



Technical University of Crete
Department of Electronic Engineering
And Computer Engineering

Section of Electronics and Computer
Architecture

Master Thesis

***«Java Software platform for Energy Buildings
Management»***

Petros M. Patelis
Electronic and Computer Engineer

Chania 2008

*I would like to give special thanks for their valuable assistance to the
professors*

George Stavrakakis

Kostas Kalaitzakis

Dionysia Kolokotsa

*This master thesis is dedicated to my family and my friends and also to
my girlfriend Christina who was helpful and supporting*

Contents

Chapter 1 – Introduction.....	5
1.1 Generally	5
1.2 Contribution of Master Thesis	6
1.3 Short Presentation of Chapters.....	7
Chapter 2 – State of the Art	8
2.1 Generally.....	8
2.2 Energy Performance building evaluation in Mediterranean Countries: Comparison between software simulations and operating rating simulation	8
2.3 Energy code for Office buildings in Israel.....	9
2.4 Development of energy performance benchmarks and building energy ratings for non - domestic buildings: An example for Irish primary schools	11
Chapter 3 – Energy Classification based on Climatic Conditions of a location	13
3.1 Normalization of Energy Consumption.....	13
3.1.1 Normalization based on Heating and Cooling degree - days.....	13
3.1.2 Normalization based on Climate Severity Index (CSI)	17
3.1.3 Energy Classification Categories	20
Chapter 4 – Energy Classification based on European Standards	23
4.1 Generally.....	23
4.2 Energy Performance Indicators.....	24
4.2.1 Generally about Indicators	24
4.2.2 Classification Procedure	26
4.3 Classification without Weather Correction.....	26
4.4 Classification with Weather Correction.....	28
Chapter 5 – Description of the Platform	39
5.1 Database System	41
5.1.1 Generally	41
5.1.2 ER diagram.....	42
5.1.3 Explanation of the Relationships.....	43
5.1.4 Presentation and Analysis of the Tables	44
Chapter 6 – Case Study and Results	47
6.1 Generally.....	47
6.2 Ground Floor.....	47
6.3 1 st Floor.....	48
6.4 Experimental Results.....	49
6.4.1 Energy class and Results for Ground Floor	49
6.4.2 Energy class and Results for 1 st Floor	54
Chapter 7 – Conclusions and Future Work	59
7.1 Generally.....	59
7.2 Analysis of the results for the 1 st Floor.....	59
7.3 Analysis of the results for the Ground Floor	60
7.4 Future Work	61
References	62
Appendix A.....	63
A.1 Energy Classification using Calculated Method	63
A.1.1 Climate Severity Index and Degree - days Methods analysis	63
A.1.2 Explanation of Building's Data.....	65

Appendix B.....	66
B.1 Energy Classification using Measured Method.....	66
B.1.1 Heating Consumption Calculation.....	66
B.1.2 Cooling Consumption Calculation.....	67
B.1.3 Lighting Consumption Calculation.....	68
B.1.4 Appliances Consumption Calculation.....	69
B.1.5 Outdoor Temperature File	70
Appendix C.....	71
C.1 Communication between sensors and Personal Computer	71
C.1.1 Use of Java Native Interface.....	71
C.1.2 Java Native Interface	71
C.2 Measurement Java Platform for PCI - 6024E	77
C.2.1 Platform Interface	77
C.2.2 Platform Operation.....	79
C.3 Description of PCI - 6024E.....	82
C.3.1 Features of PCI - 6024E device	82
C.3.2 NI - DAQ Driver Software.....	82
C.3.3 Block Diagram of 6024E.....	82
C.3.4 Measurement Precision	83
C.3.5 I/O Connector	83
C.3.6 Differential Connection.....	84
Appendix D.....	85
D.1 User Manual	85
D.1.1 Login Security System.....	85
D.1.2 Main Menu	85
D.1.3 Building's Data operation	89
D.1.4 Measured Method	91
D.1.5 Calculated Method.....	94
D.1.6 Building Grading	95
Appendix E.....	96
E.1 Features of European Standard prEN 15203/15315	96
E.2 Terms and Definitions.....	96
E.3 Symbols, Units and Subscripts	98
Appendix F	99
F.1 Description of Java Files	99
F.1.1 MyDBConnection.java file	99
F.1.2 Pfileoperations.java file	99
F.1.3 SimplifiedRatingMethod.java file	100
F.1.4 CalculateLoads.java file.....	100
F.1.5 EnergyYear.java file	101
F.1.6 EnergyRating.java file	101
F.1.7 EnergyResults.java file	102
F.1.8 EnergyGradingResults.java file	102
Appendix G.....	104
G.1 Relational Scheme and Tables	104

Chapter 1 – Introduction

1.1 Generally

In the past few years, the rapid progress of Computer Engineering science has led to the development of many intelligent and flexible systems in the level of software and in the level of hardware as well. Furthermore, according to frequent reports about the reduction of the classical energy sources (e.g oil, gas) and the environmental pollution, which is caused by their thoughtless use, the scientific community has turned its interest to using not only renewable energy systems but also to developing software applications that can offer useful information about a building. Such applications have been developed in order to achieve energy and environmental classifications in buildings.

Energy and environmental management in buildings is a new field of interest and aims at the maintenance of living and working conditions for the occupants in a specific building. The role of such applications is to inform each user of the system or the owner of a building about the weaknesses of a building. This master thesis introduces an application for energy management in buildings and tries to inform about the energy consumption and how it can be reduced without causing any discomfort conditions to the occupants. The development of such applications can give an important solution against the energy problem, which deplores the modern societies, and can upgrade the standard of living especially in regions with great number of inhabitants.

This application has been developed in Java programming language and uses efficient techniques for energy classification in buildings located in Greece. These techniques are based on two basic methodologies introduced by Climatic Conditions and European prEN Standards. Moreover, the Java application uses a storing data system by using JavaDB library. This Java library is offered by Sun Microsystems Inc. Company and it is used for the implementation of a database system which can be considered embedded to the application. Furthermore, such an application can be applied in any building. However, in this case only four types of buildings are used. These four categories are: Schools, Shops, Hotels and Offices.

1.2 Contribution of Master Thesis

This master thesis deals with energy classification methods based on Climatic Conditions and European standards methodologies. It presents useful information about each methodology and describes the techniques used for classification. Moreover, it describes each application form/interface used for energy rating implementation while it also presents the proper data needed for the application to function successfully. Furthermore, it is essential to consider that this Java application is divided in two parts. The first part deals with the proper data collection and the second part deals with the methods of classification including their results.

As far as the first part, this application supports data either provided by files, which have been stored using a Building Energy Management System, or have been provided manually depending on the classification methodology that is going to be applied. In the case of data stored in files, a Building Management System is responsible for these measurements and such a system has been set up in the Electric Circuits and Renewable Energy Sources laboratory which is located in the Technical University of Crete.

The second part can be analyzed with regard to the methodology that was used. This means that, if a user of the system desires to use the Climatic Conditions methodology then there are two additional methods that the user can choose. These methods are: Climate Severity Index and Degree – Days. Also, if the system user desires to use this methodology, which refers to a European Standard, then the methods that can be used, are: Measured and Calculated methods. With regard to the results, the application uses Java libraries which provide graphical depiction of the results and additionally they can be organized in written forms.

1.3 Short Presentation of Chapters

Chapter 1 presents a short description about the Java application and the aim of implementing it. What it should be achieved via the application and a short analysis about the contribution of thesis is presented as well. Chapter 2 constitutes a quite extended description of the most recent developed methods for energy classification in buildings located in Greece or in other countries all over the world. In chapter 3, the first methodology of energy classification (based on climatic conditions) in buildings for Greek locations is presented. The requirements of this methodology and the mathematic background are presented as well.

Chapter 4 presents the energy classification methodology based on the standard prEN 15203:2006. The required specifications are declared including mathematic background and the two categories of this energy classification methodology. In both methodologies, data required and equations used for the implementation are presented. Chapter 5 presents a flowchart of the application including a short description. Moreover it includes a description and a presentation of the database system that was used (ER diagram), the tables composing it and the existing relationships among tables.

In chapter 6, case study and the results are presented. The case study part describes the place where the application was applied while the result part is constituted by graphs replying to building's energy consumptions for a whole year. Chapter 7 includes the conclusions that arise from the analysis of the graphs presented in chapter 6. Moreover, future extensions constitute part of this chapter. This part introduces techniques and ways of extending the present application. Finally, important information about various topics that have been taken into account for the implementation is described in appendices.

Chapter 2 – State of the Art

2.1 Generally

This chapter presents some of the most recent essays based on energy classification in buildings located in Europe and other countries. It introduces a short presentation of each essay.

2.2 Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation

In this essay three different models, including software calculations, concerning Energy Performance of buildings, have been developed and compared to real energy consumption data (Tronchin & Fabbri 2007). This study has been applied to a single house in Italy and its results have been compared to results coming from software codes applied in Mediterranean countries.

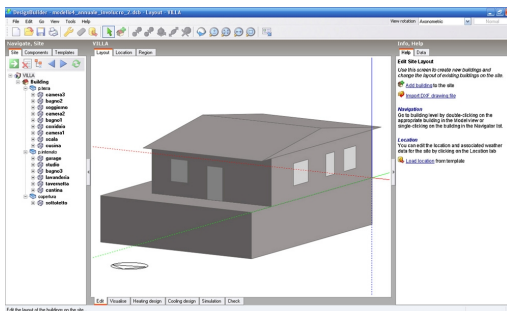


Figure 1. DesignBuilder simulation.

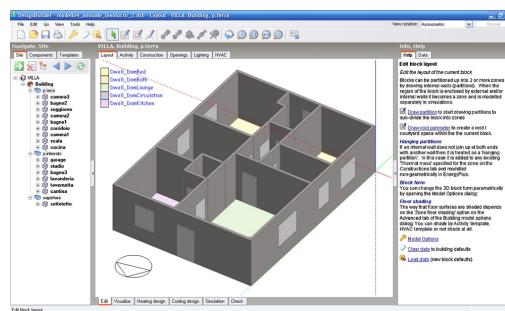


Figure 2. Ground floor

This application implements three different methods. Method A calculates the effective energy consumption for data measured in three years. This method uses methodology described by prEN standard 15603. Moreover, it uses real energy consumption data coming from gas or electrical bills. The average values of energy consumption in bills can be converted in primary energy by using primary energy factors regarding different energy carriers.

Method B is implemented by using CEN standards prEN 13790 and 15603 and plant systems. This method simulates data by using “DesignBuilder” and “EnergyPlus” softwares and it was implemented in a 3D interface using metrological data. This software allows the dynamic evaluation of heating and cooling

consumption during all seasons, including DHW and other energy consumption. It also informs users of the average temperature indoor and surface temperature during all year. Finally, method C is based on an Italian law and was implemented by Polytechnic of Milan.

2.3 Energy code for Office buildings in Israel

This section presents a new energy code for office buildings in Israel (Shavin, Yezioro & Capeluto 2007). This code is based on a prescriptive approach and can be easily applied as a tool for the design of office buildings. This approach is based on the results obtained from an energetic – economic optimization model that provides a recommended and preferred prescription for office buildings under given constraints. The method uses a model, which creates a set of suboptimal solutions, and allows the existence of energy savings with reasonable economic costs along with architectural design freedom. The model uses ENERGY software as the basic simulation application. This application includes daylight and artificial lighting calculations.

The implemented model takes into account 12 decision variables which are identified as those factors that influence the most the energetic performance for office buildings. Each one of these decision variables may obtain between 2 to 27 discrete values (see Table 1). Finally, the optimization model aims at the reduction of energy consumption for given economic constraints. In this case, the total life cycle cost (TLCC) is calculated. The TLCC includes energy cost of each design alternative and construction cost of the 12 decision variables and the cost of the air conditioning system according to the required size to keep internal thermal comfort, i.e. temperature and relative humidity, and interest on the capitalized cost of building and mechanical elements. The energy code for office buildings focuses only on electrical energy consumption as most new office buildings are cooled and heated by air conditioning units.

Design variable name		Parameters	Range of value																																											
1	Orientation	Or	8	N, NE, E, SE, S, SW, W, NW																																										
2	Infiltration	Inf	4	0.75, 1.0, 1.25, 1.5 ach																																										
3	Night ventilation	NV	7	1, 4, 10, 20, 30, 40, 50 ach																																										
4	External wall	Tm	3	Light, medium, heavy wall																																										
5	Insulation	Ins	5	Heavy/medium wall light wall 2.00 cm polystyrene $U = 1.202 \text{ Watt/m}^2/^{\circ}\text{C}$ $U = 1.133 \text{ Watt/m}^2/^{\circ}\text{C}$ 3.00 cm polystyrene $U = 0.924 \text{ Watt/m}^2/^{\circ}\text{C}$ $U = 0.883 \text{ Watt/m}^2/^{\circ}\text{C}$ 5.00 cm polystyrene $U = 0.632 \text{ Watt/m}^2/^{\circ}\text{C}$ $U = 0.612 \text{ Watt/m}^2/^{\circ}\text{C}$ 7.00 cm polystyrene $U = 0.480 \text{ Watt/m}^2/^{\circ}\text{C}$ $U = 0.469 \text{ Watt/m}^2/^{\circ}\text{C}$ 10.00 cm polystyrene $U = 0.353 \text{ W/m}^2/^{\circ}\text{C}$ $U = 0.347 \text{ Watt/m}^2/^{\circ}\text{C}$																																										
6	Albedo/color	Al	4	0.45, 0.65, 0.85, WGL* *For the light wall case, the external envelope may be covered with glass similar to that of the window. On this case the albedo will be referred as the reflection coefficient of the glazing.																																										
7	Unit depth	Dp	2	5.0, 8.2 m																																										
8	Window size	Wa	6	10%, 15%, 20%, 25%, 30%, 35% window size = % of office floor area = 50m ²																																										
9	Glazing	Glz	6	<table><tr><th>Code</th><th>Description</th><th>U (Watt/m²/°C)</th><th>SC</th><th>Tv</th><th>Tv/Sc</th></tr><tr><td>DgCl</td><td>Double glazing clear</td><td>3.57</td><td>0.86</td><td>80</td><td>0.93</td></tr><tr><td>DgGr</td><td>Double glazing green</td><td>3.57</td><td>0.58</td><td>70</td><td>1.20</td></tr><tr><td>LE01</td><td>Low emissivity glazing</td><td>1.80</td><td>0.43</td><td>68</td><td>1.58</td></tr><tr><td>LE02</td><td>Low emissivity glazing</td><td>1.80</td><td>0.31</td><td>54</td><td>1.74</td></tr><tr><td>LE03</td><td>Low emissivity glazing</td><td>1.80</td><td>0.27</td><td>41</td><td>1.52</td></tr><tr><td>LE04</td><td>Low emissivity glazing</td><td>1.80</td><td>0.18</td><td>17</td><td>0.94</td></tr></table>	Code	Description	U (Watt/m ² /°C)	SC	Tv	Tv/Sc	DgCl	Double glazing clear	3.57	0.86	80	0.93	DgGr	Double glazing green	3.57	0.58	70	1.20	LE01	Low emissivity glazing	1.80	0.43	68	1.58	LE02	Low emissivity glazing	1.80	0.31	54	1.74	LE03	Low emissivity glazing	1.80	0.27	41	1.52	LE04	Low emissivity glazing	1.80	0.18	17	0.94
Code	Description	U (Watt/m ² /°C)	SC	Tv	Tv/Sc																																									
DgCl	Double glazing clear	3.57	0.86	80	0.93																																									
DgGr	Double glazing green	3.57	0.58	70	1.20																																									
LE01	Low emissivity glazing	1.80	0.43	68	1.58																																									
LE02	Low emissivity glazing	1.80	0.31	54	1.74																																									
LE03	Low emissivity glazing	1.80	0.27	41	1.52																																									
LE04	Low emissivity glazing	1.80	0.18	17	0.94																																									
10	Blinds	Blnd	3	NoBlnd—No blinds. Shading coefficient >0.9 IntBlnd—Electrical internal rolling blinds. Shading coefficient >0.5 ExtBlnd—Electrical external rolling blinds. Shading coefficient: < 0.5																																										
11	Sun shades	SunShd	27	See Fig. 1																																										
12	Light control	Ctrl	3	OnOff1—The control includes a number of light sensors and a control box. The light is switched on or off for predetermined values at all control zones OnOff2—The control includes two light sensors and a control box. The light is switched on or off for predetermined values at each control zone Dim1—Dimmer type 1 (middum efficient dimmer)																																										

Table 1. Variables presentation including their ranges

2.4 Development of energy performance benchmarks and building energy ratings for non-domestic buildings: An example for Irish primary schools

This application presents a methodology in which energy benchmarks and rating systems are developed, starting from the data collection from a building stock (Hernandez, Burke & Lewis 2007). Moreover, this methodology is applied in an Irish school including calculated and measured methods. This analysis concerns primary schools in Ireland since they can be considered as homogeneous buildings with homogeneous occupancy and activities. In this case, data collection is achieved by questionnaires since it is expected that schools would provide a better response rate compared to other buildings.

The information, which is included in the questionnaires, refers to the following parts:

- General information about the school (name, address, etc)
- Construction details (specifications for the walls and roofs, etc)
- Heating, ventilation and lighting.

After the completion of 67 questionnaires, their data, which included occupancy densities, activity and heating schedules, were used to develop a standard activity schedule for primary school buildings. The construction values for stock reference buildings came from the data included on the questionnaire responses. A summary of the main characteristics used for the stock reference building is presented in Table 1.

Element	W/m ² K
External walls (as per original construction)	1.2
Ground floor (as per original construction)	2.0
Flat roof	1.4
Pitched roof (insulated at ceiling level)	0.47
Pitched roof (insulated on pitch)	0.47
Windows and doors	4.9 and 2.2

The reference regulation parameter for buildings, which is presented in Table 2, is based on the Irish Building Regulations 2005 Technical Guidance.

Element	W/m ² K
External walls	0.27
Ground floor	0.25
Flat roof	0.22
Pitched roof (insulated at ceiling level)	0.16
Pitched roof (insulated on pitch)	0.2
Windows and doors	2.2

The Calculated method for rating is obtained by the calculation of design values of a building. Furthermore, the measured energy rating is obtained by the weighted sum of the measured annual amounts of all the energywares used by the building. Measured energy rating is also called operational rating. Also, the software used for the calculation of energy performance in buildings is EnergyPlus. When Energy Performance indicator is calculated then a grade technique is applied. This technique is provided by the prEN standard 15217:2005 and is described in Table 3.

Class A	$EP < 0.5R_r$
Class B	$0.5R_r \leq EP < R_r$
Class C	$R_r \leq EP < 0.5(R_r + R_s)$
Class D	$0.5(R_r + R_s) \leq EP < R_s$
Class E	$R_s \leq EP < 1.25R_s$
Class F	$1.25R_s \leq EP < 1.5R_s$
Class G	$1.5R_s \leq EP$

EP corresponds to the energy performance indicator of the Irish school and parameters R_s and R_r corresponds to the building stock reference and regulation reference respectively.

Chapter 3 – Energy Classification based on Climatic Conditions of a Location

3.1 Normalization of Energy Consumption

3.1.1 Normalization based on Heating and Cooling Degree – days

The specific classification methodology takes into account a location's climatic conditions so that energy classifications of buildings in different locations can be compared. In order to define the class of a building, by using this methodology, the calculation of the normalized form of energy consumption is required. This calculation procedure requires the existence of reference climatic conditions – in this case the climatic conditions of Athens. The criterion of selecting these reference conditions is based on the fact that the evaluated and recorded buildings are located in Athens.

This methodology of energy classification is based on the modification of energy needs for heating and cooling when the building under study is in different location than the one that has reference climatic conditions. In case that the building under study exists in the reference location, its energy needs for heating and cooling do not modify.

The classification methodology which uses heating and cooling degree – days can be considered as the most popular approach of normalization in Greece. Heating and cooling degree – days are equal to the difference between base and outdoor temperatures multiplying it with the number of days which indicate the period of interest.

The following equations are used for the calculation of heating and cooling degree – days for a location:

- Cooling period

$$HDD = \sum_{t_{start}}^{t_{end}} (T_{HDD_base} - T_{out}) \quad (1)$$

- Heating period

$$CDD = \sum_{t_{start}}^{t_{end}} (T_{out} - T_{CDD_base}) \quad (2)$$

where

HDD are the heating degree - days [$^{\circ}C \cdot days$]

CDD are the cooling degree – days [$^{\circ}C \cdot days$]

T_{HDD_base} is the indoor base temperature during heating period [$^{\circ}C$]

T_{CDD_base} is the indoor base temperature during cooling period [$^{\circ}C$]

T_{out} is the mean outdoor temperature in daily base [$^{\circ}C$]

t_{start} is the starting day of heating/cooling period

t_{end} is the ending day of heating/cooling period

The implementation of this methodology requires the following rules:

- The suggested base temperature for Greece is equal to $19^{\circ}C$.
- The degree – days are calculated in daily base.
- Only positive values of differences between base and outdoor temperature are accepted since these indicate the actual needs for heating or cooling.
- The calculations are executed for a whole year including both climatic conditions for the reference location (HDD^N και CDD^N) and climatic conditions for any other location (HDD και CDD).

It is very important to be noticed that the parameter chosen for the calculation of normalized energy consumption is the outdoor temperature. Outdoor temperature is the most available parameter describing climatic conditions in Greek locations, against others, such as solar radiation. A simplified approach for energy normalization using heating and cooling degree – days is described by the following equations:

$$\bullet \quad Q_{Heating}^N = Q_{Heating} \cdot \frac{HDD^N}{HDD} \quad (3)$$

$$\bullet \quad Q_{Cooling}^N = Q_{Cooling} \cdot \frac{CDD^N}{CDD} \quad (4)$$

where

$Q_{Heating}^N$ is the annual normalized energy consumption for heating
[kWh / year]

$Q_{Heating}$ is the annual energy consumption for heating [kWh / year]

$Q_{Cooling}^N$ is the annual normalized energy consumption for cooling
[kWh / year]

$Q_{Cooling}$ is the annual energy consumption for cooling [kWh / year]

HDD^N are the heating degree – days for reference location [$^{\circ}C \cdot days$]

CDD^N are the cooling degree – days for reference location [$^{\circ}C \cdot days$]

The heating and cooling degree – days for the reference location (Athens) are 1228 and 1020 respectively, considering base temperature equal to $19^{\circ}C$. The Cooling period is the period that includes the range of months from May to September and the heating period is the one that includes the range of months from October to April (see Table 1).

	<i>Period</i>	<i>Degree – days [$^{\circ}C \cdot days$]</i>
Heating	October – April	1228
Cooling	May – September	1020

Table 1. Heating and Cooling degree – days based on reference location (Athens)

The following table presents Greek locations including their heating and cooling degree – days:

<i>Location</i>	<i>Heating Degree – days</i>	<i>Location</i>	<i>Cooling Degree – days</i>
1. Agrinio	1331	42. Kos	896
2. Agchialos	1740	43. Lamia	1467
3. Athens	1228	44. Larissa	1858
4. Aigio	1210	45. Lefkada	1146

5. Alexandroupolis	1923	46. Limnos	1449
6. Aliartos	1839	47. Lidoriki	1991
7. Anavryta	1537	48. Methoni	953
8. Antiparos	899	49. Milos	1068
9. Anogeia	1703	50. Mytilini	1234
10. Araxos	1155	51. Naxos	856
11. Argostoli	998	52. Nafplion	1095
12. Arta	1276	53. Xanthi	1910
13. Astypalaia	835	54. Oreoi	1428
14. Volos	1471	55. Orestiada	2187
15. Gortynos (Crete)	1004	56. Palaiochora (Crete)	730
16. Desfina	1974	57. Paros	932
17. Domokos	2376	58. Patra	1207
18. Drama	1945	59. Piraeus	1001
19. Edessa	2053	60. Platanos (Nafpaktias)	2363
20. Elefsina	1240	61. Polygyros	2300
21. Zakynthos	940	62. Ptolemaida	2483
22. Irakleio	829	63. Pyrgos	1110
23. Thasos	1781	64. Rethymno	714
24. Salonica	1812	65. Rhodes	935
25. Thira	1082	66. Samos	1022
26. Ierapetra	681	67. Serres	2010
27. Ikaria	877	68. Siteia	745
28. Ioannina	2027	69. Skopelos	1452
29. Kavala	1970	70. Skyros	1246
30. Kalavryta	2240	71. Souda	1055
31. Kalamata	992	72. Soufli	2124
32. Kalampaka	1813	73. Syros	971
33. Karpathos	697	74. Tanagra	1546
34. Karystos	1140	75. Germiades	2089
35. Kerkyra	1203	76. Trikala	1702
36. Kozani	2469	77. Tripoli	2085
37. Komotini	1996	78. Tympakion	898

38. Konitsa	2003	79. Farsala	1777
39. Korinthos	1167	80. Florina	2620
40. Kythira	1052	81. Chalkida	1200
41. Kymi	1516	82. Chios	1113

Table 2. Heating and Cooling degree – days for Greek locations

3.1.2 Normalization based on Climate Severity Index (CSI)

After the definition of heating or cooling energy needs, two locations can be considered identical as far as the climatic conditions are concerned, if heating energy consumption of a building is equal to cooling energy consumption of the same building under the climatic conditions of both locations. Actually, it is possible that two locations with the same heating energy consumption, can have different cooling energy consumption and reversely.

