A Thesis submitted for the degree of Master of Philosophy

"Energy Performance Regulations and Methodologies of Energy Saving in Office Buildings in Southern Europe"

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Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published work of others has been acknowledged in the text and a list of references is given.

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Signature Date

Dedicated to my parents

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Abstract

The Directive 2002/91/EC of the European Parliament and Council on energy performance of buildings entered into force on 4th January 2003, setting the minimum requirements of energy performance. All Member States had to incorporate the requirements of the new directive in national legislation by January 2006 and build up relevant systems and measures to transpose and implement these requirements.

The stage of Directive's implementation in the countries of Southern Europe is reported because of the similar climatic conditions and the geographical location for a future enforcement in Greece, as the building code in Greece is still under development.

As energy use in buildings accounts for about 40% of the final energy demand in the European Union, the application of building standards can achieve a reduction in electric energy consumption and therefore an increase in energy performance of buildings.

A record of the electric energy consumption of office buildings in the four Prefectures of Crete is implemented aiming at a future energy saving, which may be obtained by either through increased efficiency or by reducing electric energy consumption.

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Chapter 1

Introduction

1.1 Overview

Under the Kyoto protocol, the European Union has committed itself to reduce the emissions of greenhouse gases (GHGs) by 8 % in the period 2008 to 2012 compared to the level in the year 1990, [1]. The emission of carbon dioxide (CO_2), the prevailing greenhouse gas, is for the larger part linked to the combustion of fossil energy carriers.

In particular, energy use in buildings accounts for about 40% of the final energy demand in the European Union (EU) and is responsible for more than 30% of the CO_2 emissions, [1, 2]. It is obvious that increases in energy efficiency will contribute considerably to the achievement of the GHGs emissions reduction goals.

In recent years numerous efforts have been undertaken at national level to improve the energy efficiency of buildings. In particular building codes have been tightened gradually in most countries within the last three decades. However, until recently, only few initiatives were taken to establish Europe wide harmonised regulations for buildings.

This situation is substantially changing due to the new Energy Performance of Buildings Directive (2002/91/EC). This directive requires Member States to develop calculation procedures according to a number of requirements and to set minimum standards for the energy performance.

The Directive 2002/91/EC of the European Parliament and Council on energy efficiency of buildings was adopted, after a lively discussion at all levels and with overwhelming support from Member States and the European Parliament, on 16th December 2002 and entered into force on 4th January 2003, [1,2].

The Directive is set to promote the improvement of energy performance of buildings with four requirements to be implemented by the Member States:

- General framework for a methodology of calculation of the integrated performance of buildings.
- Setting of minimum standards in new and existing buildings.
- Energy certification of buildings.
- Inspection and assessment of heating and cooling installations.

The European Union, under the Kyoto Protocol and forthcoming commitments, has proposed an amount of Community Directives for reducing energy consumption in the building sector and hence carbon dioxide emissions.

More precisely, the EU Directive 2002/91 on the Energy Performance of Buildings (EPBD) creates a common framework, where each individual member state has to set the actual performance requirements in the national building regulations in order to promote the improvement of the energy performance of buildings across the EU.

However, various estimates project a cost-effective savings potential realisable by 2010 of around 22% within the building sector and therefore around 20% of the EU Kyoto commitment could be met. Transposition of this Directive in Member States Law will allow a portion of this potential to be translated into reduced energy consumption, [2].

The demands for lighting, heating and cooling, and hot water in building sector consume more energy than either transport or industry. The easiest way to minimize energy consumption is to reduce these needs; however the comfort of occupants and the quality of indoor air must be balanced with energy savings.

It is common in Europe today that when a country is considering a new regulation, it considers the requirement levels of other countries, enhanced by public authorities' approaches. In many cases, only the general principle of the calculation procedures and reference CEN standards are used.

1.2 Aim of the thesis

The aim of the thesis is the research on energy performance regulations and methodologies in buildings, regarding Directive 2002/91/EC, aiming at energy saving in office buildings of Crete island.

1.3 Objectives of the thesis

The objectives of the thesis are the research on energy performance regulations in Southern Europe, the record of offices' electric energy consumption in Crete island, in order to suggest techniques of energy saving by reduction in electric energy consumption as well as increase in energy efficiency and finally the classification of office buildings in Crete island, regarding their energy performance.

1.4 Contributions of the thesis

The current thesis provides a report of the stage of Directive's implementation in Cyprus, Greece, Italy, Portugal and Spain, a methodology for the determination of heating and cooling degree days, as well as an energy saving methodology in office buildings via TRNSYS simulation program.

Moreover, the record of electric energy consumption of offices in Crete island is reported. Meters of energy saving and techniques of increasing energy performance in office buildings are suggested and a classification of office buildings in Crete island regarding their energy performance by Matool, v.2 simulation program is implemented.

