$V_L = n \cdot V \cdot c_{air} \cdot \rho_{air} \cdot (T_S - T_A) \cdot \Delta t$$

With

V_L:	ventilation losses
n:	air change rate in 1/h
V:	exchangeable volume of indoor air
$(\rho_{air} \cdot c_{air})$:	volumetric thermal capacity of air (= 0.34 Wh/(m^3 K))
T_S:	indoor air set temperature
T_A:	ambient temperature (weather / climate data)
Δt:	calculation period

4.1.5 Effective capacity of heat storage

$$C = c_{AW} \cdot A_{AW} + c_{IW} \cdot A_{IW}$$

With

A_{AW}:	area of exterior walls
A_{IW}:	area of interior walls (calculated according to the construction of a typical one-family building)
c_{AW}, c_{IW}:	specific thermal heat storage of exterior / interior walls (per m^2 wall area)

For the interior and exterior walls CASAnova distinguishes between three types of construction: lightweight, medium and heavy. These construction types are characterised by their thermal capacity per square meter wall area:

Construction type	c_{AW} / c_{IW}
Lightweight:	25 kJ/(m^2 K)
Medium:	65 kJ/(m^2 K)
Heavy:	105 kJ/(m^2 K)

Table 4-1: Construction types

5. Calculation of energy certification for selected buildings

From the chosen countries, the ones determined for further calculations are Norway and Serbia. The results of the calculations of fictitious buildings in Oslo and Belgrade have been analysed.

5.1 Calculation of energy certification for building in Oslo

5.1.1 Input data for Oslo

Geometry:

Length of north and south facade:	48,5 m
Length of west and east facade:	20,3 m
Height (without roof):	14,0 m
Number of floors:	4
Deviation from south direction (west positive):	0,0 °

Ground area:	984,6 m2
Useful area:	3150,6 m2
Volume total:	13783,7 m3
Air volume:	11027,0 m3
Facade north resp. south:	679,0 m2
Facade east resp. west:	284,2 m2
Surface-to-volume value:	0,3 1/m

Insulation:

U values of the walls:	
north:	0,18 W/(m2 K)
south:	0,18 W/(m2 K)
east:	0,18 W/(m2 K)
west:	0,18 W/(m2 K)
Absorption coefficient of the walls:	0,50

Upper floor:

Towards: outside or non-insulated roof

U value: 0,20 W/(m2 K)

Lower floor:

Towards: non-heated cellar (with insulation)

U value: 0,20 W/(m2 K)

Door (north facade):

Area: 4,4 m2

U value: 1,20 W/(m2 K)

Thermal bridges: increase U-values of surrounding planes by 0.10 W/(m2 K) (normal construction)

Building:

Interior temperature: 20,0 °C

Limit of overheating: 27,0 °C

Ventilation:

Natural ventilation (infiltration): 0,10 1/h

Mechanical ventilation: 2,00 1/h

Heat recovery (only mech. ventilation): 80 %

efficiency factor of air conditioning: 0,9 kWh_{cool} / kWh_{electr}

Internal gains: 30,0 kWh/(m2 a)

Kind of indoor walls: medium construction

Kind of outdoor walls: medium construction

Climate:

Climate station: Oslo (Norge)

Windows:

North:

Windows area: 183,3 m2

Fraction of windows area at the facade: 27,0 %

Kind of windows: others

U value glazing: 1,20 W/(m2 K)

U value frame: 0,97 W/(m2 K)

g value glazing: 0,60

Fraction of frame: 25,0 %

Shading: 18,0 %

South:

Window area: 251,2 m2

Fraction of windows area at the facade: 37,0 %

Kind of windows: others

U value glazing: 1,20 W/(m2 K)

U value frame: 0,97 W/(m2 K)

g value glazing: 0,60

Fraction of frame: 25,0 %

Shading: 18,0 %

East:

Window area: 42,6 m2

Fraction of windows area at the facade: 15,0 %

Kind of windows: others

U value glazing: 1,20 W/(m2 K)

U value frame: 0,97 W/(m2 K)

g value glazing: 0,60

Fraction of frame: 25,0 %

Shading: 18,0 %

West:

Window area:	110,8 m2
Fraction of windows area at the facade:	39,0 %
Kind of windows:	others
U value glazing:	1,20 W/(m2 K)
U value frame:	0,97 W/(m2 K)
g value glazing:	0,60
Fraction of frame:	25,0 %
Shading:	18,0 %

Energy:

Heating system:	soil heat pump, buffer storage and distribution inside the thermal zone
Heat transfer / system temperature:	radiators (outside walls), thermostatic valves (layout temperature: 1K), system temperature: 55/45°C
Source of energy:	electricity

5.1.2 Output data for Oslo

Tables 5-1 and 5-6 show monthly consumption of heating and cooling energies in kWh/m2 The last row shows the value of the total yearly demand for heating energy, which will later be used for determining the building's energy grade.

Table 5-1: Heat energy and cooling demand for Oslo

	Heat energy demand in kWh/m2	Cooling demand in kWh/m2
January	13,8	0,0
February	11,8	0,0
March	9,3	0,0
April	4,5	0,0
May	0,5	0,0
June	0,0	0,0
July	0,0	0,7
August	0,0	0,6
September	0,3	0,0
October	4,1	0,0
November	8,8	0,0
December	12,0	0,0
Yearly sum	65,0	1,3

Tables 5-2 and 5-7 show hourly values of used heating and cooling energies, and summarized yearly, hourly, and percentage values.

Table 5-2: Heating and cooling hours for Oslo

	Heating hours in hours	Zero energy hours in hours	Cooling hours in hours
January	744	0	0
February	672	0	0
March	744	0	0
April	678	42	0
May	322	422	0
June	70	650	0
July	0	444	300
August	31	390	323
September	321	399	0
October	744	0	0
November	720	0	0
December	744	0	0
Sum (in hours)	5790	2347	623
Sum (in %)	66,1	26,8	7,1

Tables 5-3 and 5-8 show maximum, minimum and average monthly values of exterior temperature. The last row shows the averaged value of average exterior temperatures, at a yearly level.

Table 5-3: Climate data for Oslo

	Mean temperature in °C	Maximum temperature in °C	Minimum temperature in °C
January	-1,7	8,9	-18,7
February	-2,4	9,9	-18,7
March	0,3	13,7	-15,3
April	4,7	24,6	-9,6
May	10,1	19,5	0,6
June	13,9	22,3	2,3
July	17,1	25,0	1,4
August	16,2	25,1	8,2
September	13,2	25,5	3,5
October	8,7	16,0	1,3
November	3,7	17,3	-8,6
December	0,8	16,1	-10,1
Yearly mean	7,1		

Building data:

Mean U value:	0,42 W/(m2 K)
Specific transmission losses:	1641,3 W/K
Specific ventilation losses:	1975,7 W/K
Sum specific losses:	3617,0 W/K
Thermal inertia:	89,2 hours
Maximum heating load:	125,4 kW
Maximum specific heating load:	39,8 W/m2
Maximum cooling load:	73,1 kW
Maximum specific cooling load:	23,2 W/m2
Limit temperature for heating:	16,9°C
Effective heating days:	321 Tage

Tables 5-4 and 5-9 show specific heat losses values (transmission, ventilation, interior, and solar radiation), and the value of specific energy required for heating at monthly and yearly levels.