The methodology which can express heating and cooling energy needs of a building regarding climatic conditions is the Climate Severity Index (CSI) methodology. This methodology calculates severities and compares them between two different climatic conditions (that is, climatic conditions of a building's location and climatic conditions of a reference location). Actually, the higher the value of CSI the more severe the climatic conditions can be. Furthermore, only positive values of CSI are used. During a year CSI values are calculated twice. The first value refers to heating period and the other refers to cooling period. When CSI values are negative or zero then the energy needs for heating and cooling can be considered as negligible. This means that there are no energy needs under the specific climate conditions.

Now, it can be considered that energy needs for a specific building can be calculated under different climatic conditions which may indicate either different locations or different time periods for a specific location or a combination of both. The calculation of normalized energy needs for a building is achieved by dividing the value of Climate Severity Index of the reference location to the value of Climate Severity Index for a specific location and then multiplying it with the heating or cooling energy needs of the building. The absolute effect of climatic conditions on heating or cooling energy needs depends on the features of a building, but the relative climatic effect is independent from parameters like a building's envelope, the size of

the windows or the orientation of the building. The only significant parameter is the use of a building due to internal gains.

The steps required, are presented below:

- Selection of the reference climate conditions
- Selection of typologies for each building category
- Selection of climatic conditions referring to different climates (e.g typical meteorological time)

Furthermore, the energy needs for heating and cooling are calculated under different scenarios (orientation, etc) by using energy simulation models. The results of each combination of climatic conditions are evaluated while the value of Climate Severity Index for the specific combination is defined. The average value of all CSI parameters refers to an indicator of energy needs for a specific location. The equation used for the CSI calculation is presented below:

$$CSI = a \cdot DD + b \cdot (n / N) + c \cdot (DD)^2 + d \cdot (n / N)^2 + e \quad (5)$$

where:

DD are the degree – days for heating or cooling depending on the evaluation period

n/N is the fraction of the real sunlight hours to the maximum sunlight hours for the specific latitude

a, b, c, d and e are constants depending on the type of building

Table 3 presents the values for a, b, c, d, e parameters for heating/cooling periods.

<i>Period</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>D</i>	<i>e</i>
Winter	-0,002	-2,20	$9.04 \cdot e^{-6}$	1,88	0,96
Summer	0,028	8,93	$-6.62 \cdot e^{-5}$	-5,52	-4,81

Table 3. CSI constants for residences located in Greece.

The measures of annual energy consumption for a building, during a year, can be modified in order to comply with the reference year. Moreover, the measures of

annual energy consumption for a building in a specific location, can be modified in order to comply with the climatic conditions for the reference location.

The calculation of this category of normalization can be achieved by multiplying the energy consumption for heating or cooling with the fraction of the reference value of CSI index and the value of CSI index for climatic conditions for a specific location. The equations used for the calculation are:

$$\bullet \quad Q_{Heating}^N = Q_{Heating} \cdot \frac{CSI_{Heating}^N}{CSI_{Heating}} \quad (6)$$

$$\bullet \quad Q_{Cooling}^N = Q_{Cooling} \cdot \frac{CSI_{Cooling}^N}{CSI_{Cooling}} \quad (7)$$

where

$Q_{Heating}^N$ is the annual normalized energy consumptions for heating [$kWh / year$]

$Q_{Cooling}^N$ is the annual normalized energy consumptions for cooling [$kWh / year$]

$Q_{Heating}$ is the annual energy consumption for heating [$kWh / year$]

$Q_{Cooling}$ is the annual energy consumption for cooling [$kWh / year$]

$CSI_{Heating}^N$ is the value of Climate Severity Index for heating energy needs for the reference location

$CSI_{Cooling}^N$ is the value of Climate Severity Index for cooling energy needs for the reference location

$CSI_{Heating}$ is the value of Climate Severity Index for heating energy needs for a specific location

$CSI_{Cooling}$ is the value of Climate Severity Index for heating energy needs for a specific location

It is very important to be noticed that the only parameter given for the calculation of energy consumption is degree – days for heating of a specific latitude (see table 2) while cooling degree – days are not given. In this case, the calculation of degree – days was achieved by using equation 2 for each Greek location. In addition, there are four building categories tested and evaluated. These categories are: Schools, Offices, Shops and Hotels.

3.1.3 Energy Classification Categories

As it was mentioned previously, there are four types of buildings which are evaluated: Schools, Offices, Hotels and Shops. Also there are four energy categories according to the value of normalized energy consumption as well. An energy category depends on the type of building, the period of interest and whether the building has or has not insulation. The following tables present the four energy categories for each building type.

Categories Consumption	A	B	C	D
Cooling period – with Insulation (KWh / m² · year)	[0 – 10)	[10 – 20)	[20 – 40)	>=40
Cooling period – without Insulation (KWh / m² · year)	[0 – 10)	[10 – 25)	[25 – 55)	>=55
Heating period – with Insulation (KWh / m² · year)	[0 – 40)	[40 – 65)	[65 – 125)	>=125
Heating period – without Insulation (KWh / m² · year)	[0 – 45)	[45 – 75)	[75 – 130)	>=130

Table 4. Energy consumption's limits for Offices

Categories Consumption	A	B	C	D
Cooling period – with Insulation (KWh / m ² · year)	[0 – 10)	[10 – 15)	[15 – 25)	>=25
Cooling period – without Insulation (KWh / m ² · year)	[0 – 25)	[25 – 40)	[40 – 80)	>=80
Heating period – with Insulation (KWh / m ² · year)	[0 – 35)	[35 – 65)	[65 – 120)	>=120
Heating period – without Insulation (KWh / m ² · year)	[0 – 30)	[30 – 60)	[60 – 110)	>=110

Table 5. Energy consumption's limits for Shops

Categories Consumption	A	B	C	D
Cooling period (KWh / m ² · year)	[0 – 15)	[15 – 35)	[35 – 75)	>=75
Heating period – with Insulation (KWh / m ² · year)	[0 – 30)	[30 – 45)	[45 – 65)	>=65
Heating period – without Insulation (KWh / m ² · year)	[0 – 35)	[35 – 60)	[60 – 95)	>=95

Table 6. Energy consumption's limits for Schools

Categories Consumption	A	B	C	D
Cooling period – with Insulation (KWh / m ² · year)	[0 – 5)	[5 – 15)	[15 – 25)	>=25
Cooling period – without Insulation (KWh / m ² · year)	[0 – 5)	[5 – 15)	[15 – 35)	>=35
Heating period – with Insulation (KWh / m ² · year)	[0 – 90)	[90 – 140)	[140 – 215)	>=215
Heating period – without Insulation (KWh / m ² · year)	[0 – 95)	[95 – 145)	[145 – 205)	>=205

Table 7. Energy consumption's limits for Hotels

Chapter 4 – Energy Classification based on European Standard prEN 15203:2006

4.1 Generally

Standards can be considered as instructions containing methodologies which are used for achieving energy or environmental classification of buildings. This master thesis is focusing only on standards that refer to energy classification. These standards are developed by the scientific community of European Union and are legally established. Therefore each member of the European Union, is obliged to comply with them according to its energy policy. The data used for energy classification, which are measured annually, define building parameters (e.g. R_s and R_r) and climatic data (such as temperature, relative humidity etc) (CEN Members 2006). The implementation of the standards' methodologies can lead to useful conclusions about energy consumption for a building.

However, standards have not only been developed in Europe but also in the United States as well. This thesis is focusing, only, on standards developed in Europe and their implementation in buildings located in Greece. It is essential to notice that, energy classification based on standards is a more reliable and convenient way than classification using degree – days and climate severity index methods. This is based on the fact that degree – days, which are also used by climate severity index methodology, are not available for most cases of energy classification. This analysis presents two main methodologies of classification: including weather correction and not including weather correction.

4.2 Energy Performance Indicators

4.2.1 Generally about Indicators

In order to study the Energy performance of a building, an indicator's value is measured. The indicator is called Energy Performance indicator (or EP indicator) (CEN Members 2006). EP indicator is expressed by the weighted sum of a building's delivered energy. This is described by the following expression:

$$EP_{period} = \sum_{i=1}^n deliveredEnergy_i, \quad (1)$$

where $i = 1, 2, \dots, n$ declares the months of a period (heating/cooling).

Furthermore, the Energy Performance indicator can represent the Primary energy of a building (E_p), Carbon Dioxide emissions (m_{CO_2}) and the net delivered energy defined by national policies (e.g. delivered energy, E_p). In addition, indicators should be based on two types of ratings according to prEN 15203/15315. These types of ratings are:

- standard calculated energy rating
- measured energy rating

The calculated energy rating consists a convenient way for planned or actual buildings. An indicator is renamed to “standard calculated energy indicator” or “measured energy indicator” if it is based on standard calculated energy rating or measured energy rating respectively. The calculation of EP indicator demands two types of requirements:

- a) the definition of overall energy performance requirement (EP_r)
- b) several specific requirements based on
 1. energy use for heating, domestic hot water, cooling, lighting, etc
 2. energy need for heating domestic hot water and cooling

3. features of a building itself or of its technical building systems (e.g. heat transfer coefficient of building's envelope, etc.)
4. features of the building envelope or technical building systems components (e.g. thermal transmittance of walls, efficiency of boilers, insulation of heating and hot water pipes)

While each indicator must be different for

- a new building
- renovation of an existing building
- extension of an existing building
- different types of buildings

For new buildings and their renovations, requirements shall include one overall energy performance requirement. For partial renovation of an existing building and for extension to an existing building where overall requirements can be difficult to apply, simplified approaches based on specific requirements can be used. When specifying these requirements a consideration shall be given to the following important energy uses:

- thermal characteristics of the building envelope
- heating installation and hot water supply
- air conditioning installation (including dehumidification)
- ventilation (including humidification)
- built in lighting installation
- passive solar heat sources and solar protection
- energy production in particular by renewable sources and co-generation.

4.2.2 Classification Procedure

For the determination of a building's class the following steps are required:

- a) definition of the building's type (e.g. office, hotel, etc)
- b) selection of Energy Performance Regulation parameter (R_r) and Building Stock reference parameter (R_s) according to the building's type
- c) determination of EP indicator's values for each period of a year (heating or cooling)
- d) determination of the class according to the following rules:
 - i) Class A $\rightarrow EP < 0.5 \cdot R_r$
 - ii) Class B $\rightarrow 0.5 \cdot R_r \leq EP < R_r$
 - iii) Class C $\rightarrow R_r \leq EP < 0.5 \cdot (R_r + R_s)$
 - iv) Class D $\rightarrow 0.5 \cdot (R_r + R_s) \leq EP < R_s$
 - v) Class E $\rightarrow R_s \leq EP < 1.25 \cdot R_s$
 - vi) Class F $\rightarrow 1.25 \cdot R_s \leq EP < 1.5 \cdot R_s$
 - vii) Class G $\rightarrow 1.5 \cdot R_s \leq EP$

4.3 Classification without Weather Correction

The analysis based on classification without weather correction concerns annual data referring to two main periods: Heating and Cooling period. The application form that implements this methodology is presented in Appendix B. The use of this methodology demands data taken for 3 or more years (CEN Members 2006). These data come from electrical, oil or gas bills in case of heating and cooling devices. In case of lighting devices and appliances, data can come either from files (where data are stored into files by BEMS) or inputs declaring consumption in watts, the number of used devices and the total hours of usage. The application, which is responsible for annual energy classification, consists of 4 categories: Heating, Cooling, Lighting and Appliances.

Firstly, this study is focusing only on measured energy and not on calculated energy. The determination of this type of energy is based on an assessment time

period. Assessment time period is called a significant number of years (in this case, 3 or more years) where several measurements are taken in order that energy consumption of a building is calculated. Furthermore, there are requirements that must be taken into account for energyware calculation which are:

- the time period is an integer number of years. If assessment period is not an integer then the equation 2 indicates how many energywares can be calculated
- if the time of period is less than 3 years. Then energyware calculation is based on the method including weather correction (see next paragraph)
- a building cannot be modified when energy performance is changed during the assessment time period. In case that a change occurs then a new assessment time period must be defined in order to get the new energy rating

Energyware is calculated by the following equation:

$$E = \frac{t_{an}}{t_{per}} \cdot E_{per} \quad (2)$$

where

E_{per} is the amount of energyware used during assessment period

t_{an} is the duration of a year

t_{per} is the assessment time period

4.4 Classification with Weather Correction

This methodology uses the same application system for data collection and it uses data taken for less than 3 years (see Appendix B). Each building is classified annually for a specific assessment time period (1 or 2 years) (CEN Members 2006). The Energyware of a building is defined by the following equation:

$$E_{an} = \frac{Q_{an,calc}}{Q_{per,calc}} \cdot E_{per} \quad (3)$$

where

E_{per} is the amount of energyware used for heating or cooling during the assessment time period.

$Q_{an,calc}$ is the annual calculated energy need for heating or cooling.

$Q_{per,calc}$ is the calculated energy need for heating or cooling during the assessment time period.

And $Q_{an,calc}$ parameter is defined by the following equations according to a specific period of year:

$$\begin{aligned} Q_{calc,heating} &= \sum_{i=1}^n U_i \cdot A_i \cdot (T_{out} - T_i) - (Q_{floor} + Q_{sol} + Q_{air} + Q_{light} + Q_{appl} + Q_{eq}) \\ Q_{calc,cooling} &= (Q_{floor} + Q_{sol} + Q_{air} + Q_{light} + Q_{appl} + Q_{eq}) - \sum_{i=1}^n U_i \cdot A_i \cdot (T_i - T_{out}) \end{aligned} \quad (4)$$

where

U : conductivity of the walls

A : building's area (m^2)

T_i : indoor temperature ($^{\circ}C$)

T_{out} : outdoor temperature ($^{\circ}C$)

$Q_{floor}, Q_{light}, Q_{eq}, Q_{sol}, Q_{appl}$: heating or cooling loads measured on floor, lighting, building's equipment, solar irradiance and appliances respectively.

Q_{air} : heating or cooling load excluded by air. This load is calculated by $\rho \cdot C_p \cdot \dot{V}$.

Studying equation 4, someone can easily realize that the weather correction is obtained by the difference between indoor and outdoor temperature. This means that the evaluation of annual energy consumption takes into account indoor and outdoor temperatures measured according to the specific year and location.

However, the calculation of energy needs for a building considers both periods of study. This means that, two energy need values are defined, one for heating and one for cooling period. The overall energy need for the building is equal to the mean value of heating and cooling energy need amounts. So,

$$E_{overall,an} = \frac{E_{an,heating} + E_{an,cooling}}{2} \quad (5)$$

The value of $E_{overall,an}$ defines the class of a building based on the following rules:

- i) Class A $\rightarrow E_{overall,an} < 0.5 \cdot R_r$
- ii) Class B $\rightarrow 0.5 \cdot R_r \leq E_{overall,an} < R_r$
- iii) Class C $\rightarrow R_r \leq E_{overall,an} < 0.5 \cdot (R_r + R_s)$
- iv) Class D $\rightarrow 0.5 \cdot (R_r + R_s) \leq E_{overall,an} < R_s$
- v) Class E $\rightarrow R_s \leq E_{overall,an} < 1.25 \cdot R_s$
- vi) Class F $\rightarrow 1.25 \cdot R_s \leq E_{overall,an} < 1.5 \cdot R_s$
- vii) Class G $\rightarrow 1.5 \cdot R_s \leq E_{overall,an}$

4.5 Reference Values

4.5.1 Energy Performance Regulation Reference R_r

According to standard prEN ISO 15217, R_r parameter corresponds to the typical value of the requirements of energy performance regulations for new buildings. R_r is given as input before the classification process starts. Each building has its own R_r parameter. The unit of this parameter is KWh/year and compared to indicator EP it indicates the class of a building (see below).

4.5.2 Building Stock Reference

This corresponds to the energy performance reached by approximately 50% of the national or regional building stock (median value). This parameter is provided by prEN ISO 15217 standards as well. The value of this parameter differs in every building. This means that the four types of buildings have different values of R_s . For buildings in Greece this value is extracted by the following charts. The charts contain data for heating/cooling period, for different types of building and for the existence of insulation or the lack of it.

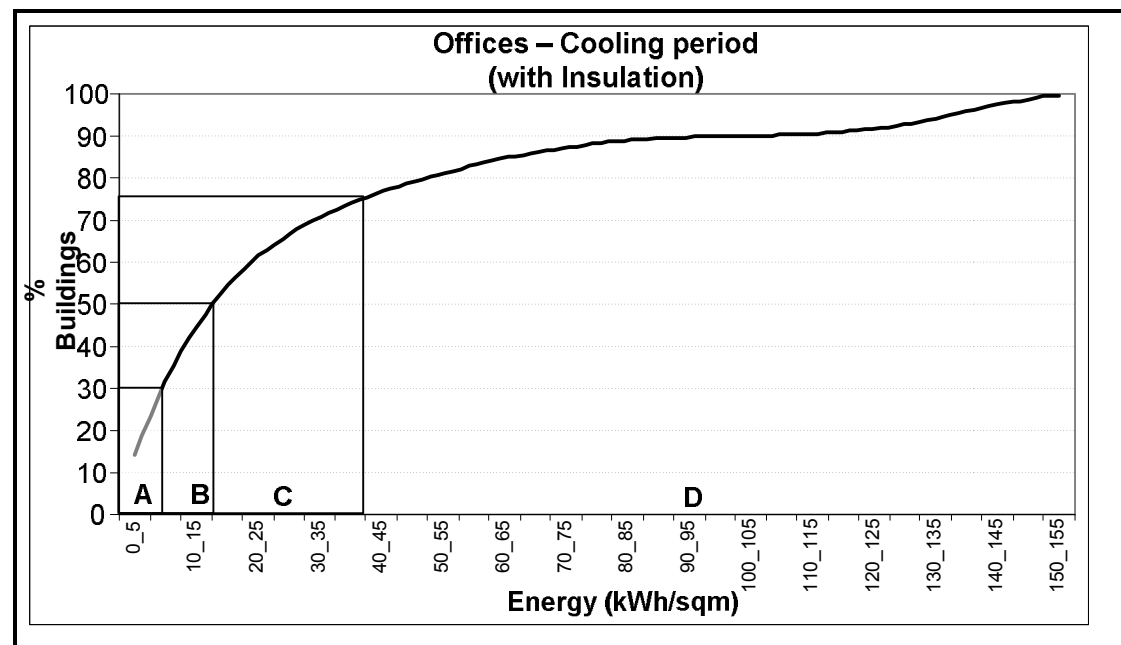


Figure 1. Graph concerning to Offices with insulation during Cooling period.

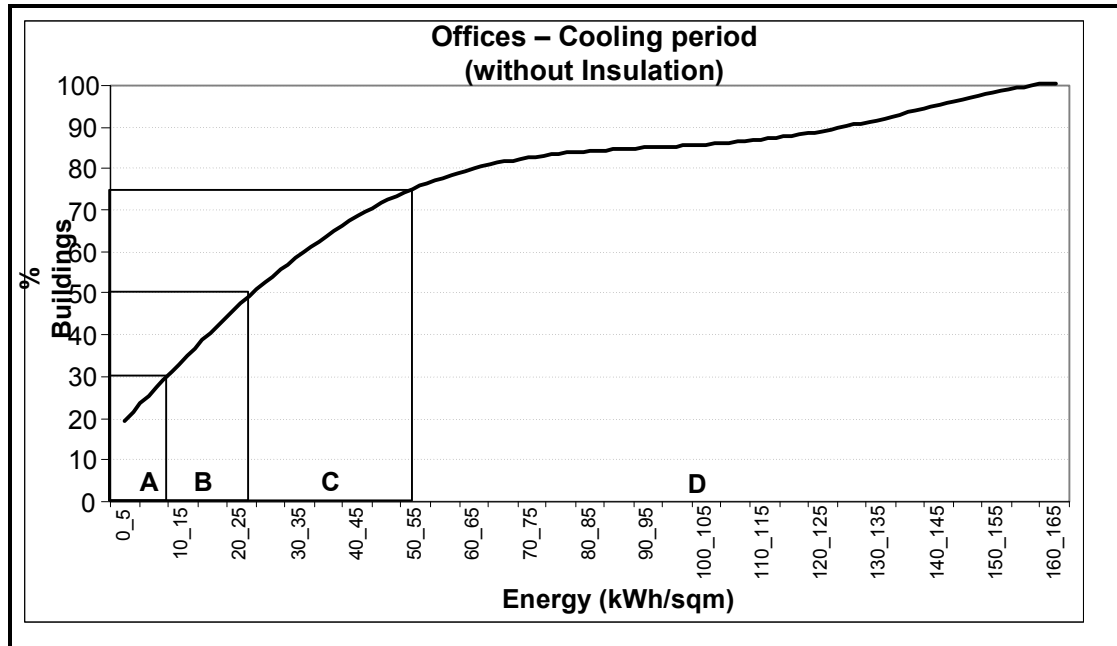


Figure 2. Graph concerning to Offices without insulation during Cooling period.

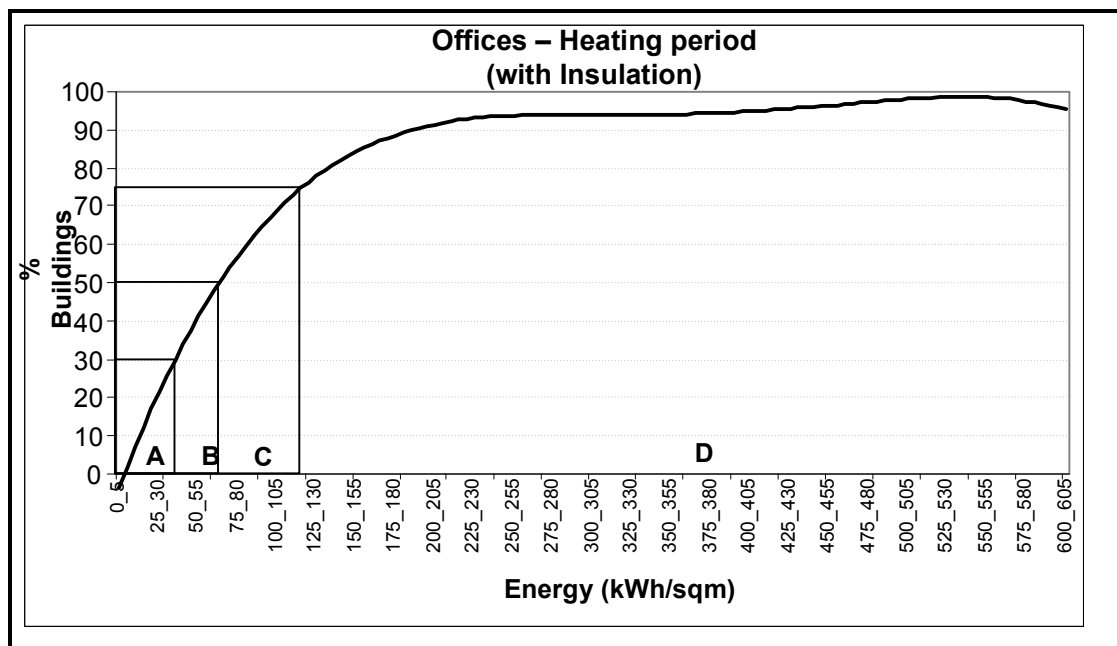


Figure 3. Graph concerning to Offices with insulation during Heating period.

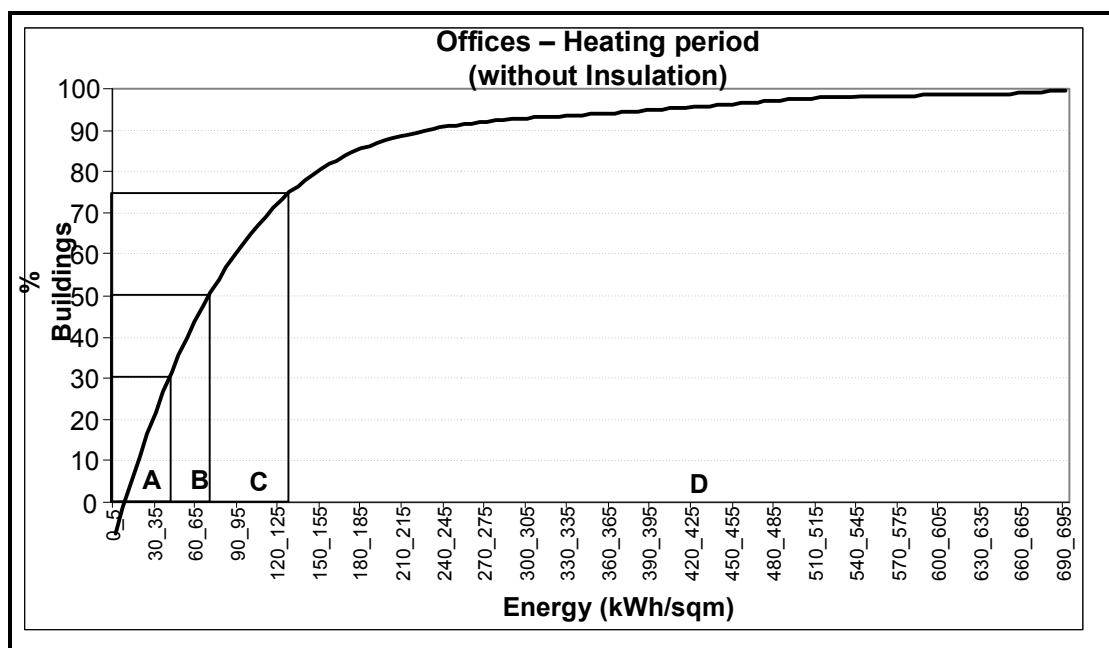


Figure 4. Graph concerning to Offices without insulation during Heating period.