Chapter 2

Directive 2002/91/EK

2.1 Electric energy consumption by building sector

Energy consumption in buildings is considerably increasing as well as greenhouse gases (GHGs) in the atmosphere. Nowadays, building sector has outgrown industry in energy use with a significant contribution of households. Two thirds of energy used in European buildings is accounted for by households. Their consumption is growing every year as rising living standards are reflected in greater use of air conditioning and heating systems.

In particular, 10 million boilers in European homes are more than 20 years old, while their replacement would save 5 % of energy used for heating. Half of the projected increase in energy needed for air conditioning could be saved through higher standards for equipment. Moreover, offices, commercial buildings and leisure facilities could save 30-50 % of lighting energy by using the most efficient systems and technologies, [1].

In Europe, building sector is responsible for the 40% of final energy consumption and for the 30% of GHGs emissions in the atmosphere. Final energy consumption in households/services covers quantities consumed by private households, small-scale industry, crafts, commerce, administrative bodies, and services with the exception of transportation, agriculture and fishing.

The values of the electric energy consumption in European Union (EU) for ten years long (from 1996 to 2006) are reported in Table 2.1, [3].

In Table 2.2, the electric energy consumption by category of use in Greece and in particular in Crete including the four Prefectures is represented for the year 2006, [4].

Table 2.1: Consumption of electricity by households/services (GWh), [3]

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
EU (27 countries)	1.279.710	1.283.181	1.320.889	1.348.490	1.375.427	1.430.444	1.434.286	1.490.524	1.517.127	(p) 1.552.543	(p) 1.598.128
EU (25 countries)	1.250.000	1.257.877	1.294.303	1.321.681	1.348.161	1.401.631	1.408.240	1.461.712	1.490.377	(p) 1.523.551	(p) 1.566.348
EU (15 countries)	1.130.493	1.140.217	1.171.664	1.196.353	1.219.099	1.267.332	1.273.562	1.324.686	1.352.059	(p) 1.384.220	(p) 1.420.192
Belgium	34.101	34.144	35.196	35.471	36.231	37.451	38.058	38.212	38.734	39.085	40.789
Bulgaria	16.821	14.230	14.673	14.725	15.095	15.058	15.113	15.477	14.748	15.427	16.439
Czech Republic	29.619	28.808	27.727	27.141	28.102	28.825	28.112	29.644	29.275	29.965	31.200
Denmark	21.865	21.704	21.813	21.942	22.057	22.158	22.227	22.289	22.559	22.753	23.282
Germany	240.344	238.605	242.101	245.564	244.767	252.284	249.068	261.336	263.285	269.200	282.322
Estonia	2.816	2.830	3.092	2.843	3.047	3.236	3.292	3.445	3.658	3.759	4.058
Ireland	9.652	10.080	10.587	11.558	12.535	13.238	13.932	15.734	16.121	16.620	16.812
Greece	23.276	24.600	26.227	27.782	29.377	30.559	32.212	34.205	35.513	36.286	38.151
Spain	79.947	86.578	90.000	97.234	98.656	106.128	108.851	116.519	123.909	(p) 131.782	(p) 137.672
France	220.337	216.608	224.062	230.813	238.566	249.430	248.157	262.353	271.030	275.333	278.711
Italy	113.479	116.550	119.838	119.297	122.614	125.971	130.677	137.604	141.732	146.199	151.231
Cyprus	1.859	1.966	2.170	2.320	2.528	2.635	2.885	3.100	3.181	3.383	3.572
Latvia	2.574	2.482	2.864	2.882	2.892	2.865	3.212	3.460	3.631	3.881	4.219
Lithuania	3.727	3.870	4.052	4.061	3.827	4.010	4.095	4.459	4.814	5.041	5.408
Luxembourg	1.821	1.892	1.918	1.723	1.767	1.839	1.875	1.933	2.081	2.084	2.159
Hungary	19.162	18.990	19.744	19.440	19.627	20.078	20.214	20.766	21.228	21.969	22.645
Malta	829	907	951	991	1.063	1.086	1.147	1.261	1.248	1.186	1.322
Netherlands	47.302	49.260	51.736	53.090	55.708	57.214	57.114	58.234	60.108	61.348	62.863
Austria	26.279	26.479	26.763	28.109	27.250	28.044	27.941	29.290	28.657	29.057	29.892
Poland	42.376	41.228	46.571	48.251	51.945	53.557	53.010	53.602	53.087	53.531	57.020
Portugal	16.341	17.670	18.906	20.661	22.059	23.418	24.592	25.909	27.118	28.678	29.616
Romania	12.889	11.074	11.913	12.084	12.171	13.755	10.933	13.335	12.002	13.565	15.341
Slovenia	4.551	4.802	4.901	5.080	4.727	5.002	5.690	5.280	5.601	5.372	5.527
Slovakia	11.994	11.777	10.567	12.319	11.304	13.005	13.021	12.009	12.595	11.244	11.185
Finland	29.879	30.389	31.518	32.160	32.234	34.347	35.419	35.922	36.387	37.026	38.158
Sweden	70.768	68.910	69.274	67.593	68.593	72.693	71.139	70.498	70.178	70.999	70.579
United Kingdom	195.102	196.748	201.725	203.356	206.685	212.558	212.300	214.648	214.647	217.770	217.955
Croatia	7.391	7.793	7.805	8.433	8.488	8.610	9.272	9.241	9.853	10.582	11.043
Turkey	32.566	38.189	41.235	44.299	49.019	49.657	51.894	55.954	60.845	67.220	74.253
Iceland	1.323	1.357	1.510	1.585	1.671	1.693	1.697	1.674	1.843	1.910	2.007
Norway	56.663	56.288	57.212	58.096	56.425	60.974	59.912	53.731	55.162	57.242	56.892
Switzerland	30.552	30.162	30.495	32.506	31.654	32.898	32.915	33.847	34.590	35.450	-