Table 5-4: Heat balance, Specific (per m2 useful area) for Oslo

	Transm. losses in kWh/m2	Ventil. losses in kWh/m2	Internal Gains in kWh/m2	Solar Gains in kWh/m2	Usability factor	Heat energy demand in kWh/m2
January	7,6	10,1	2,5	1,4	1,00	13,8
February	7,1	9,4	2,3	2,4	1,00	11,8
March	6,9	9,2	2,5	4,2	1,00	9,3
April	5,2	6,9	2,4	5,2	0,98	4,5
May	3,4	4,6	2,0	5,6	0,77	0,5
June	2,1	2,8	1,3	3,5	0,51	0,0
July	1,0	1,4	0,6	1,8	0,25	0,0
August	1,3	1,7	0,9	2,1	0,36	0,0
September	2,3	3,1	1,8	3,3	0,73	0,3
October	4,0	5,3	2,5	2,7	0,99	4,1
November	5,5	7,4	2,5	1,7	1,00	8,8
December	6,7	9,0	2,5	1,1	1,00	12,0
Yearly sum	53,0	70,8	23,9	34,9		65,0

Tables 5-5 and 5-10 show heat losses values (transmission, ventilation, interior, and solar radiation), and the value of total energy required for heating. All values are in kWh.

Table 5-5: Heat balance, Absolute (total building) for Oslo

	Transm. losses in kWh	Ventil. losses in kWh	Internal Gains in kWh	Solar Gains in kWh	Usability factor	Heat energy demand in kWh
January	23855	31868	8027	4289	1,00	43408
February	22275	29757	7249	7709	1,00	37073
March	21719	29014	8012	13329	1,00	29393
April	16309	21788	7616	16240	0,98	14241
May	10858	14506	6170	17600	0,77	1594
June	6490	8670	4000	11061	0,51	98
July	3235	4322	2008	5548	0,25	1
August	4127	5513	2865	6767	0,36	7
September	7219	9643	5674	10398	0,73	790
October	12457	16641	7943	8387	0,99	12769
November	17388	23228	7765	5276	1,00	27574
December	21109	28200	8027	3500	1,00	37782
Yearly sum	167040	223150	75357	110103		204731

5.2 Calculation of energy certification for building in Belgrade

5.2.1 Input data for Belgrade

Geometry:

Length of north and south facade: 46,4 m

Length of west and east facade: 14,0 m

Height (without roof): 16,0 m

Number of floors: 5

Deviation from south direction (west positive): 0,0 °

Ground area: 649,6 m2

Useful area: 2598,4 m2

Volume total: 10393,6 m3

Air volume: 8314,9 m3

Facade north resp. south: 742,4 m2

Facade east resp. west: 224,0 m2

Surface-to-volume value: 0,3 1/m

Insulation:

U values of the walls:	
north:	0,27 W/(m2 K)
south:	0,28 W/(m2 K)
east:	0,28 W/(m2 K)
west:	0,28 W/(m2 K)
Absorption coefficient of the walls:	0,50
Upper floor:	
Towards:	totally insulated roof ventilated roof
U value:	0,27 W/(m2 K)
Lower floor:	
Towards:	non-heated cellar (with insulation)
U value:	0,29 W/(m2 K)
Door (north facade):	
Area:	8,4 m2
U value:	1,40 W/(m2 K)
Thermal bridges:	increase U-values of surrounding planes by 0.10 W/(m2 K) (normal construction)

Building:

Interior temperature:	20,0 °C
Limit of overheating:	27,0 °C
Ventilation:	
Natural ventilation (infiltration):	0,05 1/h
Mechanical ventilation:	2,00 1/h
Heat recovery (only mech. ventilation):	50 %
efficiency factor of air conditioning:	0,9 kWh_{cool} / kWh_{electr}
Internal gains:	30,0 kWh/(m2 a)
Kind of indoor walls:	medium construction
Kind of outdoor walls:	medium construction

Climate:

Climate station: Belgrad (Serbia)

Windows:

North:

Windows area: 215,3 m2

Fraction of windows area at the facade: 29,0 %

Kind of windows: others

U value glazing: 1,30 W/(m2 K)

U value frame: 1,20 W/(m2 K)

g value glazing: 0,61

Fraction of frame: 30,0 %

Shading: 10,0 %

South:

Window area: 319,2 m2

Fraction of windows area at the facade: 43,0 %

Kind of windows: others

U value glazing: 1,30 W/(m2 K)

U value frame: 1,20 W/(m2 K)

g value glazing: 0,61

Fraction of frame: 30,0 %

Shading: 10,0 %

East:

Window area: 0,0 m2

Fraction of windows area at the facade: 0,0 %

Kind of windows: others

U value glazing: 1,30 W/(m2 K)

U value frame: 1,20 W/(m2 K)

g value glazing: 0,61

Fraction of frame: 30,0 %

Shading: 10,0 %

West:

Window area: 0,0 m2
Fraction of windows area at the facade: 0,0 %
Kind of windows: others
U value glazing: 1,30 W/(m2 K)
U value frame: 1,20 W/(m2 K)
g value glazing: 0,61
Fraction of frame: 30,0 %
Shading: 10,0 %

Energy:

Heating system: soil heat pump, buffer storage and distribution inside the thermal zone

Heat transfer / system temperature: underfloor heating (switch difference : 1K), system temperature: 35/28°C

Source of energy: electricity

5.2.2 Output data for Belgrade

Table 5-6: Heat energy and cooling demand for Belgrade

	Heat energy demand in kWh/m2	Cooling demand in kWh/m2
January	17,0	0,0
February	13,6	0,0
March	7,6	0,0
April	1,4	0,0
May	0,0	0,8
June	0,0	1,2
July	0,0	3,4
August	0,0	2,4
September	0,0	2,1
October	1,3	0,0
November	9,8	0,0
December	15,7	0,0
Yearly sum	66,3	9,9

Table 5-7: Heating and cooling hours for Belgrade

	Heating hours in hours	Zero energy hours in hours	Cooling hours in hours
January	744	0	0
February	672	0	0
March	705	39	0
April	467	253	0
May	222	341	181
June	83	353	284
July	0	204	540
August	0	313	431
September	155	229	336
October	500	244	0
November	720	0	0
December	744	0	0
Sum (in hours)	5012	1976	1772
Sum (in %)	57,2	22,6	20,2

Table 5-8: Climate data for Belgrade

	Mean temperature in °C	Maximum temperature in °C	Minimum temperature in °C
January	2,4	18,1	-12,4
February	2,9	17,6	-16,2
March	8,0	27,9	-8,3
April	13,6	30,0	1,2
May	18,6	32,8	5,4
June	20,8	32,1	4,6
July	23,5	37,8	12,7
August	23,6	36,3	12,4
September	19,6	34,2	3,7
October	14,0	27,1	1,6
November	7,5	19,4	-3,8
December	3,5	19,7	-11,3
Yearly mean	13,2		

Building data:

Mean U value:	0,53 W/(m2 K)
Specific transmission losses:	1707,3 W/K
Specific ventilation losses:	3128,5 W/K
Sum specific losses:	4835,7 W/K
Thermal inertia:	54,6 hours
Maximum heating load:	160,5 kW
Maximum specific heating load:	61,8 W/m2
Maximum cooling load:	106,7 kW
Maximum specific cooling load:	41,1 W/m2
Limit temperature for heating:	18,1°C
Effective heating days:	237 Tage

Table 5-9: Heat balance, Specific (per m2 useful area) for Belgrade

	Transm. losses in kWh/m2	Ventil. losses in kWh/m2	Internal Gains in kWh/m2	Solar Gains in kWh/m2	Usability factor	Heat energy demand in kWh/m2
January	7,3	15,8	2,5	3,5	1,00	17,0
February	6,4	13,8	2,3	4,3	0,99	13,6
March	5,0	10,8	2,5	5,7	0,97	7,6
April	2,6	5,6	2,0	4,8	0,80	1,4
May	0,6	1,3	0,5	1,4	0,20	0,0
June	0,0	0,0	0,0	0,0	0,00	0,0
July	0,0	0,0	0,0	0,0	0,00	0,0
August	0,0	0,0	0,0	0,0	0,00	0,0
September	0,1	0,3	0,1	0,3	0,05	0,0
October	2,5	5,3	2,0	4,5	0,80	1,3
November	5,0	10,9	2,4	3,7	0,99	9,8
December	6,8	14,8	2,5	3,4	1,00	15,7
Yearly sum	36,3	78,5	16,9	31,5		66,3