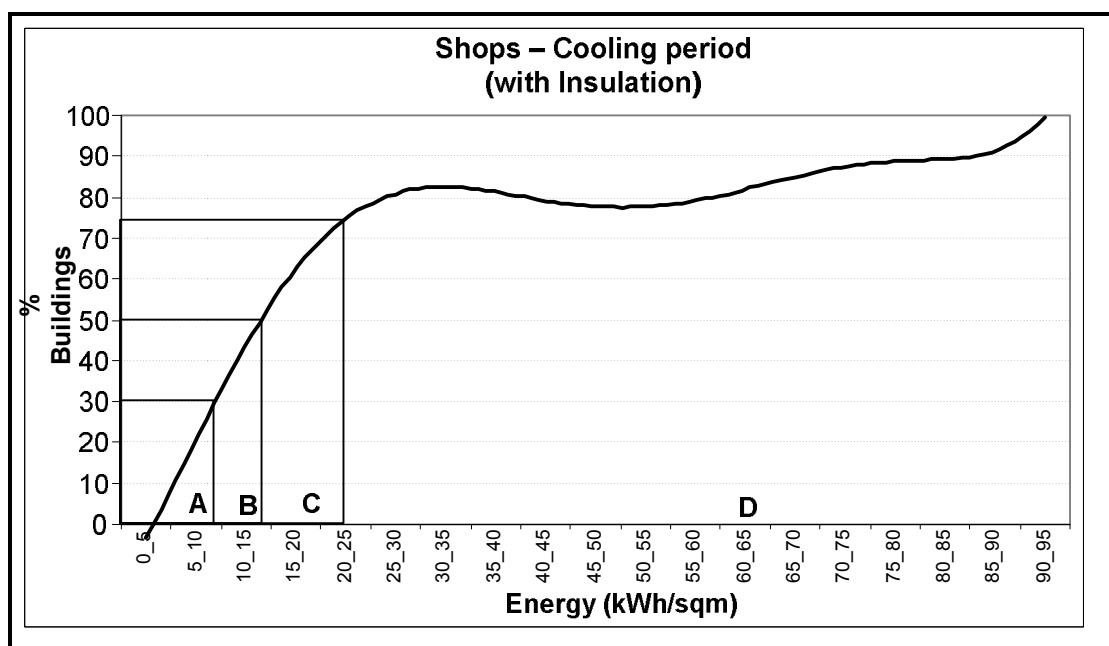


Figure 5. Graph concerning to Shops with insulation during Cooling period.

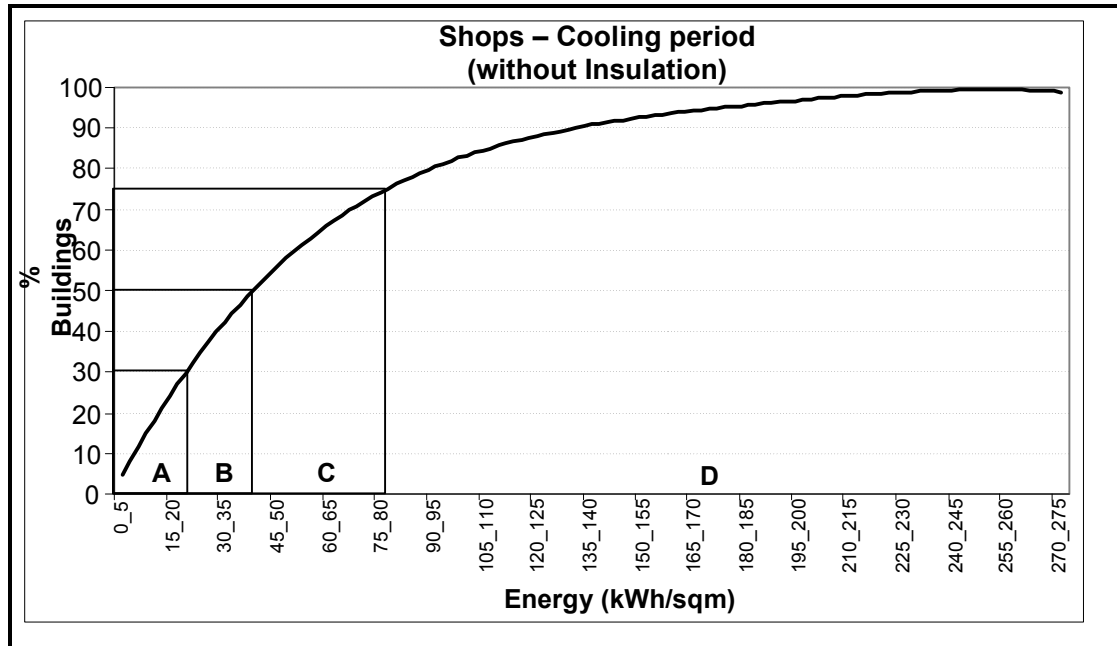


Figure 6. Graph concerning to Shops without insulation during Cooling period.

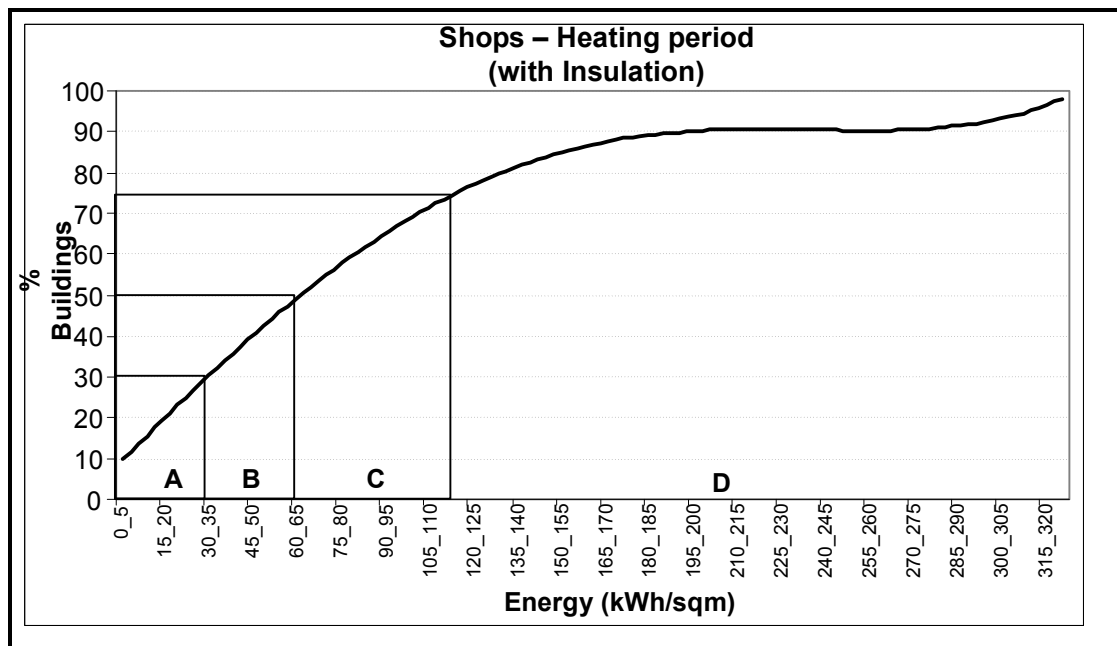


Figure 7. Graph concerning to Shops with insulation during Heating period.

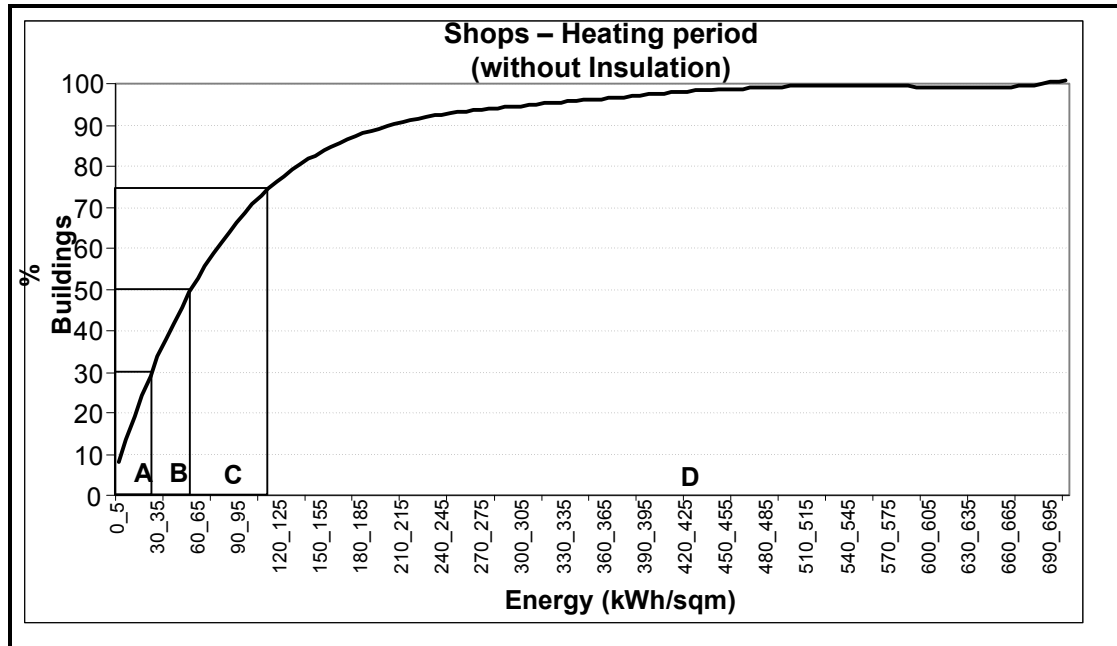


Figure 8. Graph concerning to Shops without insulation during Heating period.

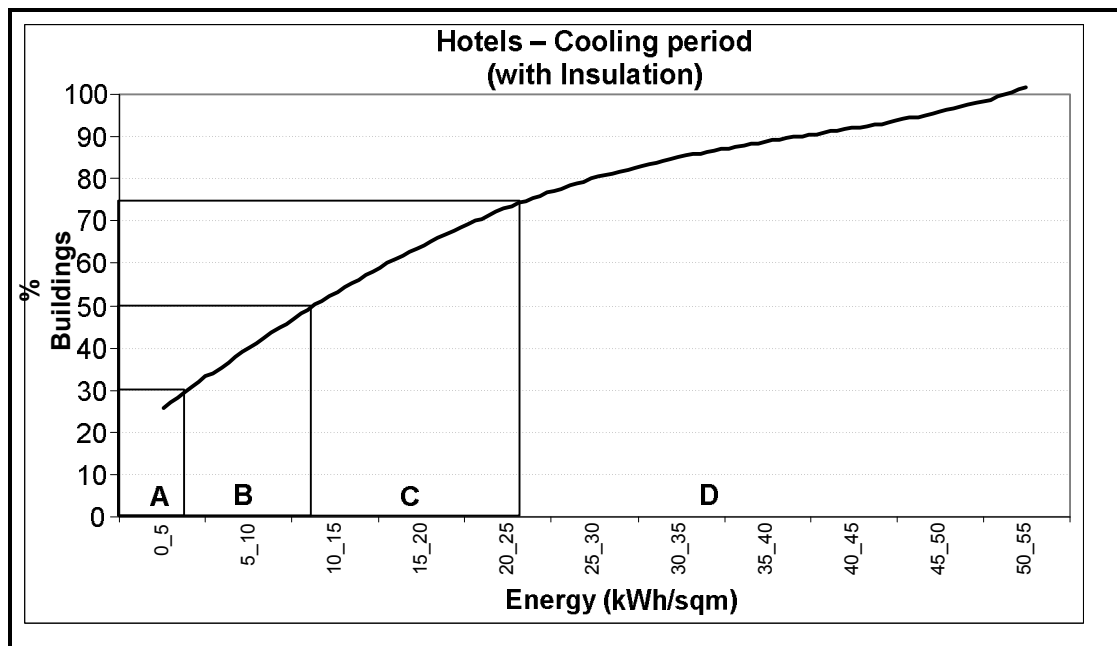


Figure 9. Graph concerning to Hotels with insulation during Cooling period.

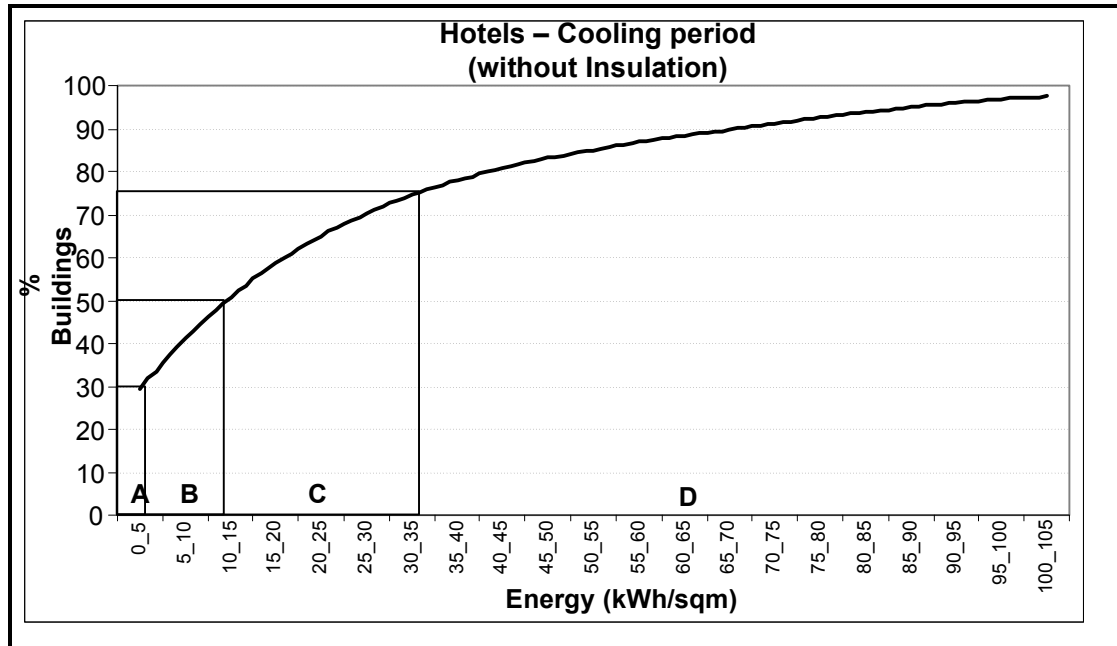


Figure 10. Graph concerning to Hotels without insulation during Cooling period.

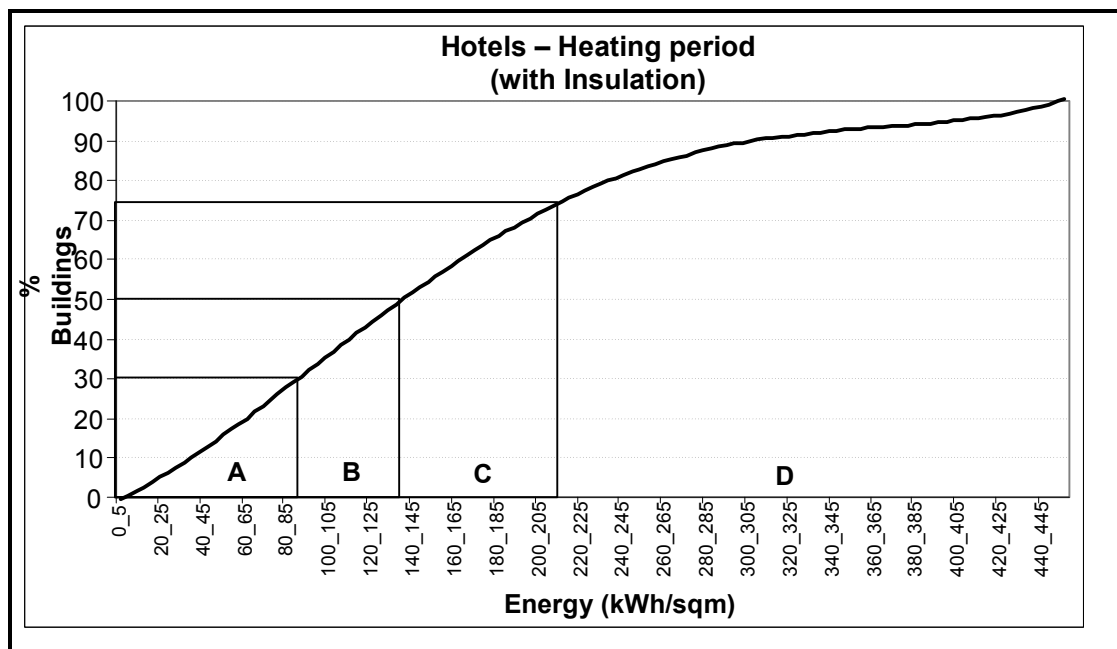


Figure 11. Graph concerning to Hotels with insulation during Heating period.

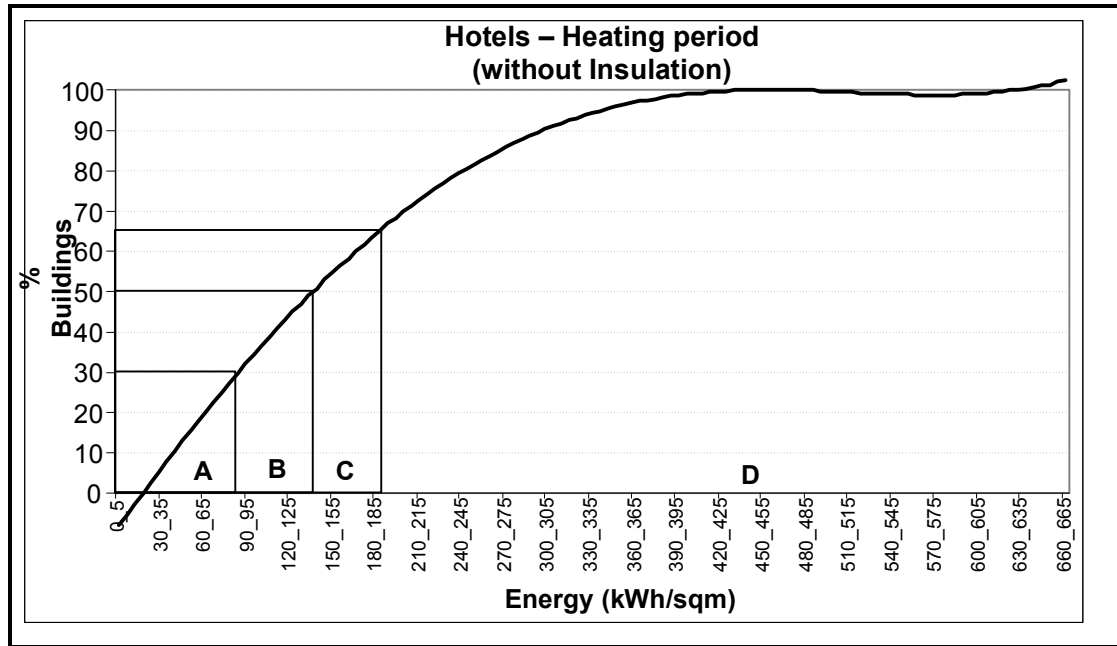


Figure 12. Graph concerning to Hotels without insulation during Heating period.

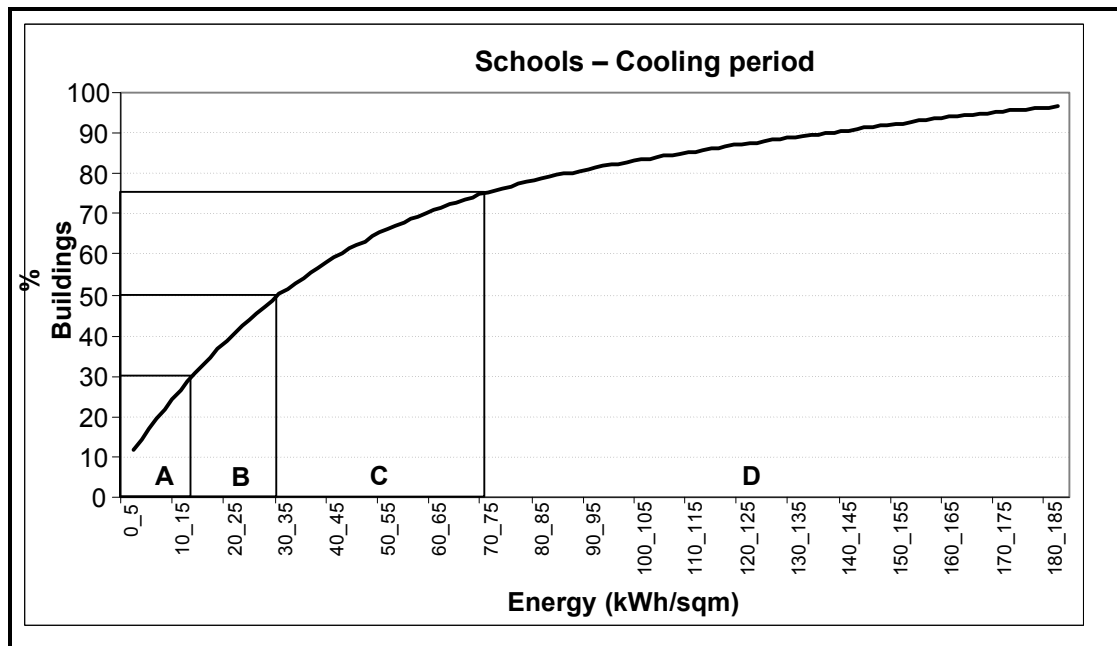


Figure 13. Graph concerning to Schools during Cooling period.

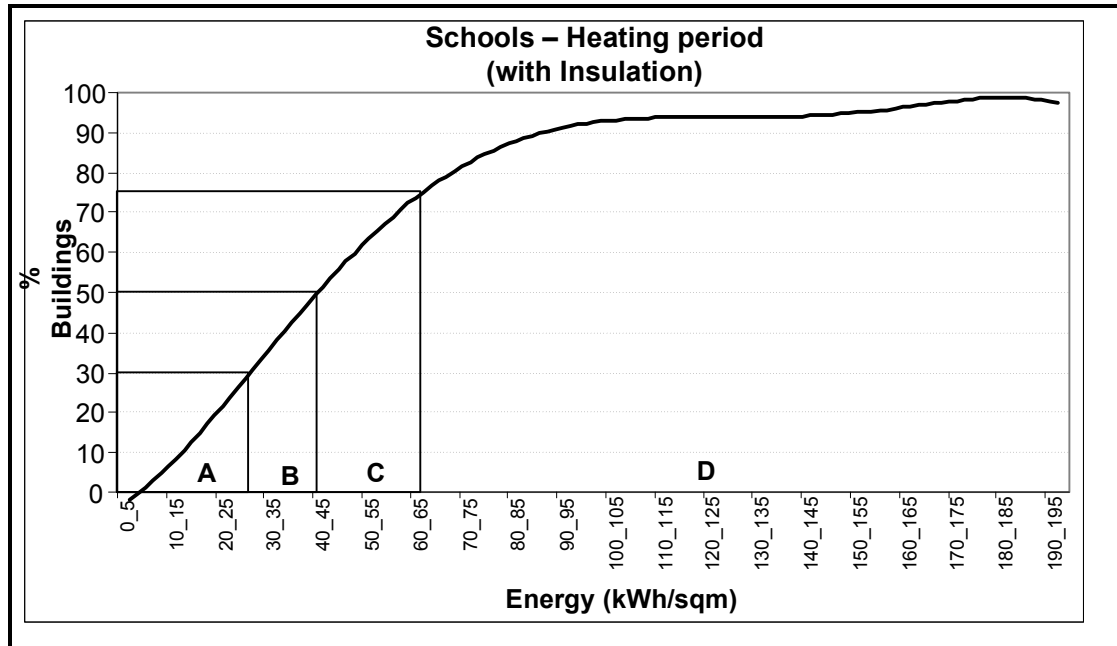


Figure 14. Graph concerning to Schools with insulation during Heating period.