(-) ‘Not applicable’ or ‘Real zero’ or ‘Zero by default’

(p) Provisional value

Table 2.2: Electric energy consumption by category of use in the year 2006 (GWh), [4]

	Total	Domestic	Commercial	Industrial	Agricultural	Public & Municipal Authorities	Street Lighting
Greece	53033,64	17669,19	14758,30	15191,59	2629,28	1989,53	795,76
Crete	2578,78	856,87	1043,11	231,08	201,83	203,74	42,15
P. Iraklio	1248,54	412,02	506,27	133,44	86,83	94,88	15,11
P. Chania	654,04	230,94	266,19	44,76	41,44	58,80	11,91
P. Lassithi	354,51	113,22	140,08	12,42	56,53	22,39	9,88
P. Rethymno	321,69	100,69	130,58	40,45	17,04	27,67	5,26

2.2 Directive 2002/91/EC on Energy Performance of Buildings

The objective of this Directive (article 1) is to promote the improvement of the energy performance of buildings within the Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness, [5]. This Directive lays down requirements regarding the following:

- The general framework for a methodology of calculation of the integrated energy performance of buildings,
- The application of minimum requirements on the energy performance of new buildings,
- The application of minimum requirements on the energy performance of large existing buildings that are subject to major renovation,
- Energy certification of buildings,
- Regular inspection of boilers and air-conditioning systems in buildings and in addition, an assessment of the heating installation in which the boilers are more than 15 years old.

In article 2 of the directive the definitions of building, energy performance of building, energy performance certification of a building, combined heat and power (CHP), air-conditioning system, boiler, effective rated output (expressed in kW), heat pump are given.

Article 3

Adoption of a methodology

According to article 3 of the directive, Member States shall apply a methodology, at national or regional level, of calculation of the energy performance of buildings on the basis of the general framework set out in the Annex, taking into account standards or norms applied in Member State legislation. This methodology shall be set at national or regional level. The energy performance of a building shall be expressed in a transparent manner and may include a CO_2 emission indicator.

Article 4

Setting of energy performance requirements

Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings are set, based on the methodology referred to in Article 3. When setting requirements, Member States may differentiate between new and existing buildings and different categories of buildings.

These requirements shall take account of general indoor climate conditions, in order to avoid possible negative effects such as inadequate ventilation, as well as local conditions and the designated function and the age of the building. These requirements shall be reviewed at regular intervals which should not be longer than five years and, if necessary, updated in order to reflect the technical progress in the building sector.

Member States may decide not to set or apply the above mentioned requirements for the following categories of buildings:

- buildings and monuments officially protected as part of a designated environment or because of their special architectural or historic merit, where compliance with the requirements would unacceptably alter their character or appearance,
- buildings used as places of worship and for religious activities,
- temporary buildings with a planned time of use of two years or less, industrial sites, workshops and non-residential agricultural buildings with low energy demand and non-residential agricultural buildings which are in use by a sector covered by a national sectoral agreement on energy performance,
- residential buildings which are intended to be used less than four months of the year,
- stand-alone buildings with a total useful floor area of less than 50 m^2.

Article 5

New buildings

Member States shall take the necessary measures to ensure that new buildings meet the minimum energy performance requirements referred to in Article 4. For new buildings with a total useful floor area over 1000 m^2, Member States shall ensure that the technical, environmental and economic feasibility of alternative systems such as:

- decentralised energy supply systems based on renewable energy,
- CHP,
- district or block heating or cooling, if available,
- heat pumps, under certain conditions,

is considered and is taken into account before construction starts.