Table 5-10: Heat balance, Absolute (total building) for Belgrade

	Transm. losses in kWh	Ventil. losses in kWh	Internal Gains in kWh	Solar Gains in kWh	Usability factor	Heat energy demand in kWh
January	18945	40940	6608	8976	1,00	44302
February	16606	35883	5950	11263	0,99	35276
March	12929	27939	6418	14829	0,97	19622
April	6709	14498	5113	12527	0,80	3567
May	1562	3375	1352	3582	0,20	4
June	0	0	0	0	0,00	0
July	0	0	0	0	0,00	0
August	0	0	0	0	0,00	0
September	375	811	334	852	0,05	0
October	6424	13882	5288	11590	0,80	3428
November	13064	28231	6346	9541	0,99	25408
December	17740	38334	6605	8755	1,00	40714
Yearly sum	94355	203892	44014	81914		172319

6. Analysis results

6.1 Heat energy and cooling demand for buildings

6.1.1 Specific heat energy and cooling demand for building

These two diagrams show the specific heat energy and cooling demand of the building. The unit is $kWh/\left(m^2, month\right)$ resp. $kWh/\left(m^2, a\right)$, i.e. the demand per square meter of heated floor area.

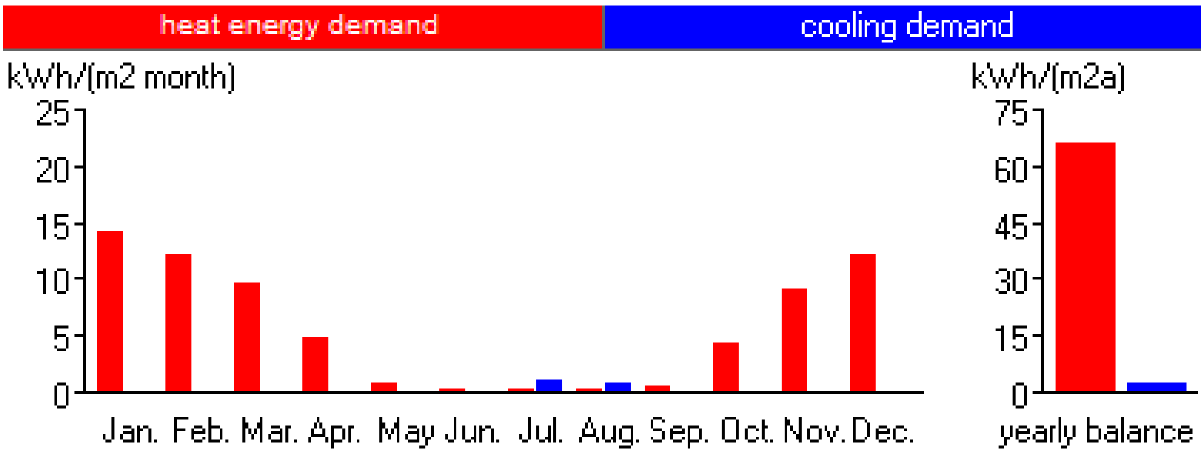


Figure 6-1: Specific heat energy and cooling demand for building in Oslo

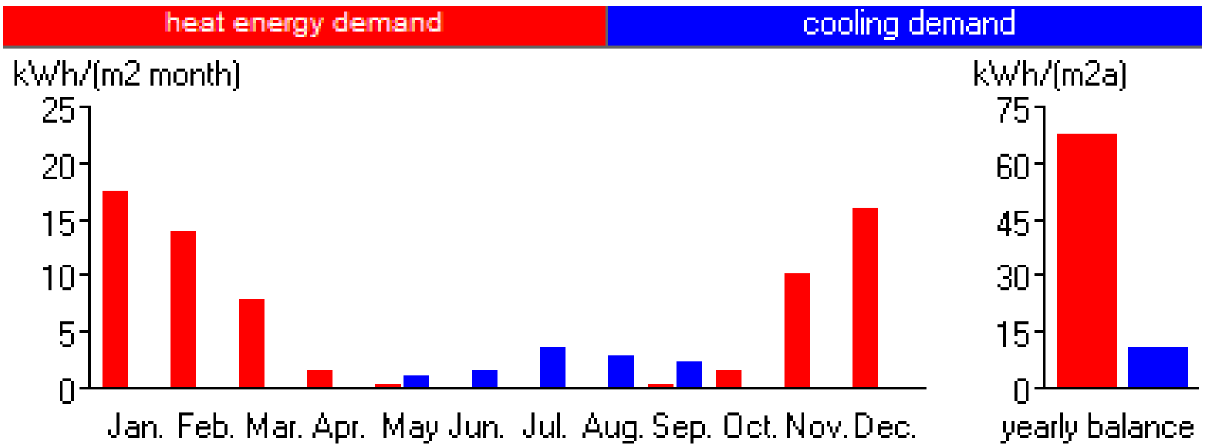


Figure 6-2: Specific heat energy and cooling demand for building in Belgrade

6.1.2 Hourly energy demand for buildings

This monthly resp. yearly diagram presents the number of hours in a month / a year during which the course of room air temperature (without heating or cooling) is lower than the indoor set temperature (heating hours) or higher then the limit of overheating (cooling hours).

Zero energy hours are those ones, during which the room air temperature is in the comfortable range (i.e. between the indoor set temperature and the limit of overheating).