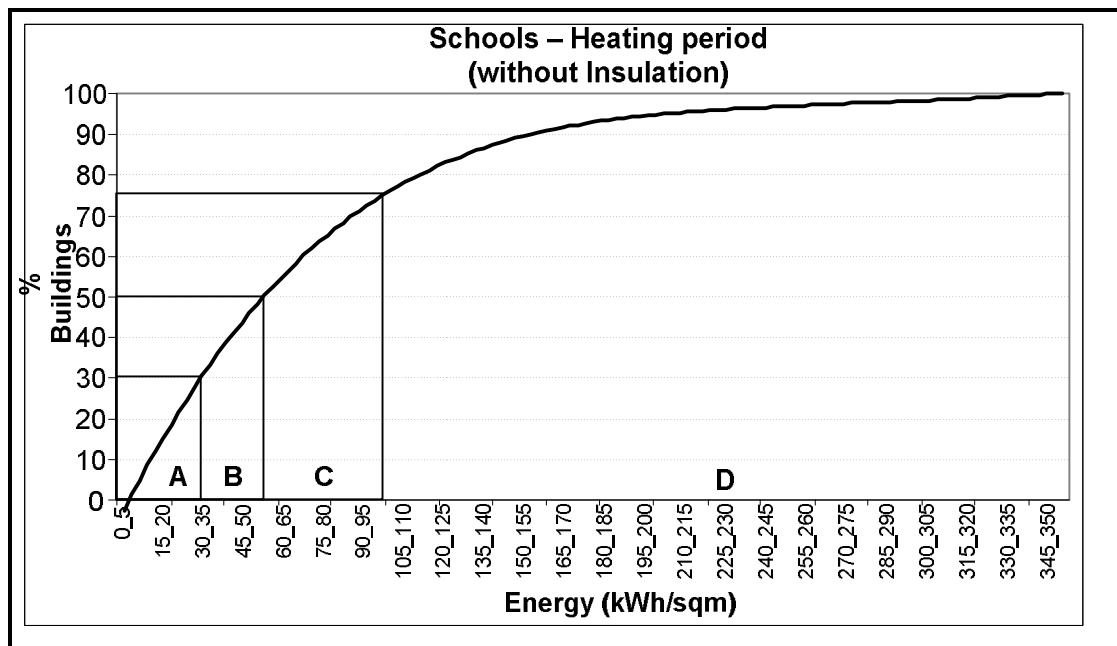


Figure 15. Graph concerning to Schools without insulation during Heating period.

Type of Building	Heating Period (KWh / m^2)		Cooling Period (KWh / m^2)	
	Insulation	No Insulation	Insulation	No Insulation
Offices	56	67	15	24
Shops	66	50	14	45
Hotels	138	139	12	12
Schools	42	58	32	32

Table 1. Values of the reference parameter Rs.

Chapter 5 – Description of the Platform

The flowchart that describes the efficiency and the main operations of the application software is presented below:

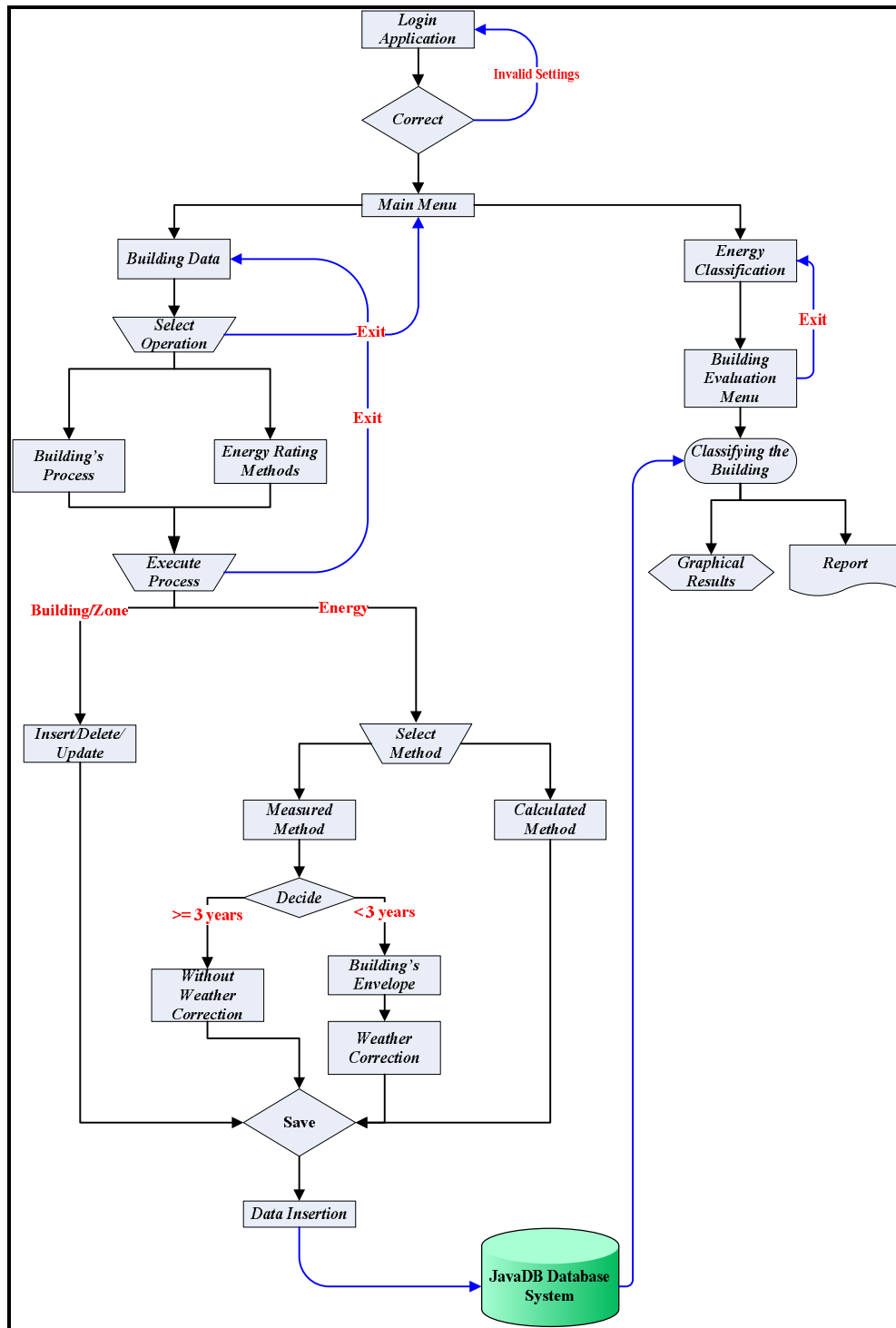


Figure 1. Application flowchart

When a user decides to use the Java application, user settings, such as username and password, are required in order to log in to the main menu. When the insertion of the settings is successful then the Main Menu form appears. From the Main Menu the user can choose each of the option he/she desires. The two options are: Building Data form and Energy Classification. The first form concerns data and information of the building of interest and the other one helps the calculation of the class of the building and the extraction of the results. When the user chooses Building Data application then he/she has two options. The first one, which is named Building Process, is referred to the insertion, deletion or update of data for the specific building or zone. By choosing any of these processes changes may occur to the database. Each change of the data updates the corresponding table of the database system.

The second one, which is named Energy Rating Methods, presents the methods that are used for the classification. Measured method requires data that either have been taken for three or more years or have been taken for less than three years. This method uses electrical, gas or oil bills of the building while data for lighting and appliances are required as well. The other method, named Calculation Method, requires data coming from the climatic conditions of the location where the specific building exists. Climatic conditions concern to heating or cooling degree – days and the hours of sunlight that are prevailed to the specific location. Both methods' data are stored in the corresponding tables of the database system.

Energy Classification process acts reversely from the other ones. This means that this procedure uses the stored data and calculates the results. This procedure is responsible for the building's classification. When the Measured method is used, the procedure identifies whether given data are referred to more than three years measures or not. If data for an assessment period of three years occur then an Energy Performance Indicator is calculated and according to its value the corresponding class of the building arises. If data measures are referred to less than three years then a weather correction procedure starts and the corresponding energyware is calculated. Its value defines the class of the building. In case of the Calculated method, Energy Classification procedure checks if the proper data exist. Anyway, whatever method is used, the results are presented either in graphical form or in a report. Graphical form is constituted by a set of graphs, which indicate the class of the building and the values of the corresponding energywares. On the other hand, the report constitutes a presentation including the graphical results and the calculated parameters.

5.1 – Database System

5.1.1 Generally

This application manages large amounts of data, hence the existence of a reliable storing system is necessary. This system must provide a faster and more convenient way of retrieving data as well. These data are responsible for the proper functionality of the application and are used for the evaluation of a building (e.g class definition) and the calculation of the normalized values of energy consumption. However, this application has been developed in Java programming language. So, this storing system must communicate with the programming language without any problem while its greatest advantage, is that the database system is incorporated to the Java application. The solution of this requirement is the implementation of an embedded database system.

The database scheme (ER diagram, see below) has been developed using JavaDB tool offered by Java Netbeans interface. The use of this JavaDB tool provides the proper connection between the Java application and the database system, while this connection is achieved easier than using any other programming languages like SQL or Oracle. SQL and Oracle programming languages may require more complicated software codes in order that the connection can be achieved.

This method of implementation was preferred against storing data into files. File processing may cause some difficulties. The first difficulty concerns the total number of the files used. This difficulty concerns the fact that each file should represent the corresponding table of the ER scheme. Hence, files should be used in order to store the data. The second difficulty is described from the size of a file – table. When new data are stored in a file then its size is getting larger. This is a problem since the first thought of implementing this application is not to occupy a large amount of the hard disk. And, finally, when an application has to process files then the proper software code, that processes the files, must exist. This makes the application more complicated and slower, since the data retrieving from files may take long time than the retrieving using JavaDB database system.

5.1.2 ER Diagram

The following image presents the ER diagram which describes the formation of the database system (Ramakrishnan & Gehrke 2000).

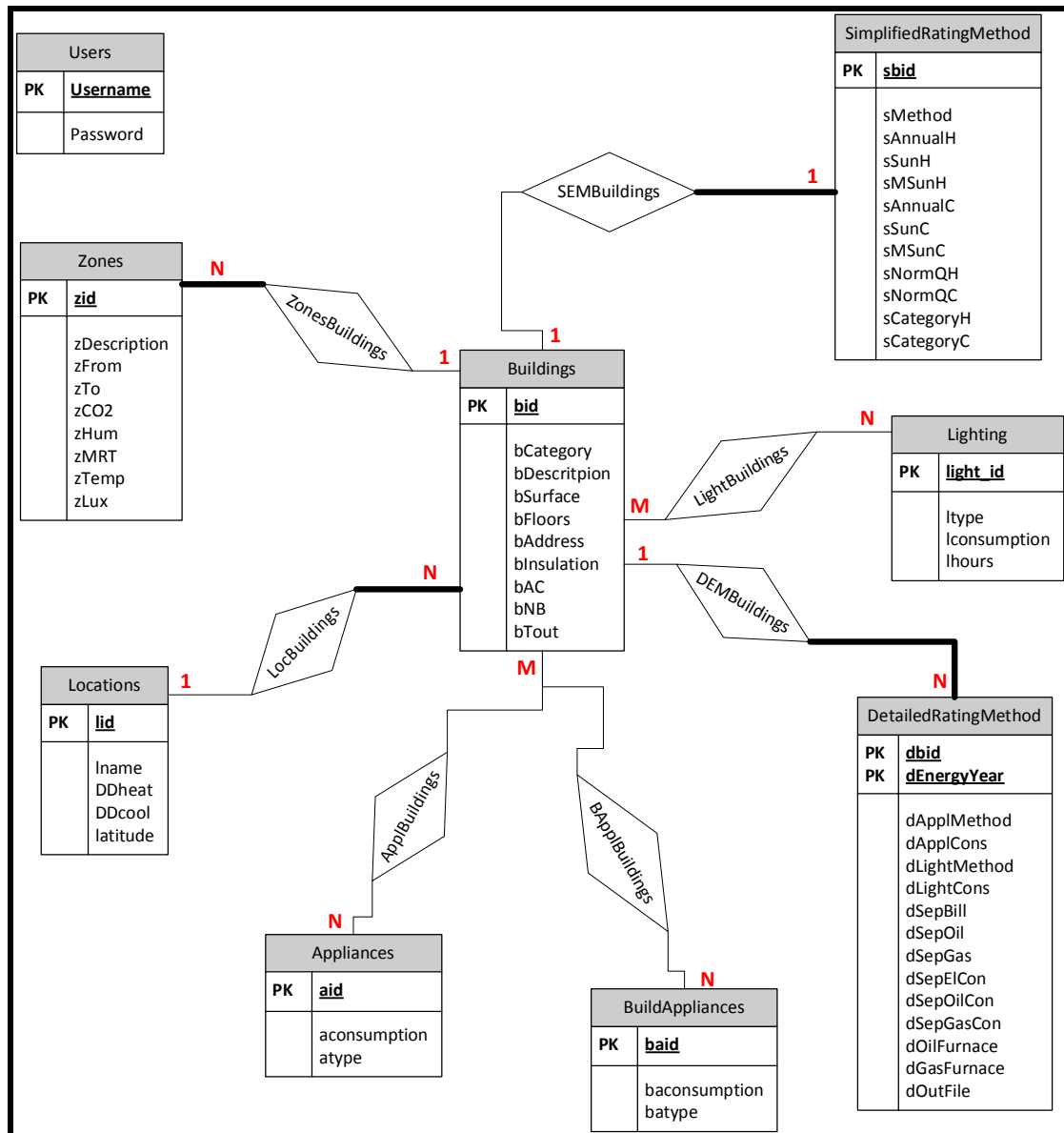


Figure 2. ER diagram

5.1.3 Explanation of the Relationships

After presenting the ER diagram and the Relational Scheme (see Appendix G) of the database system, the analysis of the relations between the tables is:

- The relationship between Buildings and Zones is 1:N as each building can contain one or more than one zones.
- The relationship between Buildings and ZonesBuildings is partial because it is not necessary for a building to have any zone(s).
- The relationship between Zones and ZonesBuildings is total because a zone must belong to a building.
- The relationship between Buildings and Appliances is M:N as each building can contain one or more appliances and an appliance can be contained in more than one buildings.
- The relationship between Buildings and Lighting is M:N since a building can contain more than one lighting devices and a lighting device can be contained in more than one buildings.
- The relationship between Buildings and BuildAppliances is M:N as each building can contain one or more than one of this type of appliances and such appliances can be contained in more than one buildings.
- The relationship between Locations and Buildings is 1:N since there might be more than one buildings in a location, but a specific building is located in a specific location.
- The relationship between Buildings and Locations is total because a building must be located in a location.
- The relationship between Buildings and SimplifiedEnergyMethod is 1:1 since a specific building can be evaluated only once by using CSI and Degree – days methods.
- The relationship between SEMBuildings and SimplifiedRatingMethod is total since the existence of such a certificate depends on the existence of a building.
- The relationship between Buildings – DetailedEnergyMethod is 1:N. This means that a building can be evaluated by many energy certificates but a specific energy certificate is assigned to a specific building. Moreover, the

relationship between DetailedRatingMethod and DEMBuildings is total since this method can be used only when a building exists.

5.1.4 Presentation and Analysis of the tables

Buildings:

- ***bid:*** is an integer number and the primary key of the table. It indicates the number of a building and the corresponding record.
- ***bdescription:*** is an attribute in string format and indicates a short description of the building.
- ***bcategory:*** is an attribute in string format and presents the category of the building (shop, office, hotel and school).
- ***blocation:*** is referred to the location where the corresponding building exists.
- ***bAddress:*** keeps information about the place that a building exists.
- ***bArea:*** is a double number concerning the area in m^2 .
- ***bFloor:*** is an integer number informing about the number of the floors in a building.
- ***bInsulation:*** is an integer flag taking 1 or 0 values. When this attribute is equal to 1, this means that the building's walls contain insulation materials. Otherwise, the walls do not contain insulation material.
- ***bConditioned:*** is also an integer flag taking 1 or 0 values. Value 1 indicates that the building has air – conditioning devices, otherwise it does not.
- ***bNewBuilding:*** is a flag with values 1 or 0. Value 1 indicates that the building is a new building, otherwise it is not.

Zones:

- ***zid:*** is an integer number and the primary key of the table referring to the number of records and the id of the zone.
- ***zDescription:*** is a string attribute referring to a short description of the building.
- ***zFrom:*** indicates the time when users start using the building.
- ***zTo:*** indicates the time that users stop using the building.

User:

- ***username:*** is a string attribute keeping the username of the user.
- ***password:*** string attribute referring to the password.
- ***Userid:*** is an integer number and the primary key of the table that indicates the number of the record.

Locations:

- ***lname:*** indicates the name of the location.
- ***DDheat:*** is a double number that keeps the value of the heating degree – days of the specific location.
- ***DDcool:*** is a double number that keeps the value of cooling degree – days.
- ***Lid:*** integer number and the primary key of the table.
- ***Latitude:*** presents the latitude of the Greek location.

Appliances:

- ***applID:*** is the primary key of the table referring to the number of the record.
- ***Description:*** provides a short description of the corresponding appliance.
- ***applWatts:*** is a double number and presents the energy consumption of the appliance.

BuildAppliances:

- ***baid:*** primary key of the table.
- ***baconsumption:*** is a double number referring to the consumption in watts for a specific equipment.
- ***batype:*** is a string referring to the type of the equipment.

Lighting:

- ***light_id:*** is an integer number and the primary key of the table.
- ***lconsumption:*** is a double number referring to the consumption in watts for a specific lighting device.
- ***ltype:*** is a string referring to the type of the lighting device.
- ***lhours:*** keeps the total hours that a lighting device is used.

The above analysis is referred to the tables joining ER diagram. In Appendix G, the relational scheme is presented as well. Furthermore, tables DetailedRatingMethod and SimplifiedRatingMethod keep all the necessary information about the energy certificates and the method of energy classification that was used which took place for a specific building.

Chapter 6 – Case Study and Results

6.1 Generally

In this chapter, a short presentation of the building under study, is presented along with the results extracted after applying energy classification methods. The building, which is classified, is the laboratory of Electric Circuits and Renewable Energy Sources (ECRESL) and it is constituted by two zones. The first zone is the ground floor and the second zone refers to the first floor of the lab. The ground floor is the main lab space and the first floor contains office staff. Both zones are going to be classified separately. The methodology used for energy classification of both zones is based on the European prEN standard 15217:2006 including methodology without weather correction. Measured data refer to the years 2005, 2006 and 2007.

6.2 Ground Floor

This floor accommodates three different labs: Electronic and Electric Circuits and Sensors. The following table presents all the devices, along with their consumptions, used for lab experiments.

Laboratory of Electronic and Sensors Circuits		
Devices	Quantity	Power Consumption (W)
Oscilloscope (HM1005)	11	43
Multi – meter (HM8011)	11	4.5
Triple Power Supply (HM8040)	11	95
Function Generator (HM8030)	11	9.8
Personal Computer Tower	4	350
Monitors	4	80
UPS Xpower µnet	2	500

Table 1. Devices, including their consumptions for Electronic and Sensors Circuit laboratory

Laboratory of Electric Circuits		
Devices	Quantity	Power Consumption (W)
Oscilloscope	11	37
Multi – meter	11	4.5
Triple Power Supply	11	160
Function Generator	11	20

Table 2. Devices, including their consumptions, for Electric Circuits laboratory

Furthermore, the lab contains a large air – conditioned device with power consumption equal to 7kW along with 12 Fluorescence lamps of 25W each.

6.3 1st Floor

This floor contains office staff of the lab. It's a single space so it is considered as one zone. The following table presents all the devices used in the office along with their consumptions.

1st Floor of ECRESL		
Devices	Quantity	Power Consumption (W)
Personal Computer – Tower	4	450
Monitors	4	75
Air – conditioned device	3	800
UPS system	3	500
Printer	2	180
Fax Machine	1	100

Table 3. Devices which are included in the 1st floor of ECRESL

6.4 Experimental Results

6.4.1 Energy Class and Results of Ground floor

The data used for the classification, have been measured for three years (2005, 2006 and 2007). The classification procedure took into account both periods under study (heating and cooling). The following table presents overall energy consumptions per year including consumptions for lighting and equipment devices.

	2005(<i>KWh / year</i>)	2006(<i>KWh / year</i>)	2007(<i>KWh / year</i>)
Equipment	5232.45	5132.45	5132.45
Lighting devices	633.6	633.6	633.6
Heating	514.24	536.16	544.06
Cooling	1721.66	285.6	285.83

Table 4. Consumptions per heating and cooling periods.

The following table presents the values of the Energy Performance indicator for both periods using regulation reference parameter equal to $24 \text{ kW} / \text{m}^2$ and the stock reference parameter equal to $65 \text{ kW} / \text{m}^2$ for heating period and $12.5 \text{ kW} / \text{m}^2$ for cooling period, respectively.

	Heating Period (<i>KWh / m²</i>)	Cooling Period (<i>KWh / m²</i>)
EP indicator	26.22	32.63

Table 5. Values of EP indicator

The Energy Classification procedure was based on the methodology not including weather correction, since data have been measured for three years. So, it takes into account the values of EP indicator for both periods and the energy consumptions referring to lighting devices, equipment and heating/cooling devices. After completing evaluation the results that arise, for 2005, 2006 and 2007 years, are presented by the following figures.