Article 6

Existing buildings

Member States shall take the necessary measures to ensure that when buildings with a total useful floor area over 1000 m^2 undergo major renovation, their energy performance is upgraded in order to meet minimum requirements in so far as this is technically, functionally and economically feasible.

Member States shall derive these minimum energy performance requirements on the basis of the energy performance requirements set for buildings in accordance with Article 4. The requirements may be set either for the renovated building as a whole or for the renovated systems or components when these are part of a renovation to be carried out within a limited time period, with the abovementioned objective of improving the overall energy performance of the building.

Article 7

Energy performance certificate

Member States shall ensure that, when buildings are constructed, sold or rented out, an energy performance certificate is made available to the owner or by the owner to the prospective buyer or tenant, as the case might be. The validity of the certificate shall not exceed 10 years.

Certification for apartments or units designed for separate use in blocks may be based:

- on a common certification of the whole building for blocks with a common heating system, or
- on the assessment of another representative apartment in the same block.

The energy performance certificate for buildings shall include reference values such as current legal standards and benchmarks in order to make it possible for consumers to compare and assess the energy performance of the building. The certificate shall be accompanied by recommendations for the cost-effective improvement of the energy performance.

The objective of the certificates shall be limited to the provision of information and any effects of these certificates in terms of legal proceedings or otherwise shall be decided in accordance with national rules.

Moreover, Member States shall take measures to ensure that for buildings with a total useful floor area over 1000 m^2 occupied by public authorities and by institutions providing public services to a large number of persons an energy certificate, not older than 10 years, is placed in a prominent place clearly visible to the public. The range of recommended and current indoor temperatures and, when appropriate, other relevant climatic factors may also be clearly displayed.

Article 8

Inspection of boilers

With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of boilers fired by non-renewable liquid or solid fuel of an effective rated output of 20 kW to 100 kW. Such inspection may also be applied to boilers using other fuels.

Boilers of an effective rated output of more than 100 kW shall be inspected at least every two years. For gas boilers, this period may be extended to four years.

For heating installations with boilers of an effective rated output of more than 20 kW which are older than 15 years, Member States shall lay down the necessary measures to establish a one-off inspection of the whole heating installation.

On the basis of this inspection, which shall include an assessment of the boiler efficiency and the boiler sizing compared to the heating requirements of the building, the experts shall provide advice to the users on the replacement of the boilers, other modifications to the heating system and on alternative solutions which may include inspections to assess the efficiency and appropriate size of the boiler. Member States that choose this option shall submit a report on the equivalence of their approach to the Commission every two years.

Article 9

Inspection of air-conditioning systems

With regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of air-conditioning systems of an effective rated output of more than 12 kW.

This inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building. Appropriate advice shall be provided to the users on possible improvement or replacement of the air-conditioning system and on alternative solutions.

Article 10

Independent experts

Member States shall ensure that the certification of buildings, the drafting of the accompanying recommendations and the inspection of boilers and air-conditioning systems are carried out in an independent manner by qualified and/or accredited experts, whether operating as sole traders or employed by public or private enterprise bodies.

Every Member State must have brought the laws, regulations and administrative provisions necessary to comply with this directive into force by 4 January 2006 at the latest.

However, if Member States believe that there are insufficient qualified or accredited experts anywhere within the European Union to implement fully the provisions of Article 7, 8 and 9, they may delay these Articles for up to three further years. If they wish to cause this delay, governments must justify this to the Commission together with a schedule detailing when they do plan to fully implement the directive, [5, 6].

2.3 Parameters of energy performance calculation

As mentioned above, in Article 3 of the Directive 2002/91/EC the calculation of the energy performance of buildings on the basis of a general framework is defined in the Annex of the Directive, [5].

The methodology of calculation of energy performances of buildings shall include at least the following aspects:

a) Thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness.

b) Heating installation and hot water supply, including their insulation characteristics.

c) Air-conditioning installation.

d) Ventilation.

e) Built-in lighting installation (mainly the non-residential sector).

f) Position and orientation of buildings, including outdoor climate.

g) Passive solar systems and solar protection.

h) Natural ventilation.

i) Indoor climatic conditions, including the designed indoor climate.

The positive influence of the following aspects shall, where relevant in this calculation, be taken into account:

a) Active solar systems and other heating and electricity systems based on renewable energy sources.

b) Electricity produced by CHP.

c) District or block heating and cooling systems.

d) Natural lighting.

For the purpose of this calculation buildings should be adequately classified into categories such as:

a) Single-family houses of different types.

b) Apartment blocks.

c) Offices.

d) Education buildings.

e) Hospitals.

f) Hotels and restaurants.

g) Sports facilities.

h) Wholesale and retail trade services buildings.

i) Other types of energy-consuming buildings.