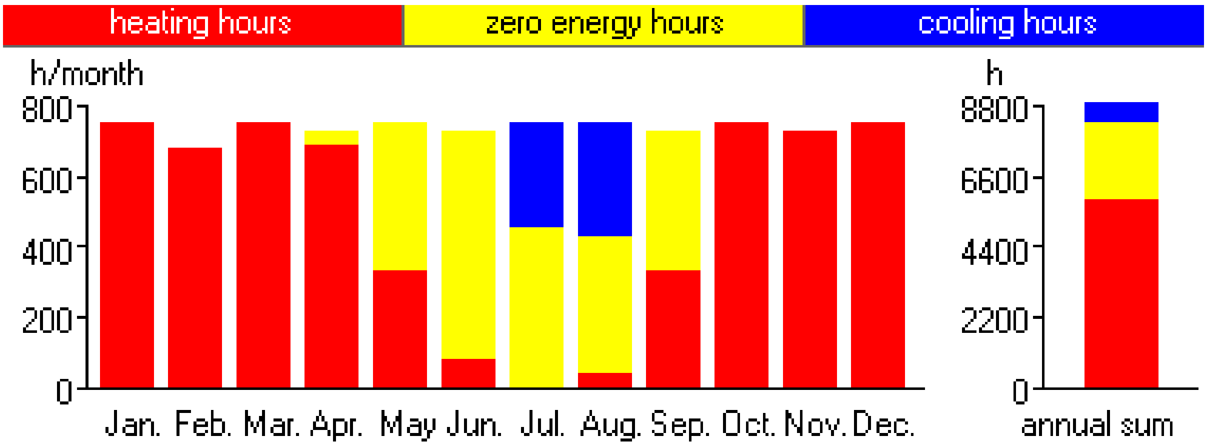


Figure 6-3: Hourly energy demand for building in Oslo

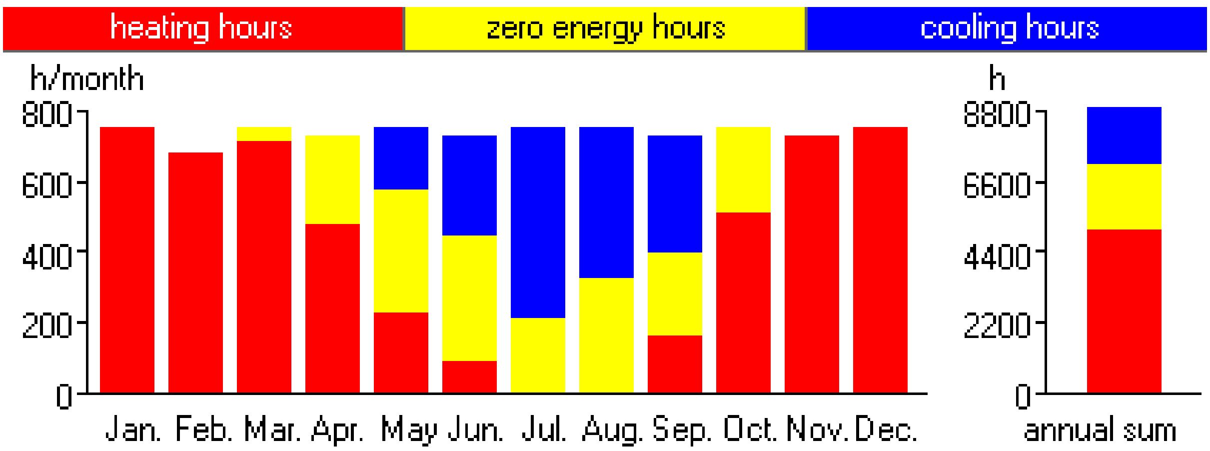


Figure 6-4: Hourly energy demand for building in Belgrade

6.1.3 Course of temperatures

This diagram visualises then hourly course of the outdoor and the room air temperature.

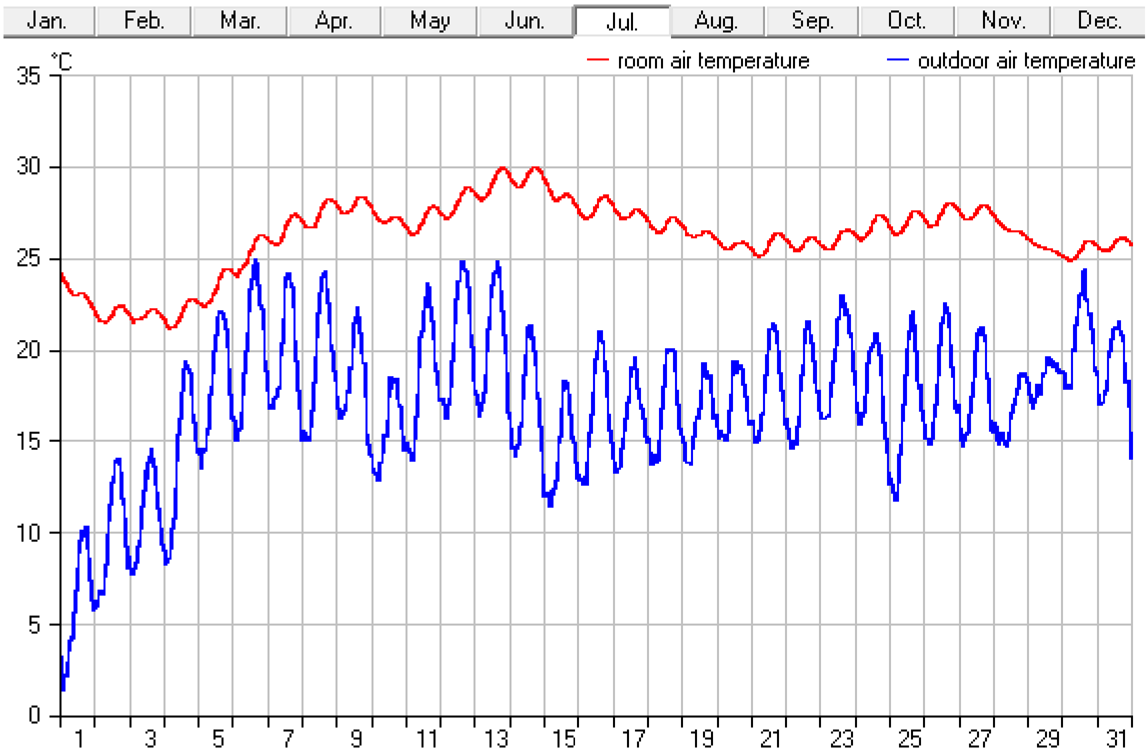


Figure 6-5: Course of temperatures for building in Oslo

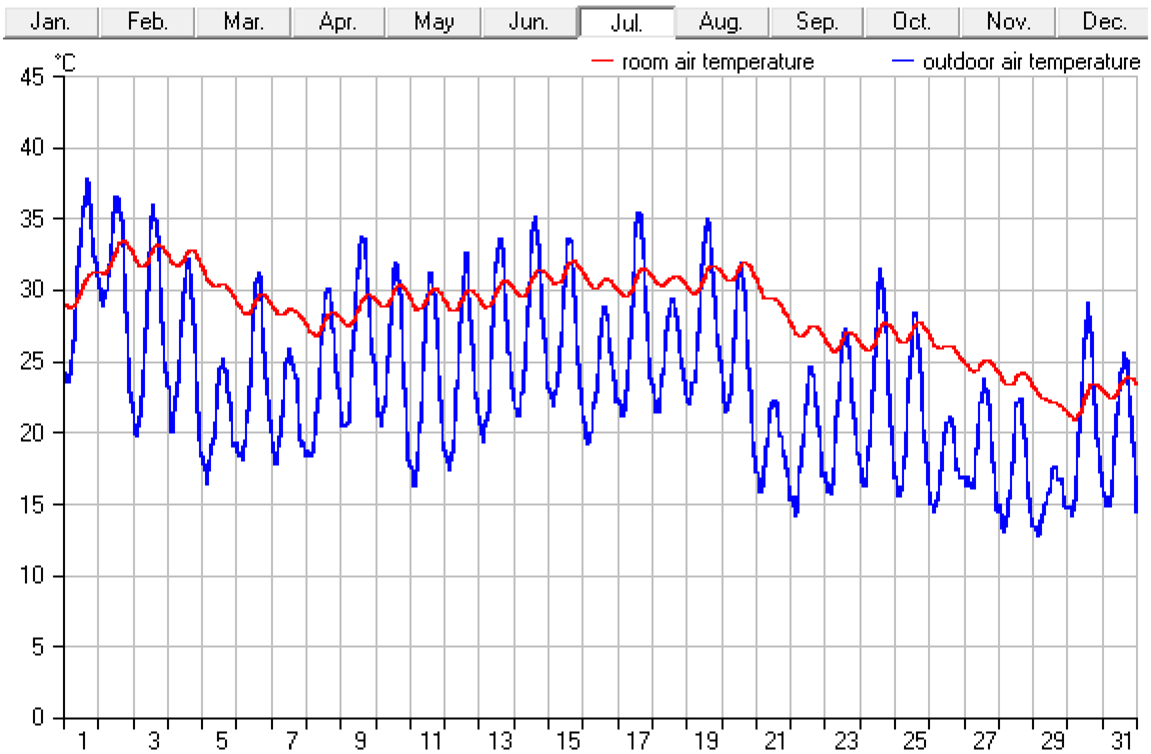


Figure 6-6: Course of temperatures for building in Belgrade

6.2 Energy flows

6.2.1 Energy flow diagram for heating

The energy-flow diagram for heating illustrates graphically the yearly demand of primary energy, energy for heating and heat energy, internal and solar gains as well as transmission and ventilation losses.