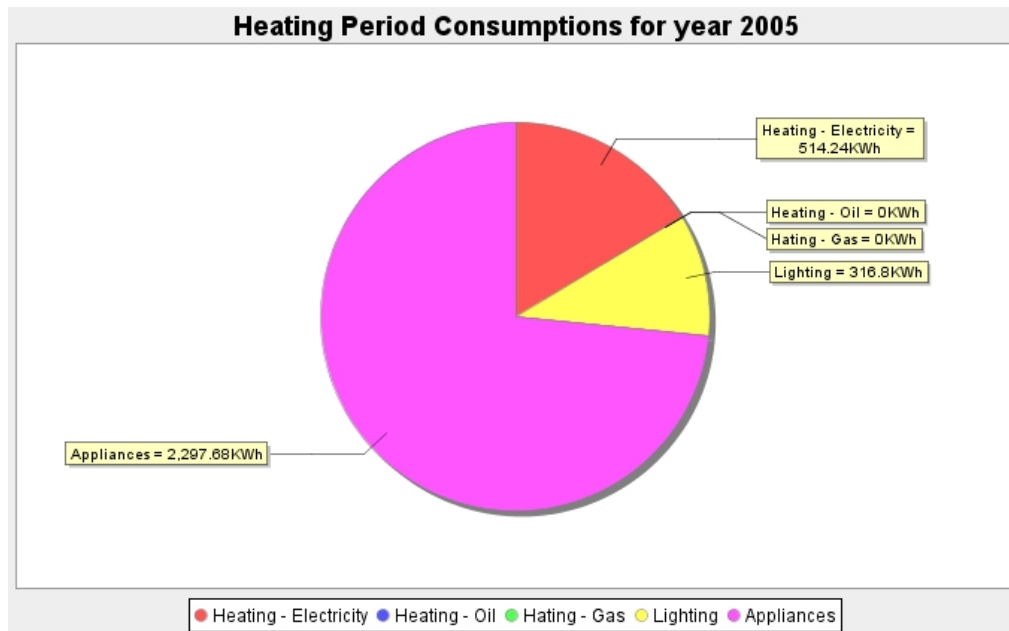


Figure 1. Consumptions for heating for 2005

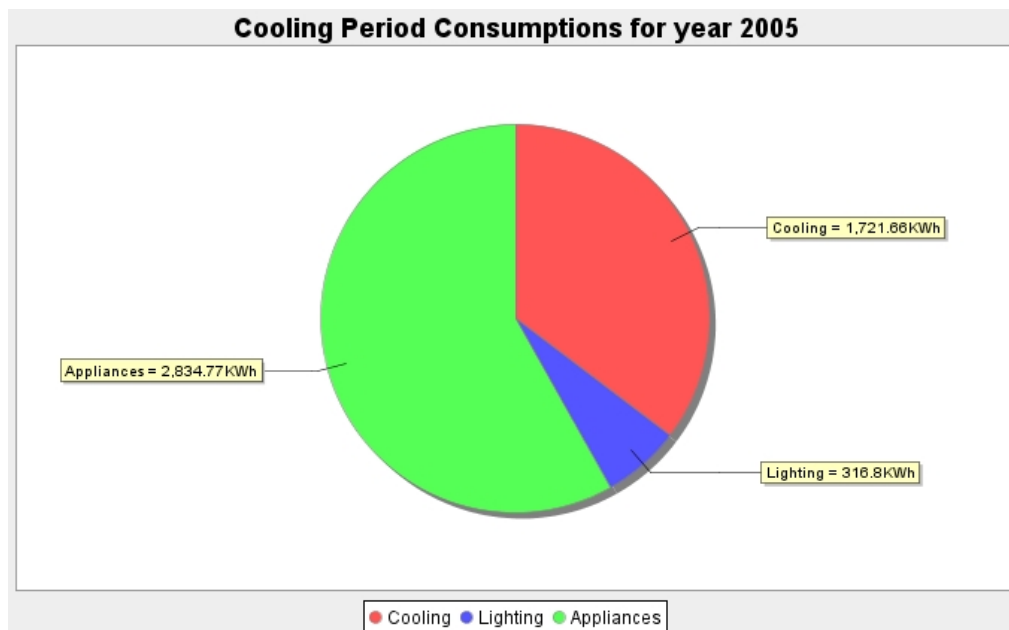


Figure 2. Consumptions for cooling for 2005

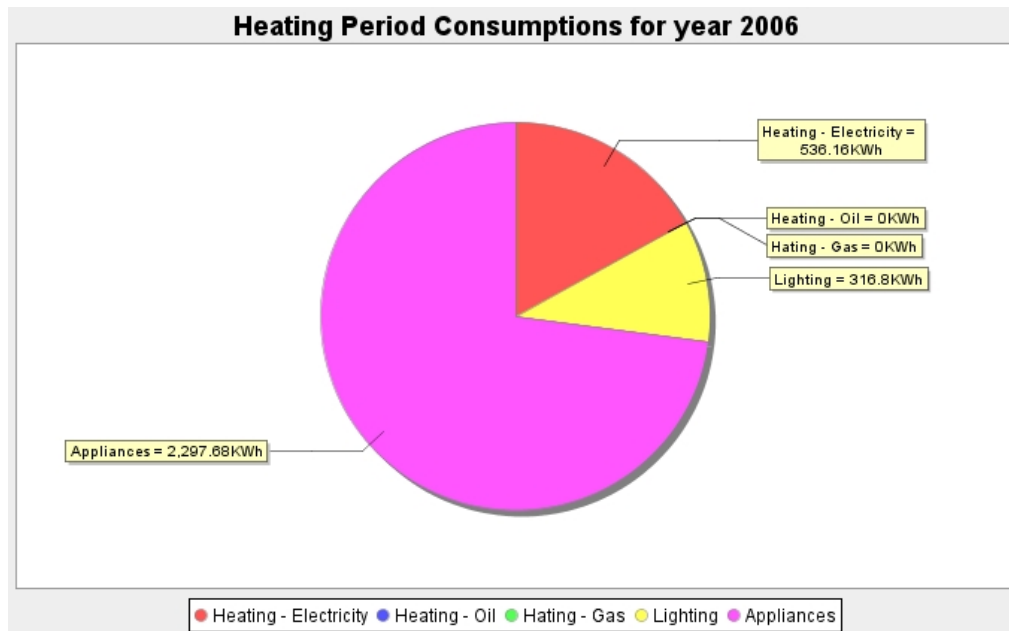


Figure 3. Consumptions for heating for 2006

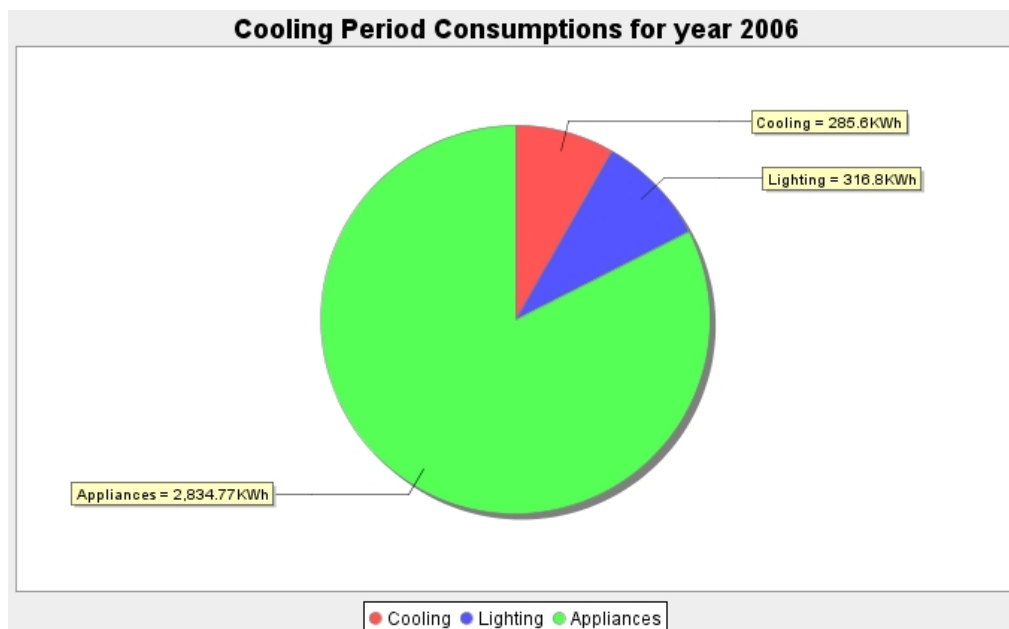


Figure 4. Consumptions for cooling for 2006

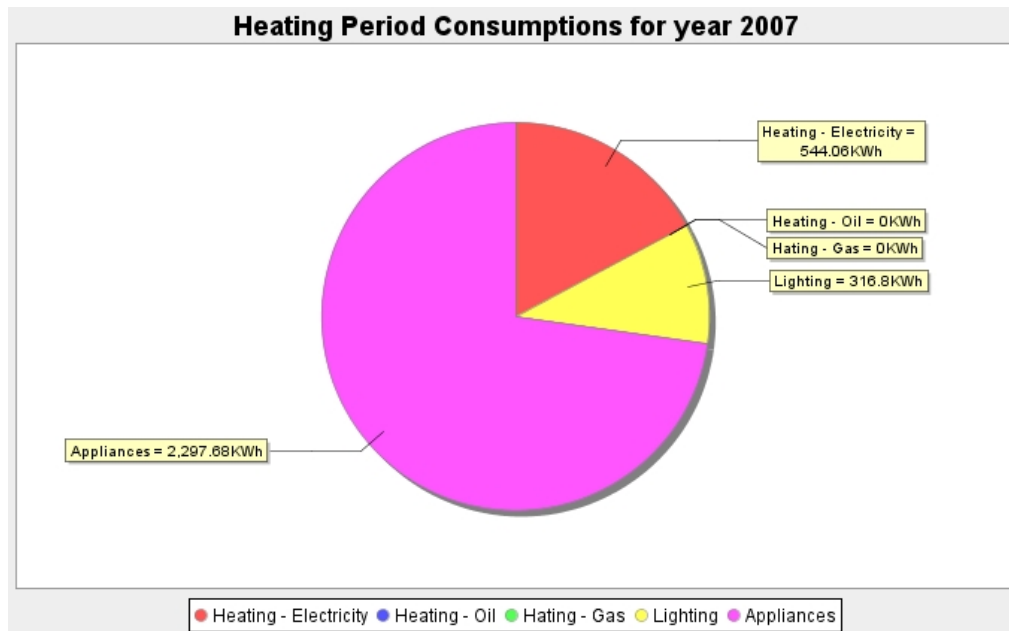


Figure 5. Consumptions for heating for 2007

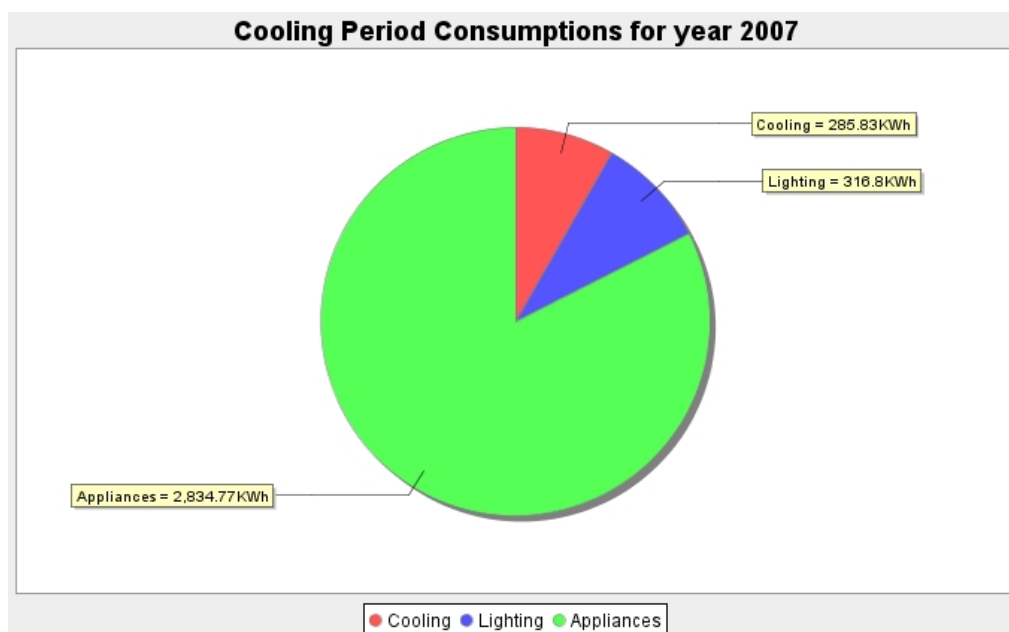


Figure 6. Consumptions for cooling for 2007

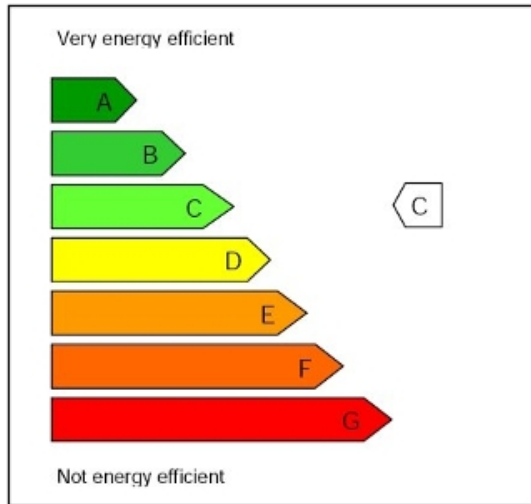


Figure 7. Class of the building for heating

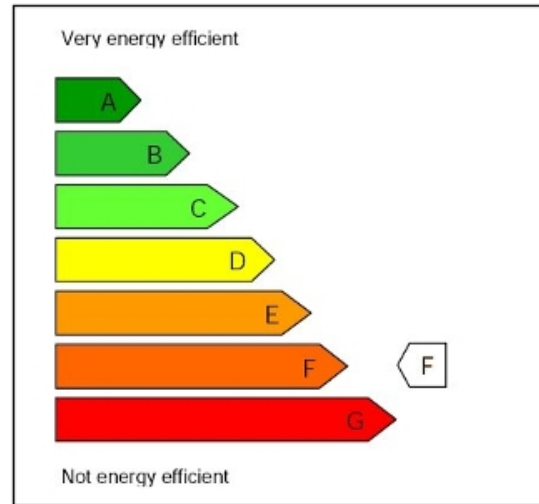


Figure 8. Class of the building for cooling

6.4.2 Energy Class and Results for 1st floor

In the 1st floor of the laboratory four offices are placed. Each office has its own equipment such as personal computer, printer, fax machine, etc. The application calculates energy consumptions based on equipment, lighting devices and heating/cooling devices, separately. Similarly to the ground floor, there are data that have been measured for three years. This means that energy classification was achieved by using the methodology not including weather correction. Also, the energy performance indicator is calculated from the given data.

The following table presents overall energy consumptions per year including consumptions for lighting and equipment devices

	2005(<i>KWh / year</i>)	2006(<i>KWh / year</i>)	2007(<i>KWh / year</i>)
Equipment	11064.3	11064.24	11064.24
Lighting devices	633.6	633.6	633.6
Heating	2507.97	2891.65	891.18
Cooling	1493.45	1614.26	1819.59

Table 6. Overall energy consumption for the 1st floor

The following table presents the values of EP indicator for heating and cooling.

	Heating Period (<i>KWh / m²</i>)	Cooling Period (<i>KWh / m²</i>)
EP indicator	64.55	62.43

Table 7. Values of EP indicator for heating and cooling periods

The values for Regulation reference and stock building reference parameters are the same to those used for the ground floor. The following figures present the results of the energy classification and the class of the 1st floor for both periods under study.

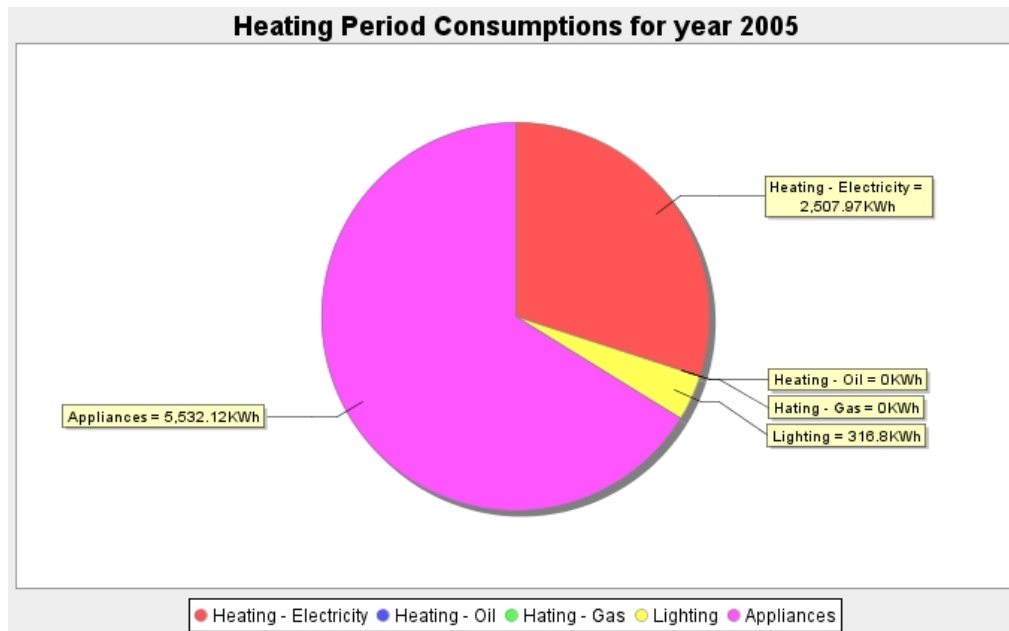


Figure 9. Consumptions for heating for 2005

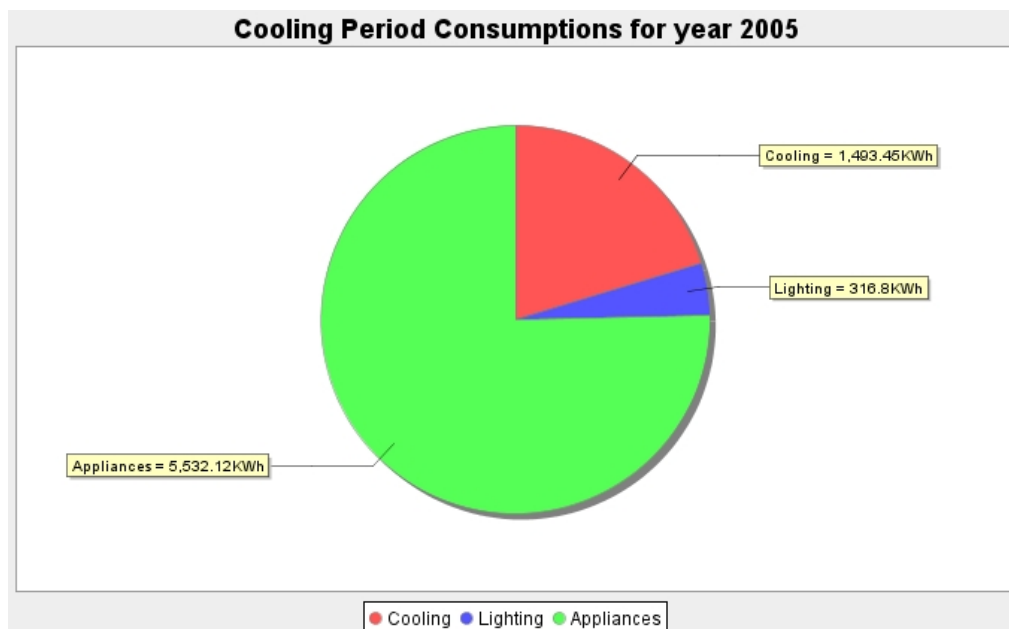


Figure 10. Consumptions for cooling for 2005

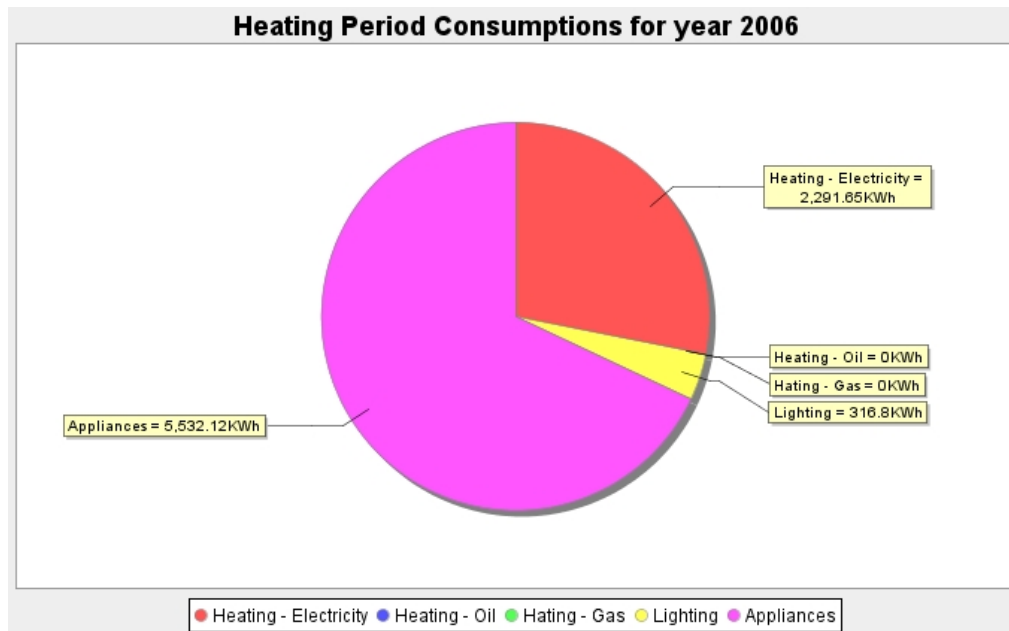


Figure 11. Consumptions for heating for 2006

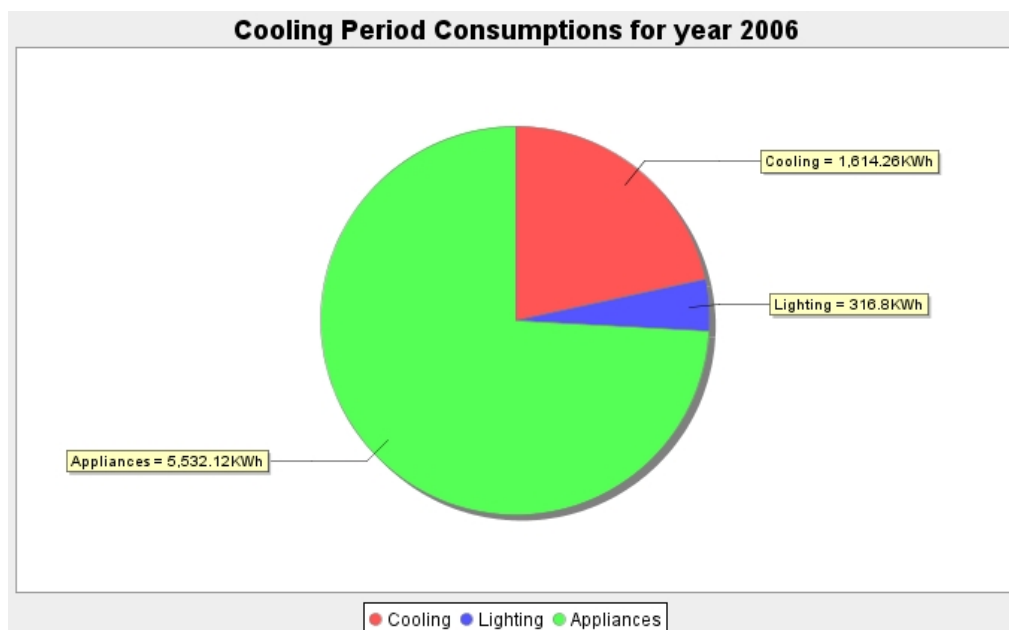


Figure 12. Consumptions for cooling for 2006

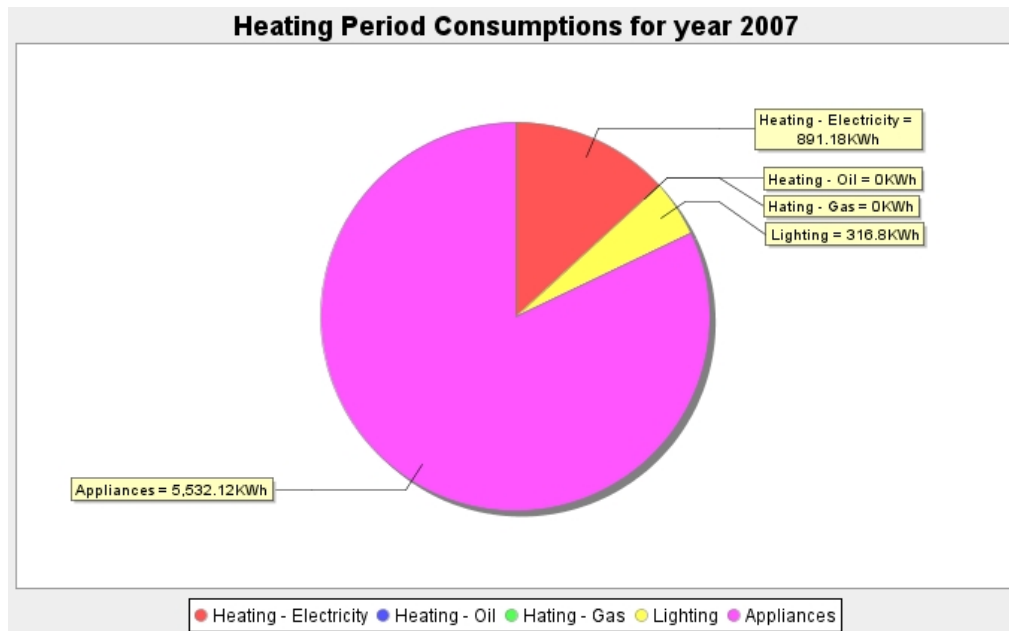


Figure 13. Consumptions for heating for 2007

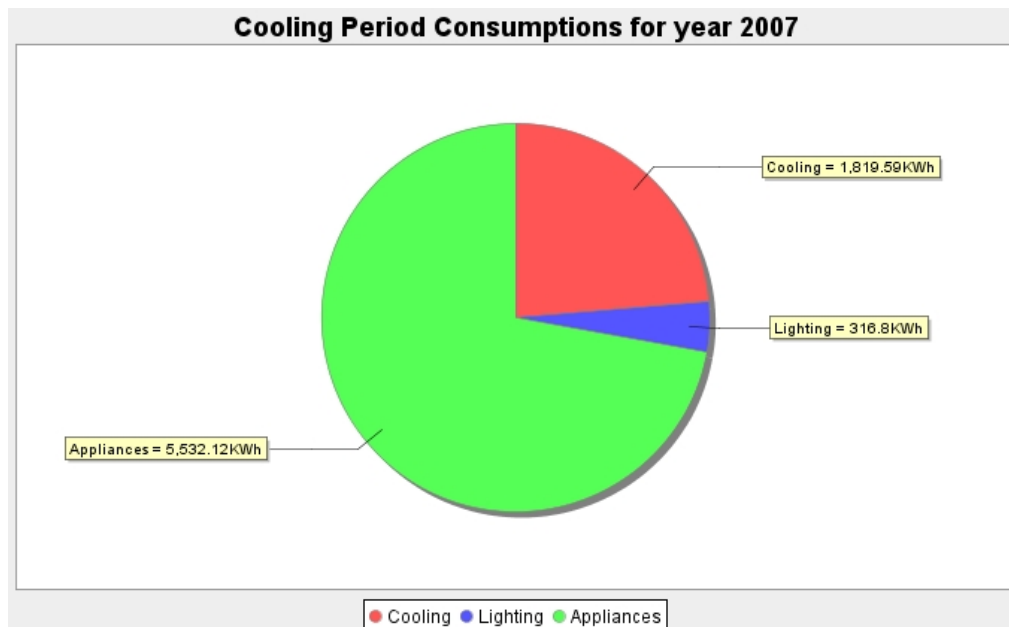


Figure 14. Consumptions for cooling for 2007

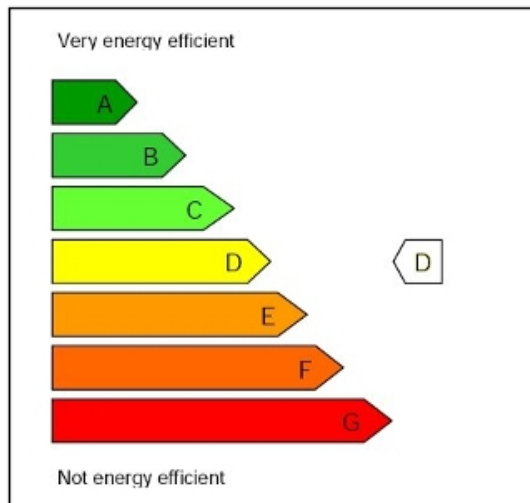


Figure 15. Building class for heating period

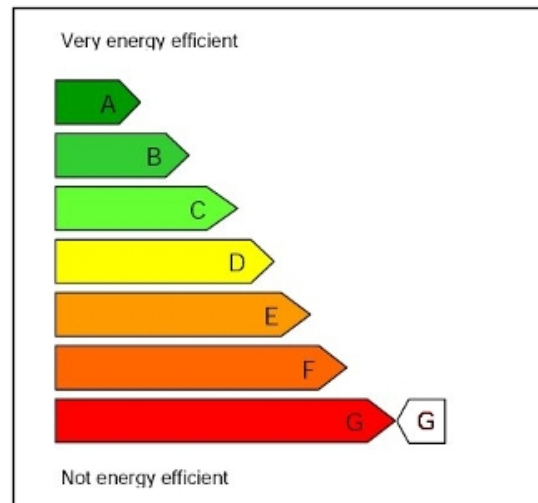


Figure 16. Building class for cooling period

Chapter 7 – Conclusions and Future Work

7.1 Generally

This chapter presents useful conclusions referring to the analysis of the results of the ground floor and the 1st floor of the laboratory. Also, several additional operations are presented, in order to improve the performance of Java application platform. Although, the analysis of the results for the 1st and the ground floor are presented separately, it is essential to be pointed out that, regulation reference parameter (R_r) was considered equal to $24kWh/m^2$ for both cases. The value of the Regulation reference parameter is not provided by the Greek energy policy and it concerns the mean value for energy policy in Italy per year.