The aim of the Member States is the enactment of methodologies of energy performance calculation that are going to contain and examine the parameters defined in the Annex. The general principles providing for a system of energy performance and its objectives should be established at Community level. But the detailed implementation should be left to Member States, thus allowing each Member State to choose the regime which corresponds best to its particular situation.

2.4 The European Committee for Standardization – CEN

CEN, the European Committee for Standardization, was founded in 1961 by the national standards bodies in the European Economic Community and European Free Trade Area (EFTA) countries.

CEN is contributing to the objectives of the European Union and European Economic Area with voluntary technical standards which promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programmes, and public procurement.

The principles that govern standards development at CEN are:

- Standards are developed through a consensus process.
- Participants in standards development represent all interests concerned, contributing mainly through their national standards bodies.
- Draft standards are made public for consultation at large.
- The final, formal vote is binding on all members.

The European Standards (ENs) must be transposed into national standards and conflicting standards withdrawn.

On behalf of governments, the European Commission may request the European Standards organizations to develop standards in support of their policies by issuing formal “mandates”.

Some European Standards are drawn up to support this policy, adopted in 1985, which decided that:

- Legislative harmonization is limited to the “essential requirements”, these being obligatory and formulated in general terms.
- Writing of the detailed technical specifications necessary for the implementation of directives is entrusted to the European, voluntary standards organizations like CEN.
- The standards are not mandatory, but products manufactured according to such “harmonized” standards gives a “'presumption of conformity” to the essential legal requirements in the directives.
- Compliance results in the right of the product to bear the CE marking of conformity and market release throughout Europe.
- Dedicated web site.
- List of harmonized standards cited in the Official Journal of the European Union.

CEN produces a number of different standards publications. All European Standards (EN) and drafts (prEN), as well as any other approved document (Technical Specifications (CEN TS), Technical Reports (CEN TR) and CEN Workshop Agreements (CWA), can be obtained from any of our National Members.

Aiming at the better and more efficient operation of CEN in connection to the enactment of energy performance standards, Technical Committees (TC) have been developed participating in the preparation of those standards. The activity’s field of CEN TC is represented in Table 2.3, [7, 8, Annex A].

Table 2.3: The activity's field of CEN TC, [7, 8]

Technical Commitees CEN	Activity's Field
TC 89	Thermal performance of buildings and building components
TC 156	Ventilation in buildings
TC 169	Light and lighting
TC 228	Heating systems in buildings
TC 247	Building automation, controls and building management

2.5 Methodology of energy performance calculation

The methodology for energy performance calculation that is followed during the procedure of CEN standards development is based on Directive 2002/91/EC. In the Annex of the Directive the parameters of energy performance calculation are formulated, which constitute either characteristics of the building or characteristics of the equipment. The methodology that is applied consists of the following stages:

- Calculation of heating, cooling and hot water energy demands and lighting and ventilation needs.
- Calculation of energy consumption of building
- Calculation of total energy performance indexes (primary energy, CO_2 emissions)

During the stage of heating and cooling demands calculation, the standards dealing with the calculation of energy consumption in buildings are used (group 3 - Annex A). During the calculation procedure only the characteristics of building are taken into account and not the characteristics of heating/cooling systems that are covered from EN ISO 13790 standard and from WI 14 "Calculation of energy use for space heating and cooling", respectively. Data concerning indoor environment, internal heat gains, and characteristics of the building are deduced from supporting standards of the Annex A.

During the stage of energy consumption, the characteristics of heating, cooling, hot water, lighting and automation systems of the buildings are taken into account. The standards used are those dealing with energy consumption in buildings (group 3 - Annex A). The energy that is used is reported individually according to the purpose and the type of fuel used. The auxiliary energy that is required for fans, pump systems etc. is included in calculation procedures.

In the end, the results of previous calculation are combined in order the total energy use to be yielded and energy performance indexes are associated with the supporting standards (group 5 - Annex A).

The abovementioned calculations as well as the stages of calculation are shown in Figure 2.1.