The width of the bars is proportional to the corresponding amounts of energy. Numbers given in the diagram are specific, i.e. they give the energy demand, gains and losses for one year per square meter of heated floor area.

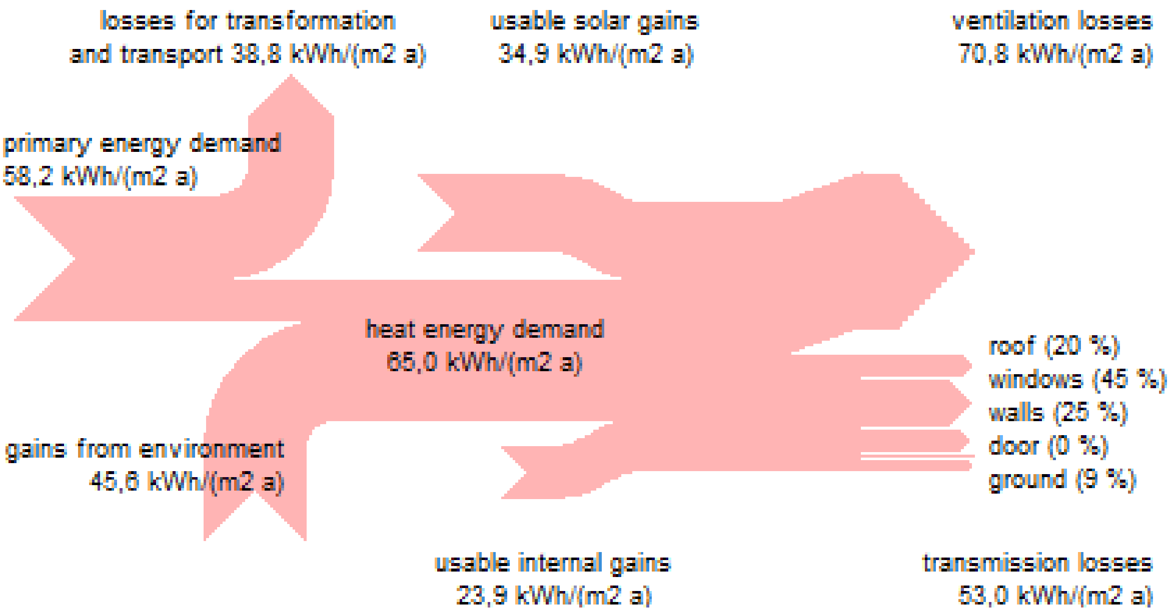


Figure 6-7: Energy flow for heating, Oslo

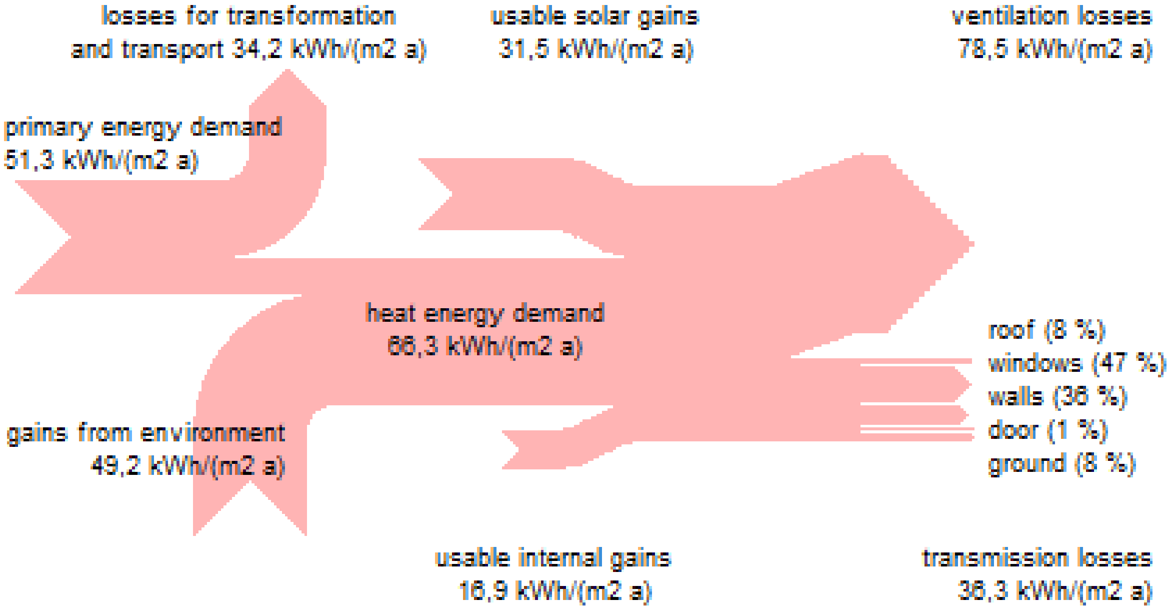


Figure 6-8: Energy flow for heating, Belgrade

6.2.2 Energy flow diagram cooling

The energy-flow diagram for cooling presents the different amounts of energy for those periods of time, during which the room air temperature exceeds the given limit of overheating. Shown are the surplus internal and solar gains as well as the supply of heat by transmission and ventilation, when there is overheating. The end cooling energy demand is that amount of energy which a cooling system (air-conditioning) would need to take out the surplus heat from the building.

Finally, this energy is also given to the surrounding as waste heat. As source of energy for the cooling system, electricity with a primary energy factor of three is supposed.