7.2 Analysis of results for the 1st Floor

The classification methodology used for the 1st floor of the laboratory is defined by prEN European standard 15217:2006. For the specific building, only the Measured method was applied, since there was no proper data (such as maximum hours of sunlight) in order for climatic conditions methodology to be used. So, measured data refer to a three – year period: 2005, 2006 and 2007. This means that, the method used for the classification is based on the calculation of the Energy performance indicator not including weather correction.

However, by studying all pie charts for both periods, the conclusion, which arises, is that 1st floor's energy consumption for heating and cooling depends exclusively on electricity, as gas and oil percentages are equal to 0. In this case, data were taken from electrical bills concerning lighting devices, the equipment of the office and air – conditioning devices. Furthermore, the energy consumption which is stated in the electrical bills derives from various devices, after considering that the office was occupied by the staff of the laboratory, for 8 hours per day (from 09:00am to 17:00pm).

After the assumption that the office's equipment does not change during the assessment period, the energy consumption referring to the equipment has the same value during the 3 – year period. Along with equipment, the percentages of lighting, during assessment period, are the same as well. On the contrary, several changes have occurred in the case of air- conditioning devices for heating and cooling. These changes may occur because of the unstable climatic conditions sustained in the

location of Chania. The term «unstable» refers to the case when warm climatic conditions occurred, during heating period and quite cold conditions occurred during cooling period and reversely.

Finally, figures 15 and 16 present the classes of the 1st floor for heating and cooling periods. In the case of heating period, the building belongs to D class. This energy classification is satisfying despite the fact that the roof of the floor is constructed by Plexiglas material. So, the roof has no insulation and the contact between warm and cold air masses is direct. For cooling period, the building belongs to G class which presents the lowest barrier of the classes, since cold air masses, afforded by air – conditioning devices, will not occur few hours after the devices stop functioning.

7.3 Analysis of results for Ground Floor

The walls of this floor do not contain insulation material and a large percentage of them is covered by windows. This floor is the main space of the laboratory. It is used for three times per week and four weeks per month. Similarly to the 1st floor, the method used for energy classification is the one not including weather correction. However, Climate Severity Index and Degree – days methods are not used as well, since there are no data available, such as maximum hours of sunlight. Naturally, the analysis includes pie charts for both periods.

Analyzing these pie charts for heating and cooling periods, it is easy to realize that the percentage of lighting for the whole period of 3 years does not modify. On the other hand, it is essential to point out that the percentage of the lab's equipment varies according to the use. That is, the percentage of the equipment during heating period differs from this during cooling period. Actually, equipment's energy consumption per day depends on the hours where the lab is used by occupants. The lab is used four hours additionally per week, during heating period than during cooling period. In any case, the energy consumption for both periods is equal to a mean value by dividing the total lab's devices consumption to the total hours of use. Furthermore, a large air – conditioning device is used for heating and cooling demands. The percentages

referring to heating and cooling respectively, varies according to the climatic conditions of the location.

Similarly to the 1st floor, data are collected by electrical bills and this explains why the percentages of gas and oil are negligible. Moreover, by studying figures 8 and 9, the class of the building during heating period is C and the class during cooling is F. This means that, the building stores warm air masses, which are provided by the air – conditioning devices, during heating period, against its behavior during cooling period.

7.4 Future Work

Despite the fact that the Java software platform takes into account large amounts of data and uses them without any difficulty, there are several possibilities which are not covered by the application. One of the functionalities, which will be added to the platform, is environmental classification methodologies based on European standards or other methodologies. The extension of the platform by running environmental procedures as well makes the existing application more completed.

In addition, Renewable Energy Sources tab in the interface, in which energy classification takes place, would be developed by adding operations and data collecting systems in the case where a building uses renewable energy sources. Furthermore, in the specific platform, each floor of a new building is discerned by one zone, which in reality does not exist. A new improved version of the application would be to take into account more than one zones of the building. Moreover, in State of the Art chapter, three applications for energy rating were presented. One of them was developed by using a 3D application developer. Naturally, the software used is different to Java programming language. Despite this fact, there are 3D Java libraries providing 3D interfaces. By using them a building simulation platform may be developed.

References

- [1] CEN Members, 2006, 'Energy performance of buildings – Methods for expressing energy performance and for energy certification of buildings', GTR Work
- [2] CEN Members, 2006, 'Energy performance of buildings – Overall energy use, CO₂ emissions and definition of energy ratings',
- [3] Patxi Hernadez, Kevin Burke, J. Owen Lewis, 2007, 'Development of energy performance benchmarks and building energy ratings for non-domestic buildings: An example for Irish primary schools', University College Dublin, Dublin
- [4] E. Shaviv, A. Yezioro, I.G. Capeluto, 2007, 'Energy code for Office Buildings in Israel', Technion – Israel Institute of Technology, Haifa
- [5] Lamberto Tronchin, Kristian Fabbri, 2007, 'Energy performance building evaluation in Mediterranean countries: Comparison between software simulations and operating rating simulation', University of Bologna, Bologna
- [6] Jan F. Kreider, Peter S. Curtiss, Ari Rabl, 'Heating and Cooling of Buildings Design for Efficiency, Second Edition', The McGraw-Hill Companies, Inc 2002 ISBN 0-7-07-237341-5
- [7] Raghu Ramakrishnan, Johannes Gehrke, 2000, 'Database Management Systems Volume A (2nd Edition)', The McGraw-Hill Companies,
- [8] Raghu Ramakrishnan, Johannes Gehrke, 2000, 'Database Management Systems Volume B (2nd Edition)', The McGraw-Hill Companies,
- [9] Apache Software Foundation, 2008, 'Java DB Developer's Guide Version 10.4', Sun Microsystems, Inc.
- [10] Apache Software Foundation, 2008, 'Java DB Reference Manual Version 10.4', Sun Microsystems, Inc.
- [11] Apache Software Foundation, 2008, 'Getting Started with Derby Version 10.4', The Apache Software Foundation.
- [12] Jonathan Knudsen, Patrick Niemeyer, 2005, 'Learning Java 3rd Edition',
- [13] Cay S. Horstmann, Gary Cornell, 2001, 'Core JavaTM 2: Volume II Advanced Features', Prentice Hall
- [14] David Gilbert, 2007, 'The JFreeChart Class Library Version 1.0.4 Developer Guide', Object Refinery Limited
- [15] David R. Heffelfinger, 2006, 'JasperReports for Java Developers Create, Design, Format, and Export Reports with the World's Most Popular Java Reporting Library'
- [16] David Faour, 2001, 'Database Normalization' [On-line]
<http://www.serverwatch.com/tutorials/article.php/1549781>
- [17] Greg Hendricks, 2001, 'Database Normalization' [On-line]
http://www.devhood.com/tutorials/tutorial_details.aspx?tutorial_id=95
- [18] National Instruments, 2000, 'NI – DAQ User Manual for PC Compatibles', part number 321644G – 01
- [19] National Instruments, 1998, 'NI – DAQ Function Reference Manual for PC Compatibles, part number 321645D – 01
- [20] e – Building Energy Classification Manual

Appendix A

A.1 Energy Classification using Calculated Method

A.1.1 Climate Severity Index and Degree – days Methods analysis

In this appendix, the functionality and the use of energy classification using Climate Severity Index and Degree – days methods are described. In figure 1, the application – interface used for the classification of a building using CSI method, is presented.

Figure 1. Interface using CSI method for Energy Classification

A user must take into consideration a certain number of inputs which vary depending on the period of year (heating or cooling). First of all, the interface provides information about a building which is going to be classified. This information concerns the location, the type of the building, the presence or absence of insulation and the heating and cooling degree – days of the specific location. It also

offers the possibility of choosing the desired method for classification. There are two options: C.S.I. or Degree – days method. For C.S.I. methodology the input data concern Annual Consumption and Real Sunlight hours which vary for each period. On the contrary, Degree – days method (see figure 2) uses only the Annual Consumptions for both periods of study.

The classification (in both methods) is achieved by calculating the normalized form of energy consumption. The calculation process begins by pressing a button named **Calculate Consumption**. Resulted information about the building, such as the classification method used, the value of the normalized energy consumption and the class of the building, for each period of year, is presented in a text field. By using button, named **Save Data**, all the proper information is stored in the corresponding table of a database system, so that the user can retrieve data for a specific building at any time (changing or checking the calculations).

The screenshot displays a software window titled "Calculated Grading Method". The main section is "Normalization & Grading of Energy Consumption". Under "Description: ECRESL", the "Calculation Methods" section shows "C.S.I." as an unchecked option and "Degree-Days" as a checked option. The interface is divided into "Heating Period" and "Cooling Period" sections. For the Heating Period, "Annual Consumption" is 345.0 Kwh/year, "Real Sunlight" is an empty field, and "Max Latitude Sunlight" is 12.09 Hours. For the Cooling Period, "Annual Consumption" is 653.0 Kwh/year, "Real Sunlight" is an empty field, and "Max Latitude Sunlight" is 12.09 Hours. At the bottom left, "Insulation" is set to "Yes", "Location" is "Chania", "Building" is "Offices", "HDD" is 834.22, and "CDD" is 977.01. On the right, a text box displays the results: "Building: Offices", "Insulation: Yes", "Location: Chania", "Calculation Method: Degree-Days", "Heating Period Normalized Consumption: 410.677 KWh/period", "Energy Grading: D", "Cooling Period Normalized Consumption: 783.445 KWh/period", and "Energy Grading: D". Two buttons, "Calculate Consumption" and "Save Data", are located at the bottom right.

Figure 2. Interface using Degree – days method for Energy Classification

A.1.2 Explanation of Building's Data

Classifying a building using CSI or Degree – days methods demands the knowledge of certain and appropriate information.

- **Annual heating or cooling energy consumption:** defines the energy a building consumes for heating or cooling, respectively. This parameter used for normalization is defined by the user.
- **Real Sunlight hours:** this input parameter defines the total number of sunlight hours of a location.
- **Max Latitude Sunlight hours:** total number of hours of sunlight according to a location's latitude.
- **Heating and Cooling Degree – days:** are calculated by using Greek temperature base (19°C) and external temperature measurements. Latitude sunlight hours and Heating/Cooling degree – days are stored in a database's table.

Appendix B

B.1 Energy Classification using Measured Method

This method is more analytical than the Calculated Method (see Appendix A), since it takes into account electrical, oil or gas bills presenting a building's energy consumptions precisely. The figures, below, present the miscellaneous interfaces used for the energy classification by using Measured method.

B.1.1 Heating Consumption Calculation

Energy Grading

File

Energy Grading Input Data

Building: George Home

Heating Cooling Lighting Appliances Renewable Sources

Heating Input Data

Month	Electricity Bill	Oil Litres	Gas Litres
September:	245.0 KWh	122.0 Litre	24.0 Litre
October:	246.0 KWh	122.0 Litre	24.0 Litre
November:	247.0 KWh	122.0 Litre	24.0 Litre
December:	248.0 KWh	122.0 Litre	24.0 Litre
January:	249.0 KWh	122.0 Litre	24.0 Litre
February:	250.0 KWh	122.0 Litre	24.0 Litre

Oil Furnace Type: Standard

Gas Furnace Type: Atmospheric with standing pilot

Calculated Consumptions

Electricity	Oil	Gas
94.5 KWh	1030.778 KWh	198.144 KWh
95.5 KWh	1030.778 KWh	198.144 KWh
96.5 KWh	1030.778 KWh	198.144 KWh
97.5 KWh	1030.778 KWh	198.144 KWh
98.5 KWh	1030.778 KWh	198.144 KWh
99.5 KWh	1030.778 KWh	198.144 KWh

You have to fill Lighting and Appliances tabs first.

Calculate

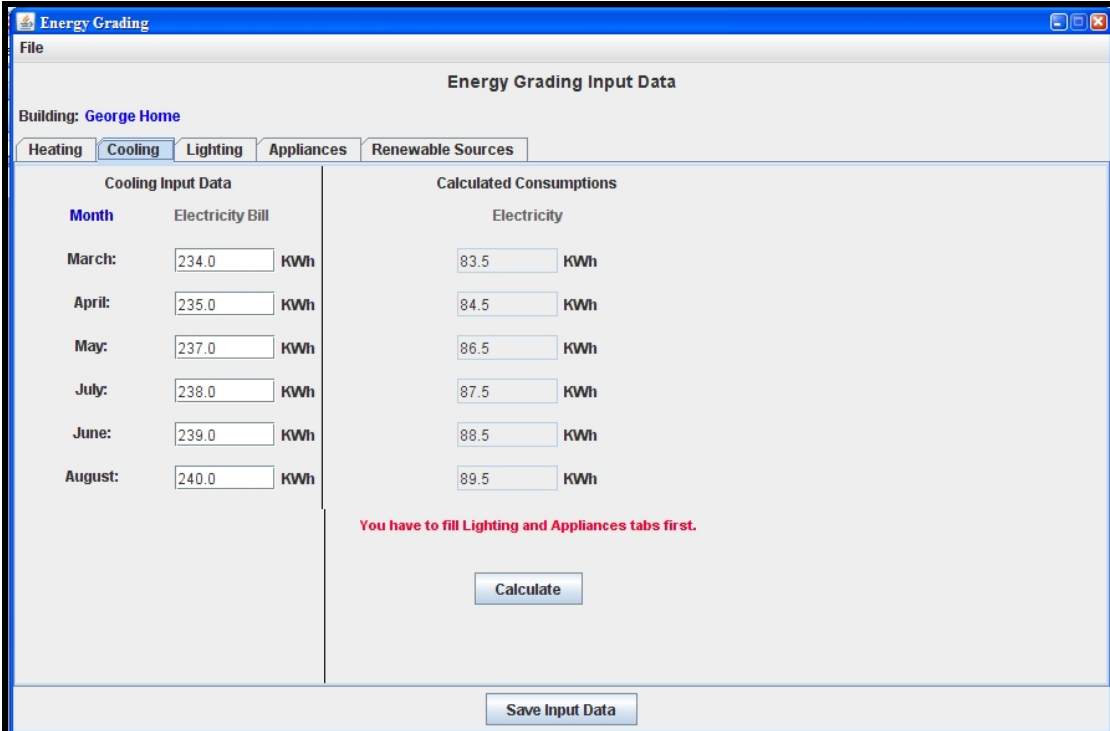
Save Input Data

Figure 1. Interface used for the calculation of heating needs

The specific method takes into account four ways of energy consumption: Heating, Cooling, Lighting and Appliances. Energy consumption for heating can be achieved by using electricity, oil or gas. This consumption concerns the range of months from September to February. The user must fill all the required fields in case of classifying the specific building. The units of energy consumption by using

electricity, oil or gas are *KWh* and *lt* respectively. In case that a building is supplied with oil and gas, the oil and gas furnace types must be selected as well. Since bills provide overall information about a building's consumption, energy consumption used for lighting and appliances must be calculated first. Removing these two consumptions the remaining value defines the consumption caused by electricity for heating and cooling needs. **Calculate** button executes an algorithm which evaluates electrical, oil and gas heating consumptions.

B.1.2 Cooling Consumption Calculation



Energy Grading

File

Energy Grading Input Data

Building: **George Home**

Heating **Cooling** Lighting Appliances Renewable Sources

Cooling Input Data		Calculated Consumptions	
Month	Electricity Bill	Electricity	
March:	234.0 KWh	83.5 KWh	
April:	235.0 KWh	84.5 KWh	
May:	237.0 KWh	86.5 KWh	
July:	238.0 KWh	87.5 KWh	
June:	239.0 KWh	88.5 KWh	
August:	240.0 KWh	89.5 KWh	

You have to fill Lighting and Appliances tabs first.

Calculate

Save Input Data

Figure 2. Interface used for the calculation of cooling needs

In case of cooling period, a building's energy consumption for cooling is calculated. In Greece, cooling needs are provided, wholly, by electricity. The calculation procedure for cooling energy consumption is similar to the procedure described in heating tab. There is a message in red, informing the user that the calculations of lighting and appliances consumptions must precede. After that, the user gives inputs concerning the cooling consumptions per month. **Calculate** button begins a process which calculates the corresponding energy consumption per month.

B.1.3 Lighting Consumption Calculation

The screenshot shows the 'Energy Grading Input Data' window with the 'Lighting' tab selected. The window title is 'Energy Grading'. The 'File' menu is visible. The 'Building: ECRESL - Year: 2005' is displayed. The 'Options & Calculation' section on the left includes a 'Measurements' checkbox (unchecked), a 'Browse' button, a 'Calculated Method' checkbox (checked), and input fields for 'Consumption Heating Period: 316.8 KWh/Year' and 'Consumption Cooling Period: 316.8 KWh/Year'. Below these is a 'Calculate Consumption' button. The 'Insert data for Lighting' section includes a 'Lamp Category' dropdown, 'Watts', 'Hours' (with a '/Day' label), and 'Quantity' input fields, and an 'Insert' button. The 'Table Of Lighting Equipment' on the right contains a table with columns 'Id', 'Type', 'Watts', 'Hours', and 'Number'. The first row shows '1', 'Mini Flourescent', '25.0', '8.0', and '12'. At the bottom of the table area is a 'Delete' button. A 'Save Energy Data' button is located at the very bottom of the window.

Id	Type	Watts	Hours	Number
1	Mini Flourescent	25.0	8.0	12

Figure 3. Interface used for the calculation of lighting consumptions

The energy need for lighting can be calculated by selecting one of the two options offered. **Calculated Method** is the default option for this application. Calculating energy needs using this method, requires a certain number of a building's lamps including their power value in watts, the total hours of usage and the number of lamps available for the specific type. At the right side of the interface, there is a list which is filled by records describing the available lamps of a building.

The other method is named **Measurements** and requires the existence of a file, stored by a Building Energy Management System, containing data with lighting consumptions. The file contains hourly records, which refer to the time and the date of the record and the total consumption in watts.

Insert button, enters a new lamp type into the list (right side) and **Delete** button removes from the list a selected record. Each lamp insertion updates a table named Lighting which stores the proper information for lamps. **Calculate Consumption** button calculates energy needs for lighting for both periods of study. The execution algorithm, which begins when the button is pressed, depends on the selected method. In case of the Measurements method the algorithm runs through a

file summing all the consumptions for the available lamps. When Calculated Method is selected, the algorithm runs through the table Lighting and sums all the lighting consumptions available for the specific building.

B.1.4 Appliances Consumption Calculation

Energy Grading

File

Energy Grading Input Data

Building: ECRESL - Year: 2005

Heating Cooling Lighting Appliances Outdoor Temperature File Renewable Sources

Table of available Appliances

ID	Appliance	Watts	Exist	Quantity	Hours/D
1	Barbeque (pit), per 5lb of food capacity	200.0	<input type="checkbox"/>		
2	Barbeque (pressurized), per 5lb of food capacity	470.0	<input type="checkbox"/>		
3	Aquarium	1000.0	<input type="checkbox"/>		
4	Clock Radio	10.0	<input type="checkbox"/>		
5	Coffee Maker	1000.0	<input type="checkbox"/>		
6	Clothes Washer	400.0	<input type="checkbox"/>		
7	Clothes Dryer	3000.0	<input type="checkbox"/>		
8	Dishwasher	1800.0	<input type="checkbox"/>		
9	Dehumidifier	785.0	<input type="checkbox"/>		
10	Electric Blanket - Single	60.0	<input type="checkbox"/>		
11	Electric Blanket - Double	100.0	<input type="checkbox"/>		
12	Fans - Ceiling	120.0	<input type="checkbox"/>		
13	Fans - Window	150.0	<input type="checkbox"/>		
14	Fans - Furnace	750.0	<input type="checkbox"/>		
15	Fans - Whole House	400.0	<input type="checkbox"/>		
16	Hair Dryer	1500.0	<input type="checkbox"/>		
17	Heater(portable)	1100.0	<input type="checkbox"/>		
18	Clothes Iron	1400.0	<input type="checkbox"/>		
19	Microwave Oven	900.0	<input type="checkbox"/>		
20	Personal Computer - CPU - awake	120.0	<input checked="" type="checkbox"/>	16	8
21	Personal Computer - CPU - asleep	30.0	<input type="checkbox"/>		
22	Personal Computer - Monitor - awake	150.0	<input checked="" type="checkbox"/>	2	8

Options & Calculation

☒ Calculate from the table

☐ I know the daily consumption

Calculate Consumption

Consumption: 30.313 KWh/Day

Save Energy Data

Figure 4. Interface used for the calculation of appliances' consumptions

Similarly to lighting interface, the appliances' energy consumption can be calculated by using two different methods. The method named **Calculate from the table**, runs through the table, on the left side, and calculates the consumptions of each partial appliance which exists in the specific building. On the other hand, the method named **I know the daily consumption** is activated when the user knows the total energy consumption for all the appliances. In both cases the result is referred to a text field and concerns the daily energy consumption for the appliances.

B.1.5 Outdoor Temperature File

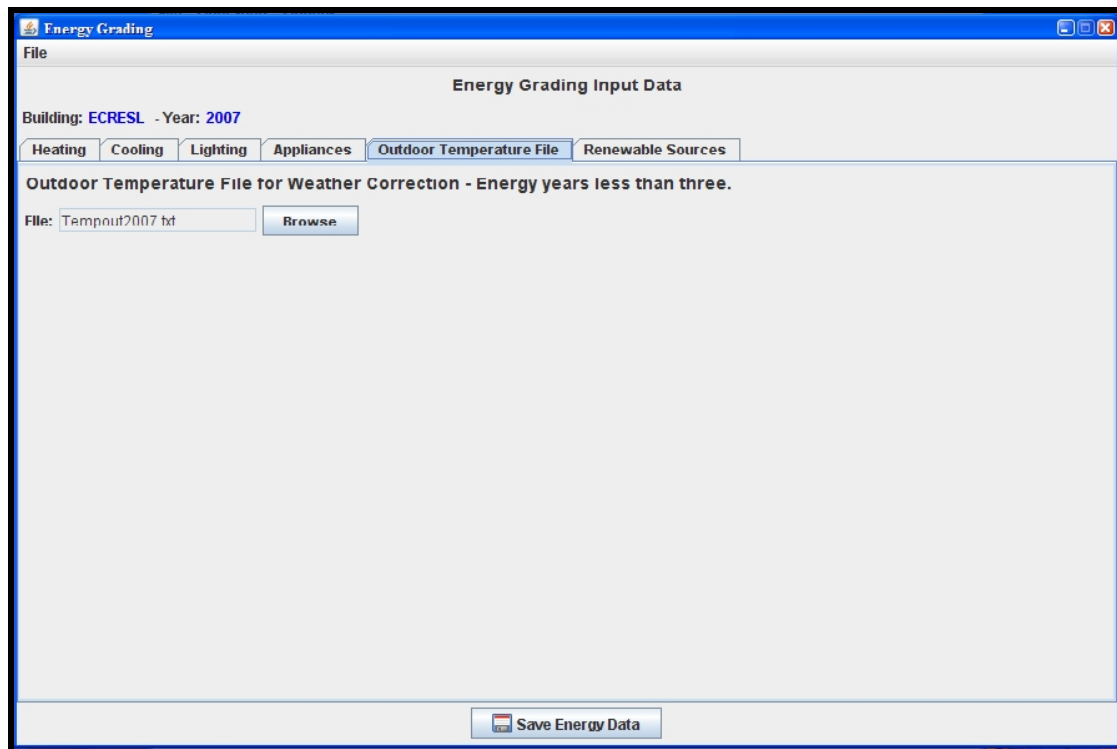


Figure 5. Additional information required for weather correction

The operation which is presented in the image above is used when a weather correction procedure must begin. This operation refers to the energy classification based on **Measured** method and when the assessment period concerns less than three years. In this case, the interface loads a file of the outdoor temperature for the specific location and for the current year.