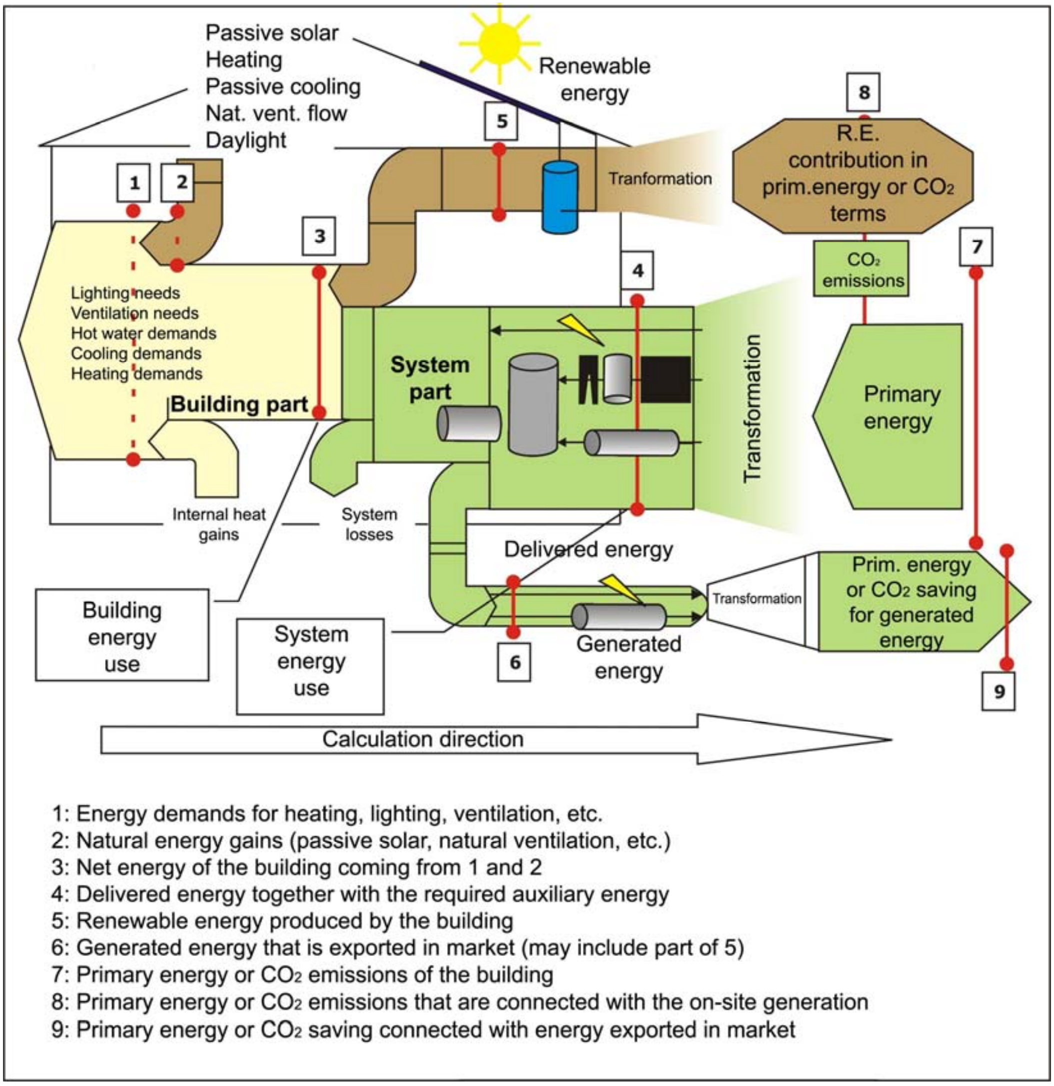

Figure 2.1: Methodology for calculating energy performance (Art.3 and Annex of Directive 2002/91/EC)

The CEN standards and the Work Items that are required to be composed for the energy performance of buildings are analytically represented in Annex A. They are classified in three main groups (General – Computational – Supporting standards), according to their activity field.

Moreover, the major Work Items for calculating the energy performance are presented in Table 2.4.

Table 2.4: Work Items for energy performance calculation

Number of Work Item	Content
14 (EN ISO 13790)	Net energy use for heating and cooling (taking account of losses and gains)
4	Delivered energy use for heating, cooling, ventilation systems, hot water and lighting, inclusive of system losses and auxiliary energy, and definition of energy rating
2	Primary energy and CO_2 emissions
1 + 3	Ways of expressing energy performance (for the energy certificate) and ways of expressing requirements (for regulations)
1 + 3	Content and format of energy performance certificate
5	Boiler inspections
6	Air-conditioning inspections

The assignment of Directive's articles with Work Items of CEN is appeared in Figure 2.2, [9, 10, 11].

In WI 1+3 "Energy performance of buildings - Methods of expressing energy performance and for energy certification of buildings" (group 1 – Annex A) the methodologies of expressing energy performance and their requirements are comprehended.

In WI 4 "Energy performance of buildings - Assessment of energy use and definition of ratings" (group 1 – Annex A) the procedure for each type of energy rating is defined. Energy rating is classified into the following categories, [12, 13]:

- Asset rating based on energy use under standard living conditions, used for buildings under construction and
- Operational rating based on data measurements and tracking performance data of energy consumption.