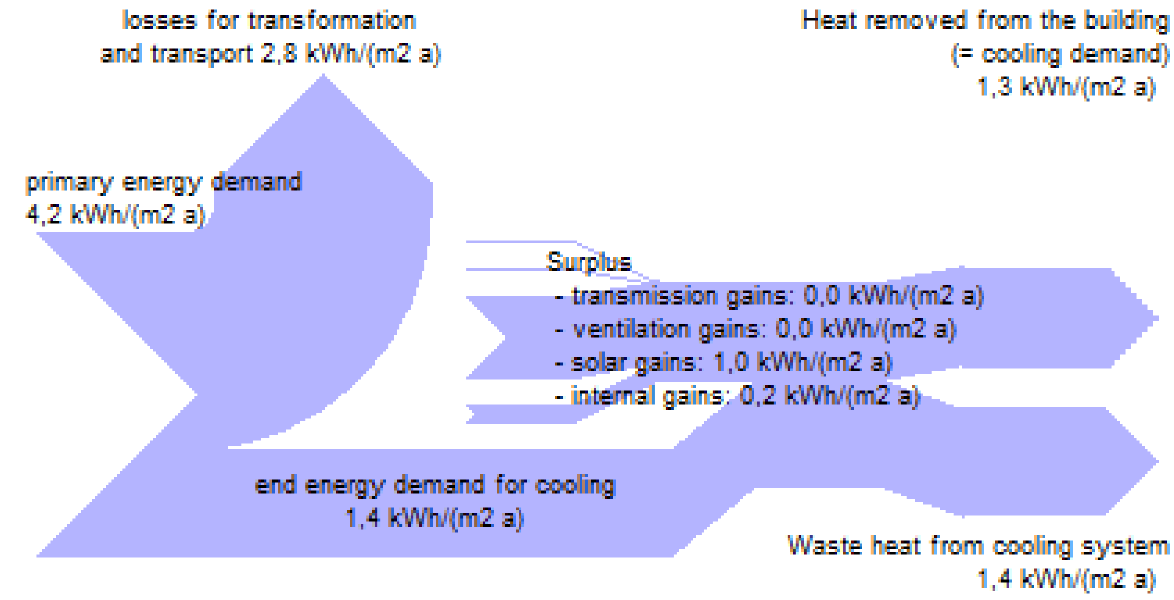


Figure 6-9: Energy flow for cooling, Oslo

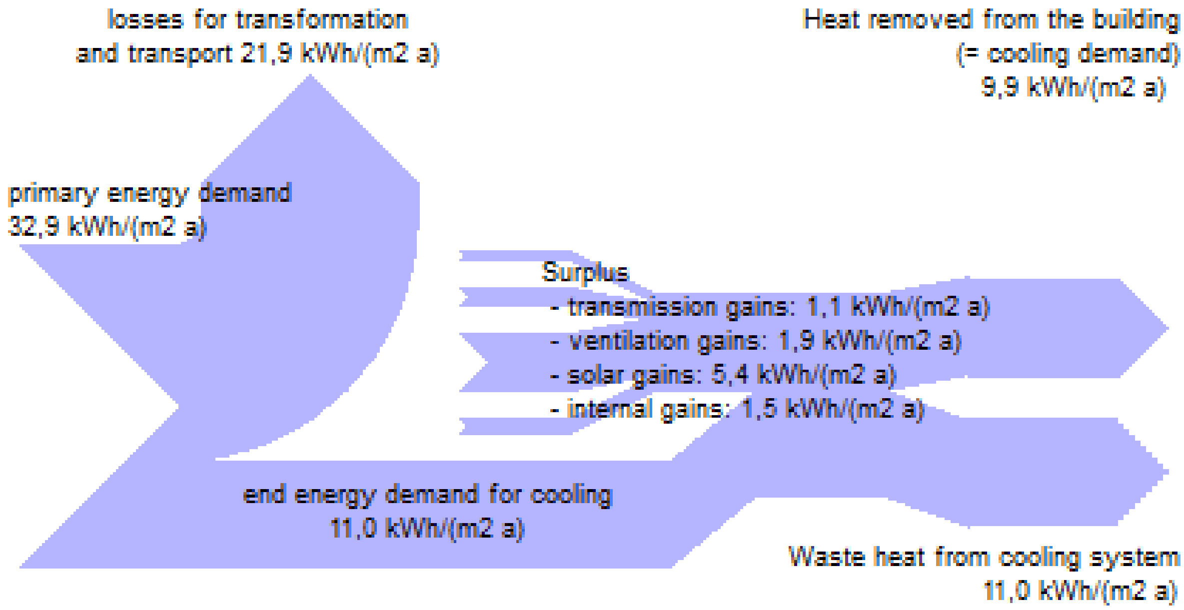


Figure 6-10: Energy flow for cooling, Belgrade

6.3 Heating

6.3.1 Yearly balance

In these tables, gains and losses of energy are summed up for one year. The difference between losses and gains is the heat energy demand for this year. All results are given as specific values, i.e. per square meter of heated floor area.

Table 6-1: Yearly balance, Oslo

	specific in kWh/(m2a)
transmission losses	53
ventilation losses	70,8
usable solar gains	34,9
usable internal gains	23,9
heat energy demand	65

Table 6-2: Yearly balance, Belgrade

	specific in kWh/(m2a)
transmission losses	36,3
ventilation losses	78,5
usable solar gains	31,5
usable internal gains	16,9
heat energy demand	66,3

By comparing the diagrams it can be noticed that the specific energies required for heating of both buildings are approximately equal, which classifies them in the same energy grade - C, and the building in Belgrade requires cooling several months more per year than the Oslo building.
Transmission losses are significantly higher in case of Oslo building than the building in Belgrade, due to larger window area.

6.3.2 Monthly and yearly heat balance

These diagrams show ventilation and transmission losses, useable internal and solar gains, as well as heat energy demand with monthly resolution as well as the yearly sums. If there is a difference between the gains and the losses, heat demand is necessary.

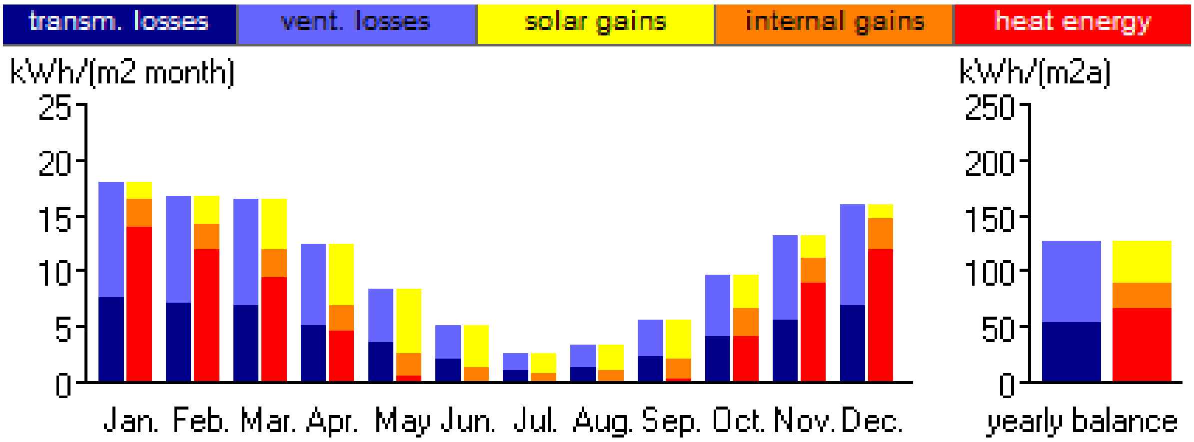


Figure 6-11: Heat balance for building in Oslo

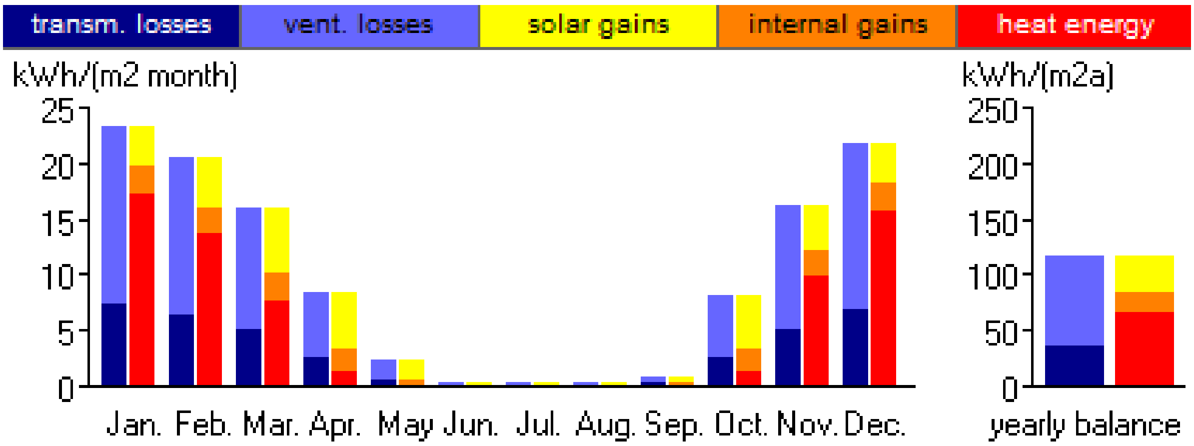


Figure 6-12: Heat balance for building in Belgrade

6.3.3 Usable and non-usable solar and internal gains

In these two diagrams (monthly / yearly), the total internal and solar gains are compared to the part of them which are needed during the heating season. All further gains led to an increasing of room air temperature higher than the set of temperature. Thereby, the usability factor for internal and solar gains are assumed as being equal.