Appendix C

C.1 Communication between Sensors and a Personal Computer

A Building Energy Management System (BEMS) constitutes a convenient way of controlling and monitoring environmental data which come from sensors. These sensors, which are placed either in internal or external environment of a building, communicate with BEMS. By using this system makes the control of reliable and accurate but few buildings use such a system in Greece. An alternative way of monitoring and processing data is offered by Nidaq Measurements Company which designs electronic cards that are connected directly to the personal computer (National Instruments 2000, 1998). In this case the sensors are connected to an external interface and this is connected to the card. After that and using proper software everyone can process and use environmental data. This appendix presents such communication system.

C.1.1 Use of Java Native Interface

All necessary functions, described before, for reading an analogue voltage value from a PCI card output are contained in an existing native library, nidaq32.lib. This library comes with the drivers of the PCI card and is implemented in C language. In order to get access to this native library, from the java code, we use the java native interface which allows Java applications to invoke native code and vice versa. The process of writing native methods that allow Java applications to call functions implemented in native libraries is described in the next chapter.

C.1.2 Java Native Interface (JNI)

C.1.2.1 Java Platform and Host Environment

The Java platform is a programming environment consisting of the Java virtual machine (VM) and the Java Application Programming Interface (API). Java applications are written in the Java programming language, and compiled into a machine-independent binary class format. A class can be executed on any Java virtual machine implementation. The Java API consists of a set of predefined classes. Any

implementation of the Java platform is guaranteed to support the Java programming language, virtual machine, and API.

The term *host environment* represents the host operating system, a set of native libraries, and the CPU instruction set. *Native applications* are written in *native programming languages* such as C and C++, compiled into host-specific binary code, and linked with native libraries. Native applications and native libraries are typically dependent on a particular host environment. A C application built for one operating system, for example, typically does not work on other operating systems.

Java platforms are commonly deployed on top of a host environment. For example, the Java Runtime Environment (JRE) supports the Java platform on existing operating systems such as Solaris, Linux and Windows. The Java platform offers a set of features that applications can rely on independent of the underlying host environment.

C.1.2.2 The Role of JNI

When the Java platform is deployed on top of host environments, it may become desirable or necessary to allow Java applications to work closely with native code written in other languages. The JNI is a powerful feature that allows us to take advantage of the Java platform, but still utilize code written in other languages. As a part of the Java virtual machine implementation, the JNI is a *two-way* interface that allows Java applications to invoke native code and vice versa.

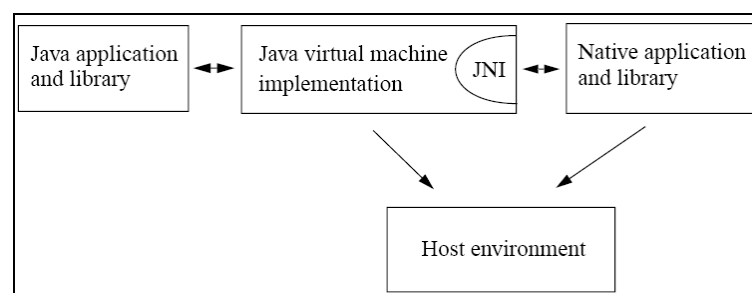


Figure 1. Role of JNI

The JNI is designed to handle situations where we need to combine Java applications with native code. As a two-way interface, the JNI can support two types of native code: native *libraries(our case)* and native *applications*.

- We can use the JNI to write *native methods* that allow Java applications to call functions implemented in native libraries. Java

applications call native methods in the same way that they call methods implemented in the Java programming language. Behind the scenes, however, native methods are implemented in another language and reside in native libraries.

- The JNI supports an *invocation interface* that allows us to embed a Java virtual machine implementation into native applications. Native applications can link with a native library that implements the Java virtual machine, and then use the invocation interface to execute software components written in the Java programming language.

C.1.2.3 Implications of Using the JNI

Once an application uses JNI, it takes the risk of losing two benefits of the Java platform.

- First, Java applications that depend on the JNI can no longer readily run on multiple host environments.
- Second, while the Java programming language is type-safe and secure, native languages such as C or C++ are not. A misbehaving native method can corrupt the entire application.

C.1.2.4 Using JNI based on our application

In our Java application we need to call NIDAQ functions, implemented in C, in order to read a value from an analogue PCI card output. The process consists of the following steps:

1. Creation of the class `NIDAQConnector.java` that declares the native method.
2. Compilation of the `NIDAQConnector` source file, resulting in the class file `NIDAQConnector.class`.
3. Generation of the C header file (`NidaqAinput.h`) containing the function prototype for the native method implementation. For the generation of the header file we use the `javah` tool provided with JDK releases.
4. Writing the C implementation (`nidaqdllAinpt.c`) of the native method.
5. Compilation of the C implementation into a native library, creating `NIDAQdll.dll`.

6. Running the java application using the java runtime interpreter. Both the class file (NIDAQConnector.class) and the native library (NIDAQdll.dll) are loaded at runtime.

Figure # illustrates the pre described process.

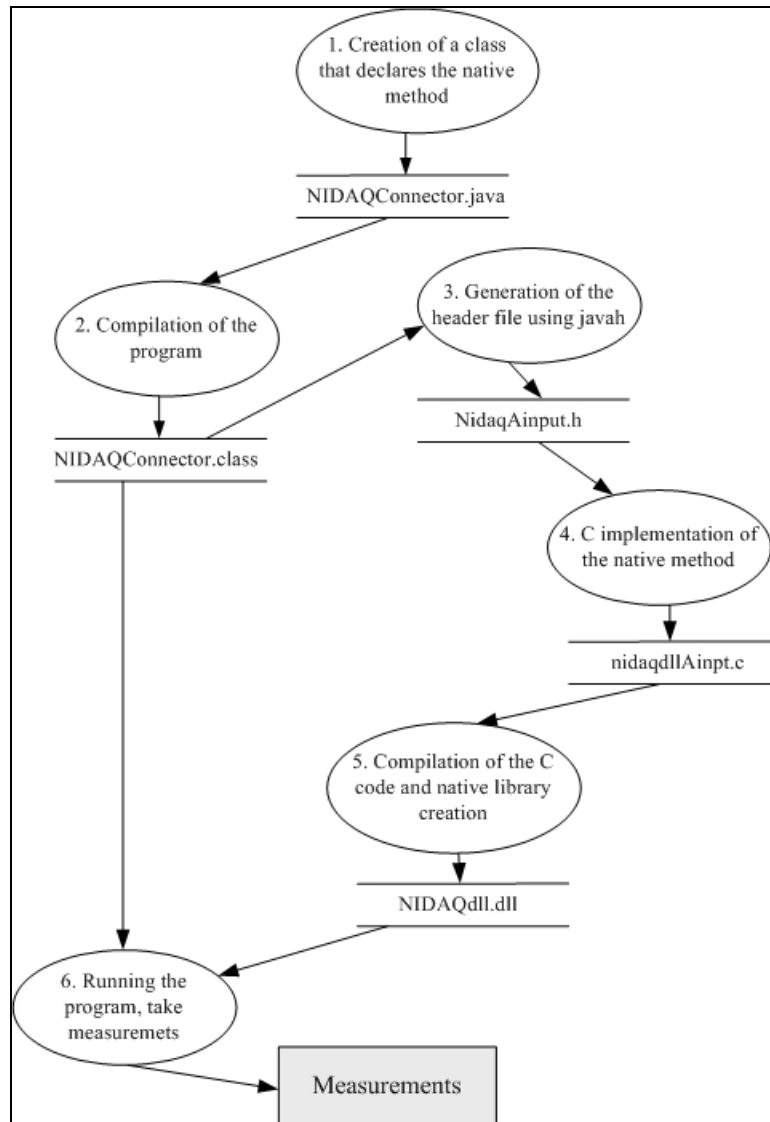


Figure 2. Steps in writing JNI method

C.1.2.5 Declare the native method

In our program the class named NIDAQConector contains the native method NIDAQ_AInput(short ch,short gn).

```
public class NIDAQConnector {
    public NIDAQConnector() {}
    public double returnvoltage(short channel, short gain){
        double voltage;
        voltage = NIDAQ_AInput(channel,gain); NATIVE FUNCTION
        return voltage;
    }
    private native double NIDAQ_AInput(short ch,short gn) ; NATIVE METHOD
    static {System.loadNIDAQdll.dll";}
}
```

The NIDAQConector class definition begins with the declaration of a function (returnvoltage) that calls the native method in order to return the voltage measurements. This is followed by the declaration of the native method. The last part of the class definition is a static initializer that loads the native library containing the implementation of the NIDAQ_AInput native method. Before the native method can be called, the native library that implements NIDAQ_AInput must be loaded. In this case, we load the native library in the static initializer of the NIDAQConector class. The Java virtual machine automatically runs the static initializer before invoking any methods in the NIDAQConector class, thus ensuring that the native library is loaded before the NIDAQ_AInput native method is called.

C.1.2.6 Compile the NIDAQConector class

After the definition of the NIDAQConector class, we save the source code in a file called NIDAQConector.java. Then we compile the source code file and the result is the generation of NIDAQConector.class file.

C.1.2.7 Create the native method header file

Afterwards we use the javah tool to generate a JNI-style header file, useful to implement the native method in C. The most important part of the header file is the function prototype for

Java_NDMeasurements_NIDAQConnector_NIDAQ_1AInput, which is the C function that implements the NIDAQConnector.NIDAQ_1AInput method:

```
JNIEXPORT jdouble JNICALL Java_NDMeasurements_NIDAQConnector_NIDAQ_1AInput
(JNIEnv *, jobject, jshort, jshort);
```

The first argument of the native method implementation is a JNIEnv interface pointer. The second argument is a reference to the NIDAQConnector object itself. The two last arguments are the arguments of the native method declared in the java file (function's inputs).

C.1.2.8 Write the Native Method Implementation and Create the Native Library

For the C implementation of the native method we used Microsoft Visual Studio 6. The function follows the prototype specified in the generated header file. The C file nidaqdllAinpt.c contains the implementation of NIDAQConnector.NIDAQ_1AInput as follows (National Instruments 1998):

```
#include <jni.h>
#include <stdio.h>
#include "NidaqAInput.h"
#include "nidaqex.h"

JNIEXPORT jdouble JNICALL Java_NDMeasurements_NIDAQConnector_NIDAQ_1AInput
(JNIEnv * env, jobject thisobject, jshort channel, jshort gain){
    i16 iStatus = 0;
    i16 iRetVal = 0;
    i16 iDevice = 1;
    i16 iChan = channel;
    i16 iGain = gain;
    f64 dVoltage = 0.0;
    i16 iIgnoreWarning = 0;

    iStatus = AI_VRead(iDevice, iChan, iGain, &dVoltage);
    iRetVal = NIDAQErrorHandler(iStatus, "AI_VRead", iIgnoreWarning);
    if (iStatus == 0) {
        return(dVoltage);
    }
}
```

The implementation of this native method uses the NIDAQ **AI_VRead()** function to read the analogue channel *iChan* and returns the voltage value according to the gain *iGain*. The C program includes four header files:

- *jni.h* - This header file provides information the native code needs to call JNI functions.
- *NidaqAInput.h* - The header file that we generated using *javah*. It includes the C/C++ prototype for the `NDMeasurements_NIDAQConnector_NIDAQ_1AInput` function.
- *nidaqex.h* - This header file provides all information for the NIDAQ functions we use and it comes with the PCI card drivers.
- *stdio.h* - This library provides all the input/output operations for C/C++

Now that all the necessary C code is written, we compile *nidaqdllAinpt.c* and build the native library. We generated a dynamic link library (DLL) *NIDAQdll* using the Microsoft Visual C++ compiler.

C.2 Measurement Java platform for PCI-6024E

C.2.1 Platform Interface

The interface of the platform consists of two parts, the PCI card's measurements settings and the measurement procedure settings.

The first part is responsible for the selection of the analogue channels' pairs, the gain of measurements for each pair of channels, the mathematical expression which converts the measured volts to the desirable unit (e.g. Celsius degrees), and the names of the txt files where measurements will be saved. It consists of eight similar rows, one for each pair of channels. Each row includes the following objects:

- A checkbox (Use), responsible for the selection of the channels' pair.
- A label (Channel Pair), which describes the pair of channels.
- A Gain combo box which contains all possible gains of the PCI card.
- A Range field which describes the range of measurement and depends on the selected gain.
- A Description field which holds the description of measurements (e.g. CO_2).

- A Conversion field which holds the mathematical expression used for the conversion of voltage value to the desired unit (e.g. Celsius Degrees).
- A Name field which holds the name of the txt file where measurements will be saved.

Finally, this part of the interface includes two buttons: a) the save settings button which is responsible to save card's measurement setting into a property file, b) the clear settings button which clears all platform's fields.

The second part of the interface is responsible for the measurements procedure. It consists of the following objects:

- The Sample Rate field which holds the measurements sample rate, in seconds.
- The start button which starts the measurements procedure.
- The stop button which stops the measurements procedure.

NI PCI-6024E Settings And Measurements

Menu

National Instruments PCI-6024E Settings

USE	Channel Pair	Gain	Range	Description	Conversion	Txt File Name
<input type="checkbox"/>	Channels 0 & 8	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 1 & 9	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 2 & 10	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 3 & 11	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 4 & 12	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 5 & 13	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 6 & 14	0.5	-10V to 10V			
<input type="checkbox"/>	Channels 7 & 15	0.5	-10V to 10V			

Save Settings Clear Settings

National Instruments PCI-6024E Measurements

Sample Rate: seconds

Start Measurement Stop

Figure 3. Application Interface

C.2.2 Platform Operation

This section describes the platform operation and gives a little explanation of the java files which implement this application.

The user has to select which channels are connected to sensors in order to take measurements with this platform. Also, he has to select the measurement gain for each pair of channels, give the descriptions of the channels' measurements and give the mathematical expressions for each channels' pair. Furthermore, he has to give the names of the files, where measurements will be saved, for each pair of channels. Finally, he has to give the sample rate (T) of measurements, in seconds, and press the start button in order to start the measurements procedure. The program measures all selected channels' outputs (volts) every T seconds, converts them into the desirable units, and saves these values in the txt files respectively. The format of each line in the txt files is as follows: DATE TIME MEASUREMENT (e.g.: 25/02/2004 12:35 25.4). In order to stop measurements, he has to do is to press Stop button. In order to start the measurement procedure, all fields for the selected channels must have been filled. Also sample rate field must contains a number (seconds).

C2.2.1 Presentation of application's java files

NIDAQConnector.java

As mentioned in the previous chapter, this java file is responsible for the declaration of the native method that measures the analogue card's outputs. It contains the class NIDAQConnector which declares the native method and the function *returnvoltage(channel, gain)*. This function calls the native method and returns the measured voltage value for channel "*channel*" with gain "*gain*".

RangeGainCon.java

This java file declares the class RangeGainCon which is responsible for two operations:

- First, to change the value of the range field, according to the gain combo box selection. *RangeChange(combobox, textfield)* function is responsible for this operation.
- Second, to return the short value of the gain according to the gain combo box selection. *ReturnShort(combobox)* function is responsible

for this operation. The returned short value is inserted as the second argument of the *returnvoltage()* function, described before.

Gain Selection	Short value
0.5	-1
1	1
10	10
100	100

Table 1. Gain to short values

Pfileoperations.java

This java file declares the class Pfileoperations which is responsible for the write and read operations of the property file PCI6034E.properties. This property file stores the platform's settings when save settings button is pressed. The structure of the file is as follows: property = value. *SetProperties()* function is responsible for writing into the property file. It takes as input an array of properties and is called when the save settings button is pressed. *Returnproperty()* function is responsible to read and return the stored information from the property file. This function is called, each time the application starts.

GlobalTimer.java

This java file declares the class GlobalTimer. This class sets a timer (class Timer) and contains two timer functions:

- *Settimer(Timetask, delay, period)*: this function initializes the timer and starts a periodical procedure after a *delay* of time. It repeats the task (*Timetask*) every *period* (seconds).
- *Stoptimer()*: this function stops the timer.

Filewriter.java

This java file declares the class Filewriter which is responsible for the write operation of the txt files that hold the measurements. It contains the function *FileWriter(name, value)* which appends the *value* to the txt file with name, *name*.

Conversion.java

This java file is responsible for the conversion of data. The sensor's output varies between 0 to 10 volts. The technical manual of this sensor reports that when the output is equal to 0 volts then the temperature is -10 and when it is equal to 10 volts then the temperature is 40°C . So, this java file reads the output of the sensor and converts it to the corresponding temperature value.

MeasureSettings.java

This java file is the main file of our application. It contains the main function and implements the interface of the platform. Also, it contains the measurement operation.

The measurement operation starts when the start measurement button is pressed. A new GlobalTimer is declared and a number of checks are performed. These checks examine if all fields for the selected channels have been filled. Also a check, if sample rate field contains a number, is performed. If all checks are passed, the Timetask for the GlobalTimer is declared. This contains a block of operations for each pair of channels, as shown below:

```
if(usebox.isSelected()==true){ //if channel is selected
    String conversion = conversionfeild.getText().toString(); //conversion expression
    String txt = filepathfeild.getText().toString(); //name of the output txt file
    short gain = RGConn.Returnshort(gaincombobox); //The short value for the selected
    gain
    short channel = #; //number of channel
    double voltage = NIDAQAI.returnvoltage(channel,gain); //voltage measured value
    voltage = conver.ReturnConversion(conversion,voltage); //Conversion voltages
    → desired unit
    fw.FileWriter(txt,voltage); //write the converted value to the txt file
}
```

After the declaration of the Timetask, the *settimer()* function is performed, and the measurement procedure starts.

```
gt.settimer(nt,delay,period);
```

where *nt* is the Timetask, *delay* is 3 seconds and *period* is the sample rate field's value(sample rate in seconds).

C.3 Description of PCI – 6024E

C.3.1 Features of PCI – 6024E Device

The 6024E hardware card is constituted by 16 channels of analog input, two channels of analog output, a 68-pin connector and eight lines of digital I/O (National Instruments 2000, 1998). The specific device uses the NI – DAQ STC system including timing controller for time – related functions. The DAQ-STC consists of three timing groups that control analog input, analog output, and general-purpose counter/timer functions. These groups include a total of seven 24-bit and three 16-bit counters and a maximum timing resolution of 50 ns.

C.3.2 NI – DAQ Driver Software

The software driver offered makes the NI – DAQ device compatible to any Personal Computer. It contains libraries and functions which can be used in a programming environment. Furthermore, the software is quite consistent among the different versions in order minimal modifications of the programming code to be achieved.

C.3.3 Block Diagram of 6024E

This part of the appendix presents the block diagram of National Instrument's PCI Card 6024E.

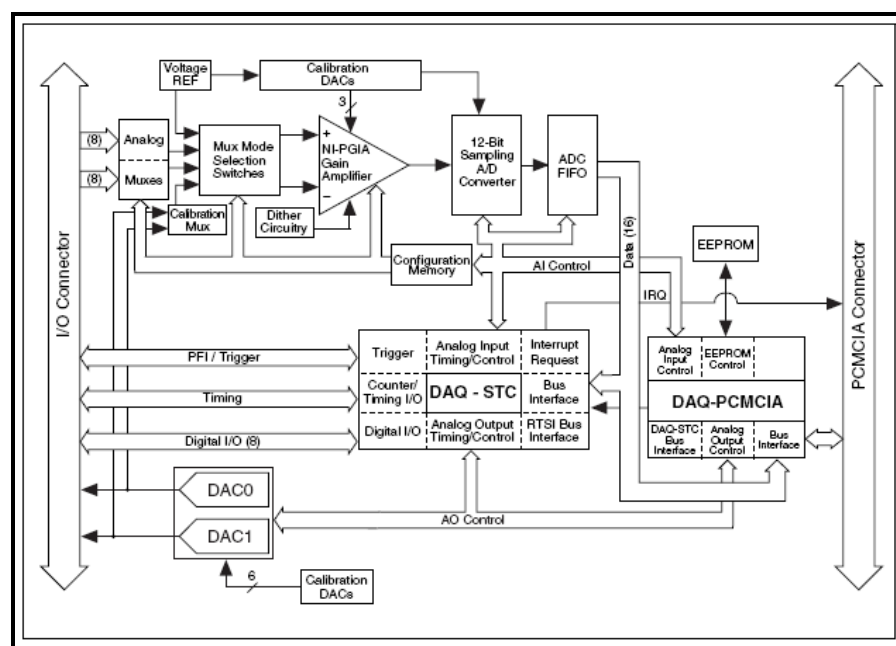


Figure 4. Block diagram of 6024E

C.3.4 Measurement Precision

PCI 6024E device has a bipolar range which modifies according to the gain. In this case, each channel of the card can be programmed with gains (see the following table) maximizing the resolution.

Gain	Input Range	Precision ¹
0.5	–10 to +10 V	4.88 mV
1.0	–5 to +5 V	2.44 mV
10.0	–500 to +500 mV	244.14 μ V
100.0	–50 to +50 mV	24.41 μ V

Table 2. The various gains supported by the card including the range of the voltage per gain

C.3.5 I/O Connector

The following image presents the I/O connector for the 6024E device.

ACH8	34	68	ACH0
ACH1	33	67	AIGND
AIGND	32	66	ACH9
ACH10	31	65	ACH2
ACH3	30	64	AIGND
AIGND	29	63	ACH11
ACH4	28	62	AISENSE
AIGND	27	61	ACH12
ACH13	26	60	ACH5
ACH6	25	59	AIGND
AIGND	24	58	ACH14
ACH15	23	57	ACH7
DAC0OUT1	22	56	AIGND
DAC1OUT1	21	55	AOGND
RESERVED	20	54	AOGND
DIO4	19	53	DGND
DGND	18	52	DIO0
DIO1	17	51	DIO5
DIO6	16	50	DGND
DGND	15	49	DIO2
+5 V	14	48	DIO7
DGND	13	47	DIO3
DGND	12	46	SCANCLK
PFI0/TRIG1	11	45	EXTSTROBE*
PFI1/TRIG2	10	44	DGND
DGND	9	43	PFI2/CONVERT*
+5 V	8	42	PFI3/GPCTR1_SOURCE
DGND	7	41	PFI4/GPCTR1_GATE
PFI5/UPDATE*	6	40	GPCTR1_OUT
PFI6/WFTRIG	5	39	DGND
DGND	4	38	PFI7/STARTSCAN
PFI9/GPCTR0_GATE	3	37	PFI8/GPCTR0_SOURCE
GPCTR0_OUT	2	36	DGND
FREQ_OUT	1	35	DGND

¹ Not available on the 6023E

Figure 5. I/O Connector for 6024E device

C.3.6 Differential Connection

The connection used for the communication between the temperature sensor and the NI – DAQ device 6024E is presented below.

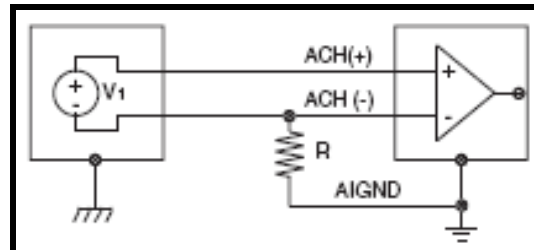


Figure 6. Differential Connection between sensor and 6024E

From the image above, it is obvious that a Resistor R has been inserted between the sensor and the device. This resistor is equal to $100K\Omega$. But it is essential to point out that this was not the first connection which had been used. Another connection similar to this had been used but without a resistor. In this case, the system (programming code and device) did not behave very well. Although the programming code read the inputs of the sensor, these values were not accurate and compatible with the real measurements of the temperature that prevailed in that day. Moreover, the values of the inputs varied and were not constant.

This phenomenon led to the conclusion that a resistor should have been used. The role of the resistor was essential since after using it, the measurements approached the real ones without any variance and they were constant.

Appendix D

D.1 User Manual

D.1.1 Login Security System

After installing the .exe file, the application starts with the following form:



Figure 1. Login Form.

This form allows a user to enter the system. Two settings are required for a successful login. The first one is the username and the other is the password of the user. The correct insertion of those settings leads to the main menu (see fig. 2) of the application. In case of invalid insertion of the settings, warning messages appear and inform the user about the setting which was inserted incorrectly.

D.1.2 Main Menu

This form is the main form of the application and permits the user to choose the desired operation. The following figure presents the form of the main menu.



Figure 2. Main Menu

It is constituted by two buttons and three additional options on the menu bar.

- **Buildings Data** button: leads to another form which is responsible for building processing (see below).
- **Buildings Grading** button: leads to a list of buildings and a user can execute either environmental or energy classification.

As it was mentioned above, menu bar contains three options: File, Settings and Application. File option contains a button named Exit which terminates the application. The components of button Settings are presented in figure 3 below.

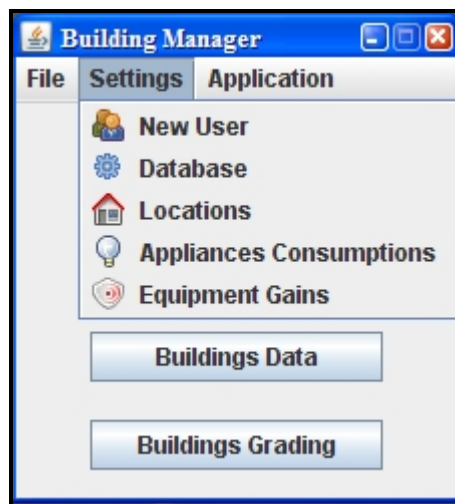


Figure 3. Components of Settings option.