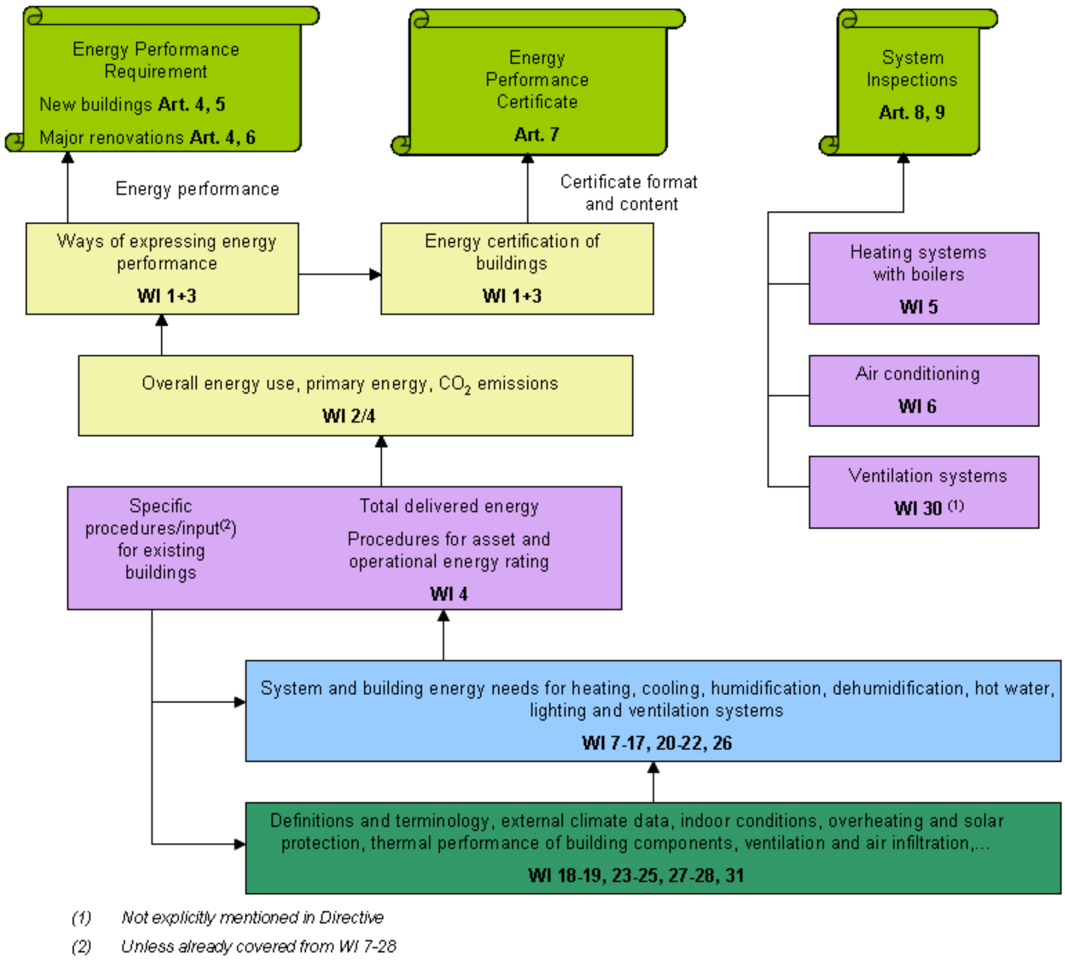

Figure 2.2: Methodology for calculating energy performance (Article 3 and Annex)

The calculation of heating and cooling energy demands are based on specific conditions of indoor environment that are based on WI 29 "Data requirements for standard economic evaluation procedures related to energy systems in buildings, including renewable energy sources" (group 5 – Annex A).

Although the application of the calculation procedure is not precisely defined, the criteria and terms that are formulated in WI 17 "Thermal performance of buildings - Calculation of energy use for space heating and cooling - General criteria and validation procedures" (group 4 – Annex A) must be satisfied.

In accordance with the Articles 8 and 9 of the Directive 2002/91/EC, the regular inspection of heating and air-conditioning systems is obligatory. The general principles and the framework for these inspections are defined in WI 5 "Energy performance of buildings - Inspection of boilers and heating systems" and in WI 6

"Energy performance of buildings - Guidelines for the inspection of air-conditioning systems" (group 2 – Annex A).

2.6 Energy rating calculation

According to prEN 15203 / 15315 of CEN/BT WG173, "Energy performance of buildings - Overall energy use, CO_2 emissions and definition of energy ratings", two principal types of energy ratings for buildings are proposed in this standard:

- The calculated energy rating,
- The measured energy rating.

The aggregation methods are based on:

- Primary energy,
- Production of carbon dioxide,
- A parameter defined by national energy policy.