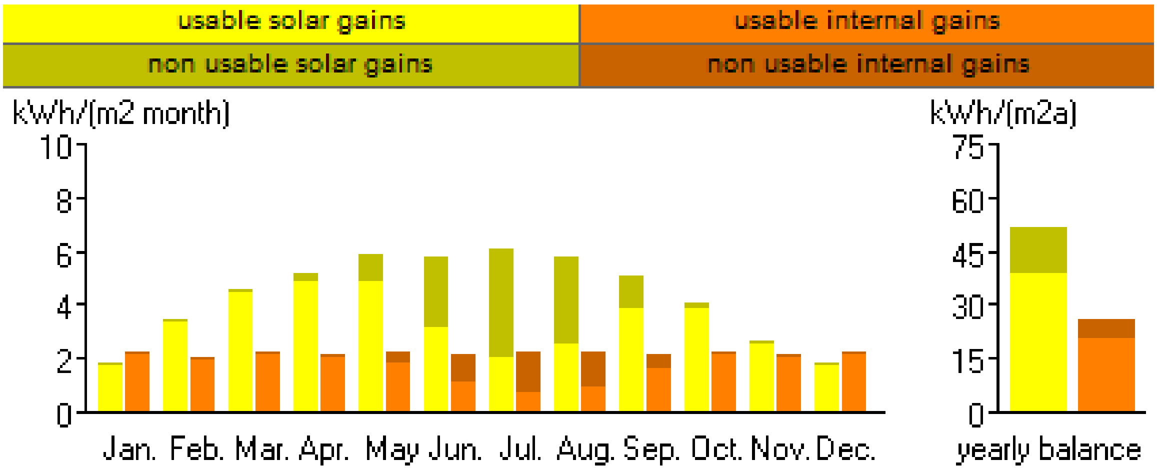


Figure 6-13: Solar and internal gains for building in Oslo

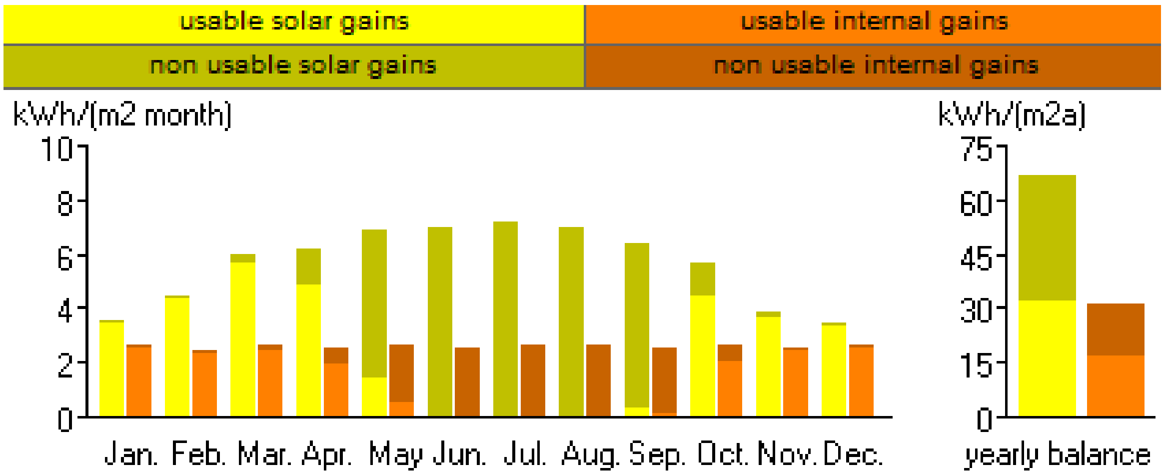


Figure 6-14: Solar and internal gains for building in Belgrade

6.4 Cooling

6.4.1 Monthly average of overheated hours per day

These two diagrams display the monthly averages of daily overheating hours as well as their annual mean for the case, that the building has no cooling system or air-conditioning.

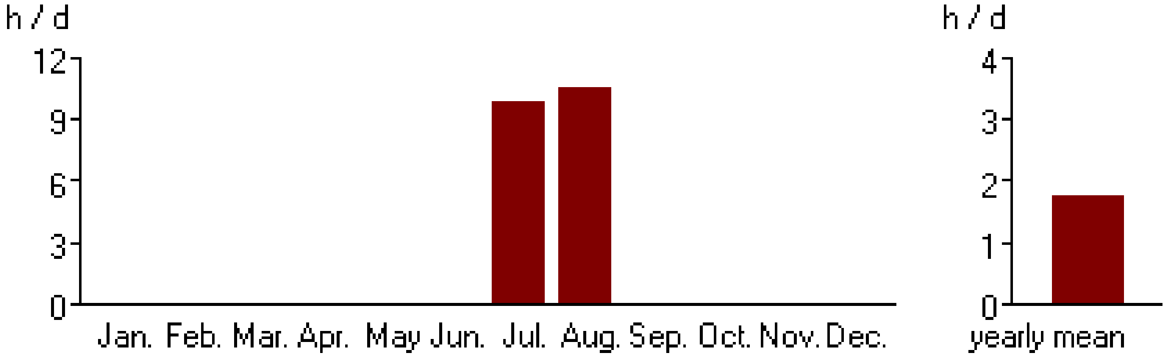


Figure 6-15: Monthly averages of daily overheating hours, Oslo

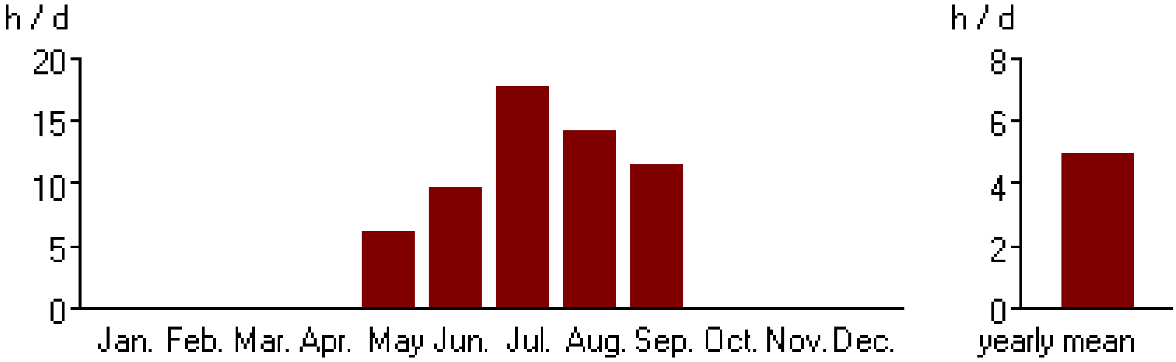


Figure 6-16: Monthly averages of daily overheating hours, Belgrade

6.4.2 Cooling demand

The graphics visualise the cooling demand inside the building per month resp. per year. The values are specific, i.e. it is the mean cooling demand per m2 of heated floor area.