- **New User:** adds a new user in the system (see fig. 4). Verify Password field checks if the user has chosen the desired password.
- **Database:** informs about the settings of the existed database (see fig. 5). The password of the database is not visible. However, the user of the system can change the settings of the specific database by using button Edit. After that, the database's settings are updated when button Save is pressed.
- **Locations:** inserts or changes the data of a specific location (see fig. 6). A location is described by its name, the heating and cooling degree – days and the latitude. Moreover, a location can be removed from the system if button Delete Location is pressed. The deletion is achieved when the user selects and marks a location from the list.
- **Appliances Consumptions:** adds or changes an appliance of a building (see fig. 7). The information needed for appliances, concerns the name and the consumption in watts. Similarly to Locations, the user marks the appliance that

he/she desires to delete and afterwards he/she presses the button Delete Appliance.

- **Equipment Gains:** inserts, updates or deletes the building's heating or cooling gains concerning different types of equipment (see fig. 8).

The 'New User' dialog box has a blue title bar with the text 'New User'. The main area is titled 'Insert A New User' and features a user icon on the left. It contains three text input fields: 'Username:', 'Password:', and 'Verify Password:'. At the bottom, there are two buttons: 'Insert' and 'Exit'.

Figure 4. New User form

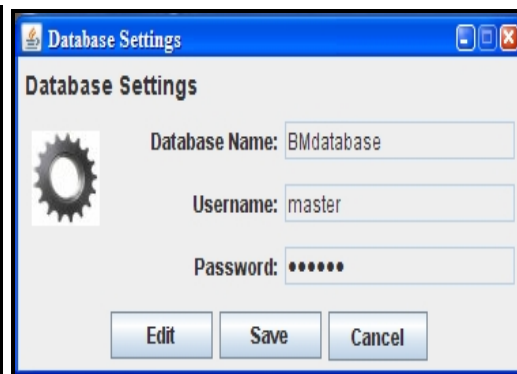
The 'Database Settings' dialog box has a blue title bar with the text 'Database Settings'. The main area is titled 'Database Settings' and features a gear icon on the left. It contains three text input fields: 'Database Name:' (with the value 'BMdatabase'), 'Username:' (with the value 'master'), and 'Password:' (with masked characters '*****'). At the bottom, there are three buttons: 'Edit', 'Save', and 'Cancel'.

Figure 5. Database settings definition.

Locations	Heat DDays	Cool DDays	Latitude
Alexandroupolis	1956.73	823.86	40.51
Andravida	1161.71	923.41	37.54
Araxos	1062.37	1030.8	38.1
Athens	993.03	1172.18	37.59
Chania	834.22	977.01	35.31
Eleusina	1279.97	1136.45	38.02
Helliniko	1059.77	1200.9	37.23
Ioannina	2112.21	746.1	39.4
Irakleio	805.55	1063.02	40.46
Kalamata	1137.02	1055.87	37.02
Kalitheia	978.7	1175.03	37.57

Figure 6. Locations

Appliance Type	Watt
Aquarium	1000.0
Barbeque (pit), per 5lb of food capacity	200.0
Barbeque (pressurized), per 5lb of food capacity	470.0
Clock Radio	10.0
Clothes Dryer	3000.0
Clothes Iron	1400.0
Clothes Washer	400.0
Coffee Maker	1000.0
DVD	23.0
Dehumidifier	785.0
Dishwasher	1800.0

Figure 7. Appliances

Appliance Type	Gains
Copier	225.0
Impact printer	20.0
Laser printer	150.0
Personal Computer	125.0
Refrigerator	150.0
Television Set	75.0

Figure 8. Building's Equipment

Application Option informs about the developers of the Java application and the version of it.

D.1.3 Buildings Data operation

After using this operation the user can be informed about all the proper information of a building. However, this information is not visible until the user clicks on one of the buildings in the list (see fig. 9).

ID	Description	Location	Address
1	ECRESL	Chania	T.U.C.

Figure 9. Building's Menu

When a building in the list is marked and the user presses Delete button then the marked record is removed from the system and the database. This part of the application is divided to three parts. The first one is named Insert and it is responsible for the insertion of a new building in the system. View part can be considered as a monitor of the building's data and the last part allows a user to update one or more data for the building.

In Building's zones (see fig. 10), a user can insert, delete and update a zone of a building similarly to the previous operation. The other operation, entitled Energy Grading, reports a message and allows a user to make a decision about the method that he/she wishes to use for energy classification (see fig. 11).

The screenshot shows a software window titled "Zones Menu". It has a menu bar with "File" and "Operation". Below the menu bar, it displays "Building: ECRESL" and "Floors: 2". There are three tabs: "View", "Insert", and "Change". The "View" tab is active, showing "Zone Details".

Zone Details:

- Zone ID: 1
- Description: Ground
- Time Usage: 09:00 - 17:00

FILES:

- CO2: CO2.txt
- Humidity: Humidity.txt
- Temperature: TinNew.txt
- MRT: MRTNew.txt
- Lux: Lux.txt

A "Delete" button with a red X icon is located at the bottom right of the Zone Details section.

Zones' Table:

ID	Description	Time Usage
1	Ground	09:00-17:00
2	First Floor	09:00-17:00

Figure 10. Building's Zones

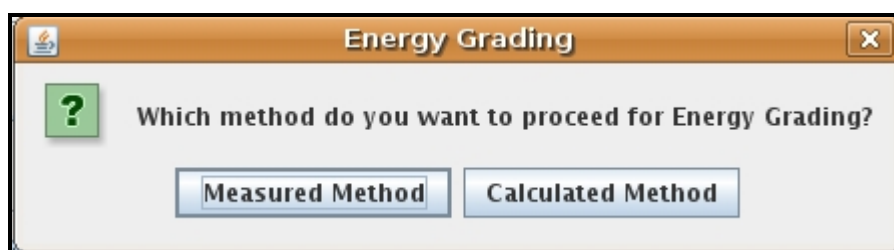


Figure 11. Energy classification method selection.

Figure 11 presents both of the energy classification methods that are implemented by this application.

D.1.4 Measured Method

This method, whose form is presented in figure 12, takes into account electrical, oil or gas bills for the specific building. It uses two methodologies based on measured data. If data have been taken for three or more years then the system decides whether the energy classification methodology that should be used, is the one without Weather Correction. Otherwise, this means that the measured data refer to less than three years of measurements and then the system decides to use energy classification methodology including Weather Correction.

Figure 12. Form used for Measured method

This form informs about the duration of measurements. If the measurements are referred to less than three years then the option «Number of years less than three» is activated. Moreover, a list appears and presents in which year the energy

classification has been realized. View button presents a form with existed data for the building. Delete button removes a classified year from the system and New button inserts a new year to the system. However, the proper use of this method requires an additional parameter. This parameter is called Regulation Reference and depends on each nation's policy about energy certifications. Heat Gains option is used only when energy classification with Weather Correction methodology is used. The following figure presents the main form of Measured method.

The screenshot shows the 'Energy Grading' software window. The title bar says 'Energy Grading'. Below the title bar is a menu bar with 'File'. The main area is titled 'Energy Grading Input Data'. Below this, it says 'Building: ECRESL - Year: 2007'. There are five tabs: 'Heating', 'Cooling', 'Lighting', 'Appliances', and 'Outdoor Temperature File'. The 'Heating' tab is selected. Below the tabs, there are two main sections: 'Heating Input Data' and 'Calculated Consumptions'. The 'Heating Input Data' section has a table with columns: 'Month', 'Electricity Bill', 'Oil Litres', and 'Gas Litres'. The 'Calculated Consumptions' section has a table with columns: 'Electricity', 'Oil', and 'Gas'. Below these tables, there are dropdown menus for 'Oil Furnace Type' and 'Gas Furnace Type'. At the bottom, there is a 'Calculate' button and a 'Save Energy Data' button.

Heating Input Data				Calculated Consumptions		
Month	Electricity Bill	Oil Litres	Gas Litres	Electricity	Oil	Gas
September:	100.0 KWh	100.0 Litre	100.0 Litre	39.77 KWh	904.4 KWh	825.6 KWh
October:	100.0 KWh	100.0 Litre	100.0 Litre	39.945 KWh	904.4 KWh	825.6 KWh
November:	100.0 KWh	100.0 Litre	100.0 Litre	39.815 KWh	904.4 KWh	825.6 KWh
December:	100.0 KWh	100.0 Litre	100.0 Litre	39.735 KWh	904.4 KWh	825.6 KWh
January:	100.0 KWh	100.0 Litre	100.0 Litre	39.775 KWh	904.4 KWh	825.6 KWh
February:	100.0 KWh	100.0 Litre	100.0 Litre	39.805 KWh	904.4 KWh	825.6 KWh

Oil Furnace Type: Standard with improved heat tra...
Gas Furnace Type: Atmospheric with standing pilot

You have to fill Lighting and Appliances tabs first.

Calculate

Save Energy Data

Figure 13. Energy classification form based on Measured method

This form is divided in 4 categories: Heating, Cooling, Lighting and Appliances.

- **Heating:** is referred to the energy needs for heating and depends on electricity, oil or gas bills. The user defines energy consumptions during heating period.
- **Cooling:** is referred to energy needs for cooling and depends only on electricity for buildings located in Greece. The user defines energy consumptions during cooling period
- **Lighting:** concerns energy needs used for lighting.
- **Appliances:** concerns energy needs for building's appliances.

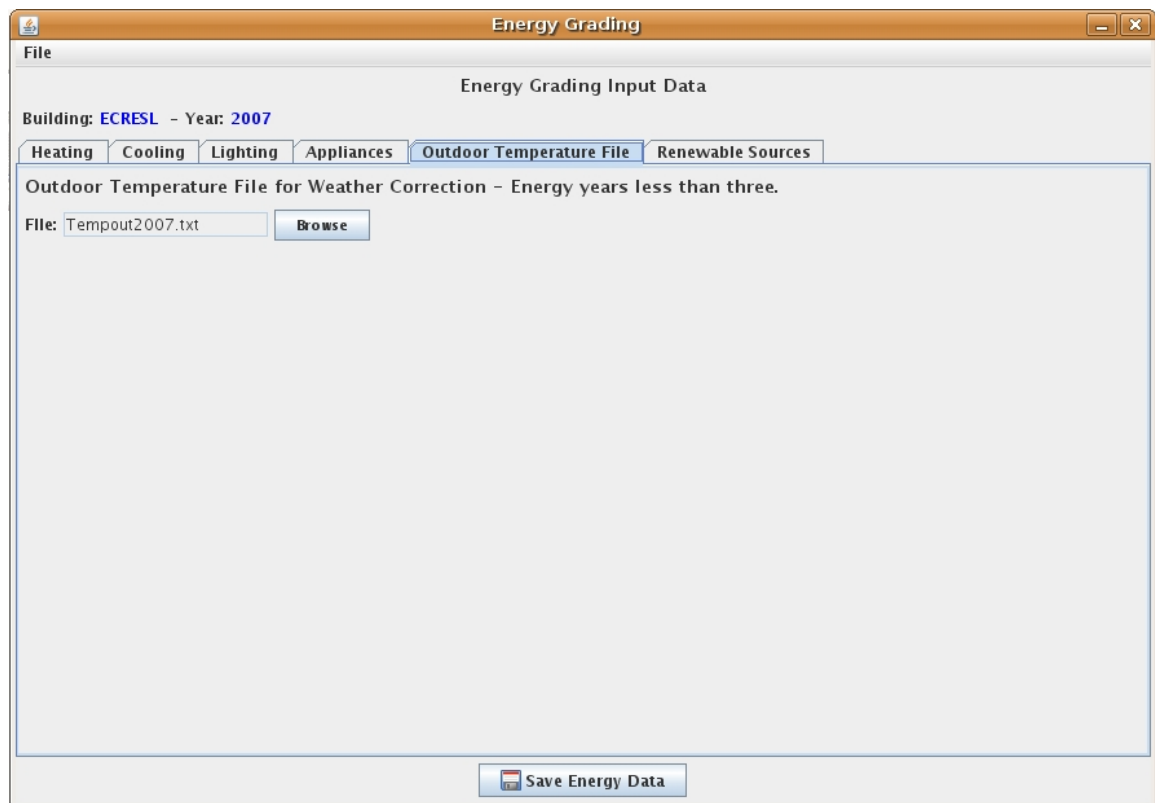


Figure 14. Input for outdoor Temperature file when measures are less than 3 years.

When the measured data have been taken for less than three years, then the weather correction procedure must be executed. This procedure requires the existence of a file with outdoor temperature data referring to a whole year. Outdoor Temperature File tab (see fig. 14) allows a user to insert a new file.

D.1.5 Calculated Method

The form, which appears when the Calculated Method is used, is presented below.

Figure 15. Calculated method.

From the figure above, it's obvious that the calculated method uses two different methodologies: Climate Severity Index (C.S.I.) and Degree – days methodology. Climate Severity Index methodology constitutes the default methodology.

- **C.S.I.:** this methodology calculates the normalized energy consumption for a building for both periods of interest. The data used for the calculations are the annual consumption for heating and cooling, the real sunlight hours and the maximum sunlight hours for a specific location.
- **Degree – days:** this methodology uses only the annual consumption for heating and cooling.

Both methodologies use heating and cooling degree – days of the location of the building. Calculate Consumption button starts a procedure which calculates the normalized energy consumption, depending on the selected method, for a building and uses it for the class definition. The results are reported in a text field. Finally, Save Data button saves the data used and the calculations in the corresponding table of the database system.

D.1.6 Building Grading

In this part of the application, the user selects the desired building to be classified and executes the procedure for energy classification (see fig. 16).

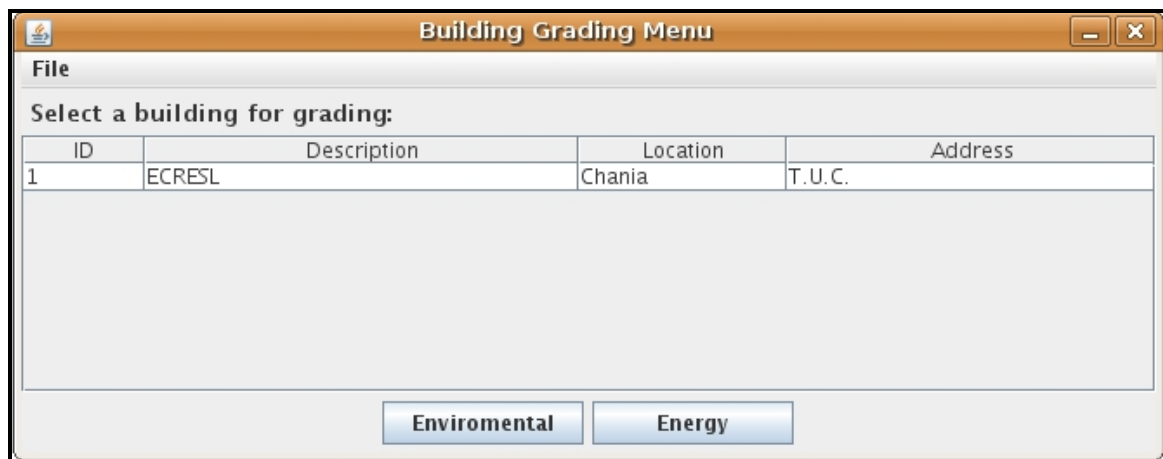


Figure 16. Energy classification menu

Energy classification procedure begins after pressing button, named, Energy.

Appendix E

E.1 Features of European Standard prEN 15203/15315

This appendix provides some general information about the standard prEN 15203/15315:2006 (CEN Members 2006). This information includes terms and definitions that can be used in order a new building to be evaluated.

E.2 Terms and Definitions

Building

Construction as a whole, including its envelope and all technical building systems, for which energy is used to condition the indoor climate.

New Building

Building at design stage or under construction or (for measured energy rating) too recently constructed to have reliable records of energy use.

Existing Building

Building that is erected and (for measured energy rating) for which actual data necessary to assess the energy use are known or can be measured.

Technical Building System

Technical equipment for heating, cooling, ventilation, domestic hot water, lighting and electricity production.

Conditioned Space

Part of building which is heated or cooled

Conditioned Zone

Part of a conditioned space with a given set-point temperature or set-point temperatures, throughout which the internal temperature is assumed to have negligible spatial variations and which is controlled by a single heating system, cooling system and/or ventilation system.

Dehumidification

Process of removing water vapor from air to reduce relative humidity.

Humidification

Process of adding water vapor to air to increase relative humidity.

Energyware

Tradable commodity used mainly to produce mechanical work or heat, or to operate chemical or physical processes, and listed in Annex A of ISO 13600. [ISO 13600].

Delivered Energy

Total energy, expressed per energy carrier, supplied to the building through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity.

Primary Energy

Energy that has not been subjected to any conversion or transformation process. Primary energy includes resource energy and renewable energy. If both are taken into account it can be called total primary energy.

Total Primary Energy Factor

Resource and renewable primary energy divided by delivered energy, where the primary energy is that required to supply one unit of delivered energy, taking account of the energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used

Primary Resource Energy Factor

Primary resource energy divided by delivered energy, where the resource energy is that required to supply one unit of delivered energy, taking account

of the resource energy required for extraction, processing, storage, transport, generation, transformation, transmission, distribution, and any other operations necessary for delivery to the building in which the delivered energy will be used.

E.3 Symbols, Units and Subscripts

Symbol	Quantity	Unit
A	area	m^2
E	Energy in general (including primary energy, all energy carriers, energywares and energy needs, except heat and work,)	kg, m^3 , Wh, J, ^{b)}
I	Irradiation	J/ m^2 , kWh/ m^2
f	Primary energy or policy factor	-
H_L	heat transfer coefficient	W/K
K	CO ₂ emission coefficient	kg/J; g/kWh
m	mass (e.g. quantity of CO ₂ -emissions)	kg
O	occupancy	persons
Q	quantity of heat	J, Wh ^{a)}
t	time, period of time	s ^{a)}
V	volume	m^3
η	efficiency, utilisation factor	-
θ	Celsius temperature	°C

Table 1. Symbols and Units

Appendix F

F.1 Description of Java Files

This appendix presents a description of the java files including the functions used in the application.

F.1.1 MyDBConnection.java file

This java file includes the following functions:

- *int initre()*: reads the settings which are included in the properties file and it is responsible for the connection to the database. If the connection is successful then the function returns 1.
- *Connection getMyConnection()*: returns a parameter which indicates the connection to the database.
- *void destroy()*: terminates the connection with the database system.

F.1.2 Pfileoperations.java file

This java file is responsible for processing the properties file. The functions included in this file are:

- *String [] ReturnDatabase()*: reads properties file and stores 4 properties in a string array.
- *void SetDatabase(String [] drivers)*: writes three of the four properties in the property file and uses data coming from the string drivers.

F.1.3 SimplifiedRatingMethod.java file

This file includes the following functions:

- *double round(double value, int decimalPlace)*: reads decimal numbers and returns a number with decimal digits which is defined by the value of decimalPlace parameter.
- *String findBuildingCategory(String bcateg, String insulation, String prd, double energy)*: is responsible for the class definition of a building using climatic conditions methodology. It takes into account some parameters such as the building's category, if the building has or has not insulation and the period of interest. Energy parameter keeps the value of the normalized energy consumption for the specific building. This value is used for the classification.
- *void getAllAppropriateData(int build_id)*: returns all the proper data used for the calculation of the normalized energy consumption and the classification.
- *void FillFieldsandArea()*: presents all the results into a text field.

F.1.4 CalculateLoads.java file

This file includes the following functions:

- *ResultSet getallenvelope()*: returns all the records of table Envelope and stores them in a ResultSet parameter.
- *void SaveEquipTable()*: stores the appliances of a building into the corresponding table.

F.1.5 EnergyYear.java file

This file includes the following functions:

- *int ValidateYear(String d)*: checks if the format of the date is valid.
- *int YearExists(String y)*: when a new year is going to be inserted for a specific building then the function checks if the building has been evaluated before, for the same year.
- *String [] ReturnRR(int bid)*: returns the values for R_r parameter for heating and cooling for a specific building.
- *int ReturnYears()*: checks if there are data for three or less than three years. This function is very important because it defines the method of classification that must be used.

F.1.6 EnergyRating.java file

This file includes the following functions:

- *int IsHeatDouble()*: checks if the electrical, oil and gas bills for the heating period are in double format. If they are empty then they can be considered as zero.
- *int IsHeatEmpty()*: checks if the fields of electricity, oil and gas for heating are empty.
- *int IsHeatConEmpty()*: checks if the calculations of heating consumption have been realized.
- *void CalculateHeat()*: calculates energy consumption for the heating period.
- *int IsCoolDouble()*: checks if the bills for the cooling period are in double format. If they are empty then they are equal to zero.
- *int IsCoolEmpty()*: checks if the fields of electricity, oil and gas for cooling are empty.
- *void CalculateCool()*: calculates energy consumption for the cooling period.
- *int IsCoolConEmpty()*: checks if the calculations of cooling consumption have been realized.
- *void LightingConsumptionPerMonth(String month, String consumption)*:

calculates the lighting consumption per month for a whole year.

- *int ValidateAppliancesQuantityHoursCell()*: checks if hour and quantity fields of appliances' table are integer numbers. Otherwise, it informs about the false.
- *void FillEverything()*: loads all the saved information into the corresponding forms and fields.

F.1.7 EnergyResults.java file

The functions included in this file are presented below:

- *JFreeChart ReturnenergyChart(int zonenum)*: returns the energy chart for the specific zone for the heating period.
- *JFreeChart ReturnenergyChartCooling(int zonenum)*: returns the cooling energy chart for the specific zone.

F.1.8 EnergyGradingResults.java file

This file includes the following functions:

- *void EnergyGrading()*: checks if there are proper data for the classification and the method chosen.
- *void EPclass(int bid)*: calculates the Energy Performance Indicator for heating and cooling for the specific building according to the selected method (measured method, including or not including weather correction).
- *String EPClassification(double ep, double rr, double rs)*: defines the class of a building by the comparison of the EP indicator to the R_s and R_r parameters.
- *Double ReturnRS(int ins, String type, int heatcool)*: returns the value of R_s parameter according to the type of building, the presence or absence of insulation material and the period of study.
- *void ReturnDDFromFile(String file)*: calculates the average daily value of

outdoor temperature.

- *int ReturnBuildingMethod(int bid)*: returns the method used for the classification.
- *int SearchForData(int bid,int method)*: returns 1 if the proper data for evaluation exist.
- *JRDataSource createReportDataSource()*: creates the format of the report.

The following table presents .java files used for general operations in order for the classification to be achieved.

<i>java files</i>	<i>Description</i>
<i>NewUser</i>	adds a new user to the system
<i>DatabaseSettings</i>	database settings such as name, username and password can be defined
<i>Locations</i>	adds, changes or deletes a location from the system
<i>Appliances</i>	adds, removes or updates an appliance for a building
<i>Login</i>	allows a user to enter to the main menu of the system
<i>MainFrame</i>	is the main menu of the system
<i>Buildings</i>	adds, removes or updates information about a specific building
<i>Zones</i>	adds, removes or updates information about a specific zone

Table 1. Basic java files including a short explanation about their functionality

Appendix G

G.1 Relational Scheme and Tables

This appendix presents the tables, including their attributes, deriving from the relational database analysis. The database system's tables are presented by the following tables.

Zones		
zid	PK	Integer
zDescription	-	String
zFrom	-	String
zTo	-	String
zCO2	-	File
zMRT	-	File
zHum	-	File
zLux	-	File
zTemp	-	File
bid	FK	Integer

Buildings		
bid	PK	Integer
bDescription	-	String
bSurface	-	Double
bFloors	-	Integer
bAddress	-	String
bInsulation	-	Integer
bAC	-	Integer
bNB	-	Integer
bTout	-	File
lid	FK	Integer

ApplBuildings		
aid	FK	Integer
bid	FK	Integer

BApplBuildings		
baid	FK	Integer
bid	FK	Integer

LightBuildings		
light_id	FK	Integer
bid	FK	Integer

SimplifiedRatingMethod		
sbid	PK	Integer
sMethod	-	String
sAnnualH	-	Double
sSunH	-	Double
sMSunH	-	Double
sAnnualC	-	Double
sSunC	-	Double
sMSunC	-	Double
sNormQH	-	Double
sNormQC	-	Double
sCategoryH	-	String
sCategoryC	-	String
bid	FK	Integer

DetailedRatingMethod		
dbid	PK	Integer
dEnergyYear	PK	String
dApplMethod	-	String
dLightMethod	-	String
dLightCons	-	Double
dLightYear	-	String
dLightDay	-	String
dLightFile	-	File
dSepBill...dFebBill	-	Double
dMarBill...dAugBill	-	Double
dSepOil...dFebOil	-	Double
dSepGas...dFebGas	-	Double
dSepElCon...dFebElCon	-	Double
dMarElCon...dAugElCon	-	Double
dSepOilCon...dFebOilCon	-	Double
dSepGasCon...dFebGasCon	-	Double
dOilFurnace	-	String
dGasFurnace	-	String
dOutFile	-	File

Where PK and FK labels are referred to the primary and foreign keys respectively.