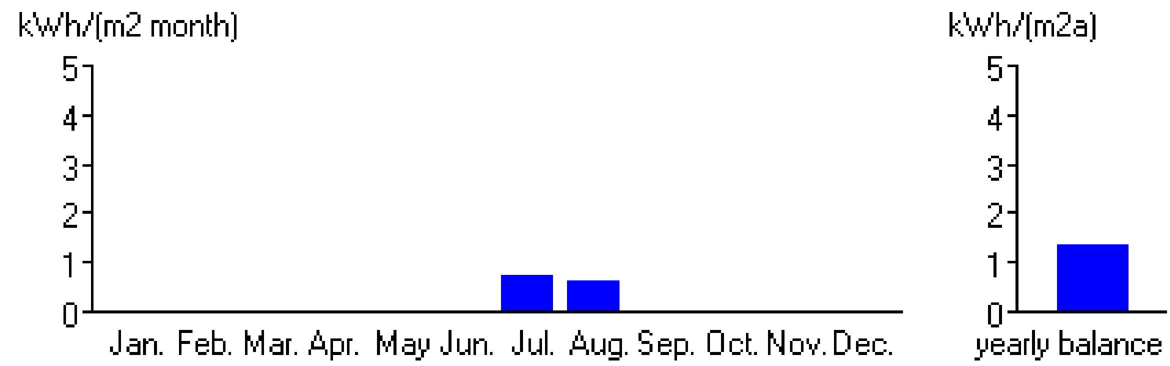


Figure 6-17: Cooling demand, Oslo

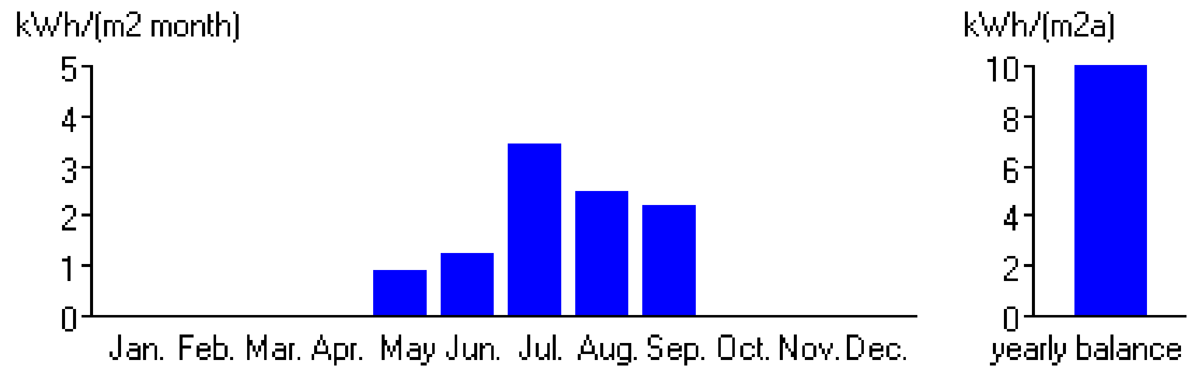


Figure 6-18: Cooling demand, Belgrade

6.4.3 Cooling degree hours

Cooling degree hours are the result of the multiplication of the number of hours, during which the comfortable temperature range is exceeded with the temperature difference between the limit of overheating and the room air temperature. The unit of the cooling degree hours is Kh (Kelvin-hours).

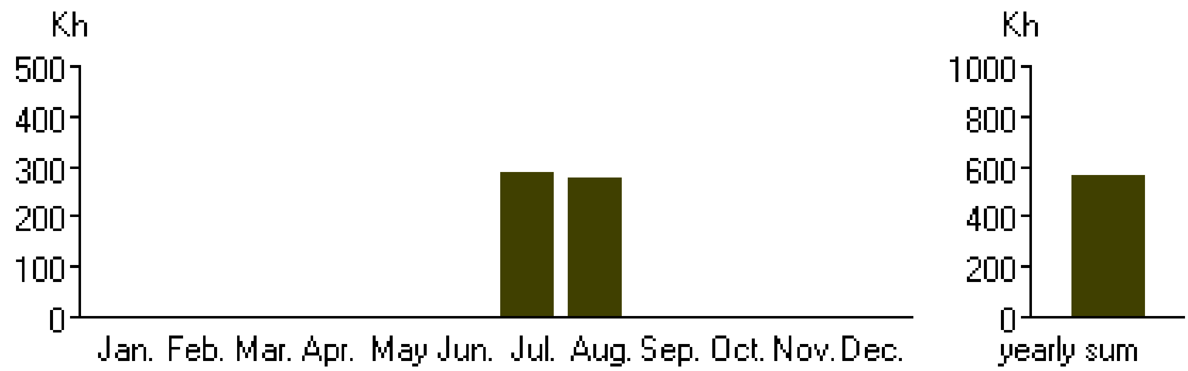


Figure 6-19: Cooling degree hours, Oslo

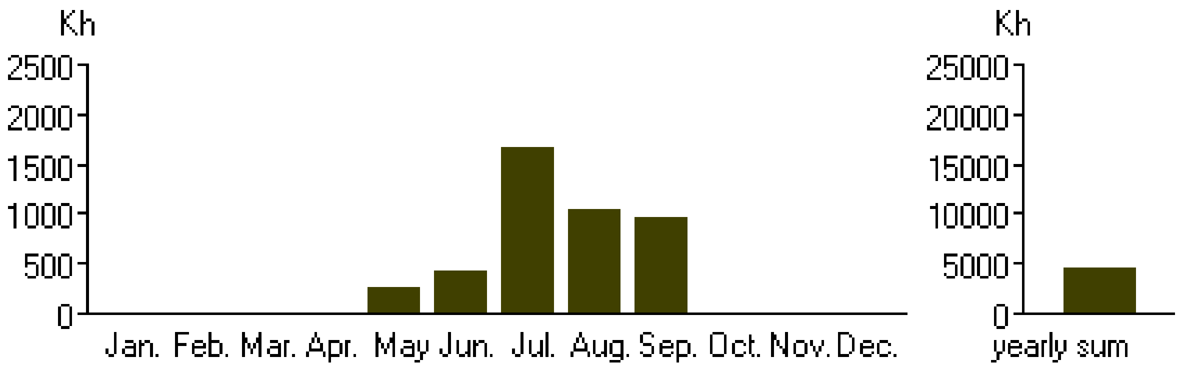


Figure 6-20: Cooling degree hours, Belgrade

7. Conclusions

Energy efficiency is a global and multi-faceted issue. EU's goal is to improve energy efficiency by 20% by the end of this decade. Building construction and buildings seem to be the most effective tool for accomplishing this task.

As new buildings are being built, the requirement for restoration and renovation of existing buildings is also given much more significance. This issue is even more important to Balkan countries that are still in development and where there is quite a large number of unregistered and insecure buildings, in comparison to the members of the EU.

The advancement of energy efficiency in building construction implies a continuous and wide array of activities whose ultimate goal is to reduce consumption of all types of energy, while providing same or better conditions in the facility. The consequence of the reduction of non-renewable energy sources (fossil fuels) consumption, and the usage of renewable energy sources is the reduction in greenhouse gasses emission (CO2, etc.) which contributes to protection of the environment, reduction of global warming and sustainable development of a country.

Energy remediation of buildings is an activity that realises the main goals of enhancing energy efficiency of buildings. If the goal is to enhance the energy characteristics, what is strived for are maximum insulation, best window quality, and the most efficient heating system. Problems occur when the remediation is realised with limited resources. Due to the aforementioned, multi-criterion optimisation is one of the approaches when solving such problems.

Energy remediation of structures as one of activities done in order to enhance energy efficiency has to be promoted with better prices, subsidies and other measures that will provide for its wide application. Incentive measures are expected from creators of energy policies and institutions that should take care of societal development.

An important parameter in energy remediation is the time required (in years) to return the funds invested in a project, and it is called a return period (deadline). Return period must be shorter than the maximum acceptable return period.

Both buildings in this work, according to the calculated yearly heating energy consumption are classified as energy grade C. This is, in this case, completely acceptable, considering the fact that these are existing buildings, while, in the case of new buildings, according to energy efficiency regulations, higher energy efficiency grades are expected.

In both objects it is possible to elevate the energy grade by remediation.

In case of Oslo building, elevating the energy grade could be achieved by window replacement, and in case of Belgrade building the elevation could be achieved by adding outer wall insulation, and window replacement, all with the aim of reducing heat transfer coefficient.

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