Primary energy

Primary energy is calculated from the delivered and exported energy for each energy carrier:

$$\mathrm{E}_{prim} = \sum \left(E_{del,i} \, f_{prim,del,i} \right) - \sum \left(E_{ex,i} \, f_{prim,ex,i} \right) \qquad (2.1)$$

Where,

$E_{del,i}$: the delivered energy for energy carrier i,

$E_{ex,i}$: the exported energy for energy carrier i,

$f_{prim,del,i}$: the primary energy factor for the delivered energy carrier i,

$f_{prim,ex,i}$: the primary energy factor for the exported energy carrier i.

Carbon dioxide rating

The emitted mass of CO_2 is calculated from the delivered and exported energy for each energy carrier:

$$m_{co_2} = \sum\left(E_{del,i} K_{del,i}\right) - \sum\left(E_{ex,i} K_{ex,i}\right) \qquad (2.2)$$

$E_{del,i}$: the delivered energy for energy carrier i,

$E_{ex,i}$: the exported energy for energy carrier i,

$K_{del,i}$: the CO_2 emission coefficient for delivered energy carrier i,

$K_{ex,i}$: the CO_2 emission coefficient for the exported energy carrier i.

Policy energy rating

The policy energy rating is calculated from the delivered and exported energy for each energy carrier:

$$E_{pol} = \sum\left(E_{del,i} f_{pol,del,i}\right) - \sum\left(E_{ex,i} f_{pol,ex,i}\right) \qquad (2.3)$$

$E_{del,i}$: the delivered energy for energy carrier i,

$E_{ex,i}$: the exported energy for energy carrier i,

$f_{pol,del,i}$: the policy factor for energy carrier i,

$f_{pol,ex,i}$: the policy factor for exported energy.

2.7 Available building energy performance simulation programs

Wide variety of building energy simulation programs have been developed enhanced and are in use throughout the building energy community. A list of the main available energy performance simulation programs as well as a generic description is represented, [14].

2.7.1 BLAST, Building Loads Analysis and System Thermodynamics tool

The Building Loads Analysis and System Thermodynamics (BLAST) system predicts energy consumption and energy system performance and cost in buildings. BLAST contains three major subprograms: Space Loads Prediction, Air System Simulation, and Central Plant. Space Loads Prediction computes hourly space loads given hourly weather data and building construction and operation details using a radiant, convective, and conductive heat balance for all surfaces and a heat balance of the room air. This includes transmission loads, solar loads, internal heat gains, infiltration loads, and the temperature control strategy used to maintain the space temperature. Blast can be used to investigate the energy performance and cost of new or retrofit building design options of almost any type and size, [15].

2.7.2 BSim, Building Simulation

BSim is a user-friendly package of simulation programs that provides means for detailed, combined hygro-thermal simulations of buildings and constructions. The package comprises several modules: SimView (graphic editor), tsbi5 (building simulation), SimLight (daylight), XSun (direct sunlight and shadowing), SimPV (photovoltaic power), NatVent (natural ventilation) and SimDxf (import from CAD). BSim has been used extensively over the past 20 years, previously under the name tsbi3. Today BSim is the most commonly used tool in Denmark, and with increasing interest abroad, for energy design of buildings and for moisture analysis, [16].

2.7.3 DeST, Designer's Simulation Toolkits

DeST (Designer's Simulation Toolkits) allows detailed analysis of hourly building thermal processes, energy consumption and ratio of loads satisfied by the HVAC systems, and economic results based on the user description. DeST comprises a number of different modules for handling different functions: Medpha (weather data), VentPlus (natural ventilation), Bshadow (external shading), Lighting (lighting), and CABD (CAD interface).

BAS (Building Analysis & Simulation) performs hourly calculations for indoor air temperatures and heating/cooling loads for buildings, including complicated buildings of up to 1000 rooms. There are five versions in the DeST family: DeST-h (residences), DeST-c (commercial), DeST-e (building evaluation), DeST-r (building ratings) and DeST-s (solar buildings). DeST has been widely used in China, as it is available only in Chinese version for various prestige large structures such as the State Grand Theatre and the State Swimming Centre, [17].

2.7.4 DOE-2.2

The calculation program DOE-2.2 is an up-to-date, unbiased computer program that predicts the hourly energy use and energy cost of a building, given hourly weather information and a description of the building and its HVAC equipment and utility rate structure.

DOE-2.1E has one subprogram for translation of input (BDL Processor), and four simulation subprograms (LOADS, SYSTEMS, PLANT and ECON). LOADS, SYSTEMS and PLANT are executed in sequence, with the output of LOADS becoming the input of SYSTEMS, etc. The output then becomes the input to ECONOMICS. Each of the simulation subprograms also produces printed reports of the results of its calculations.

DOE-2.1E has been used extensively for more than 25 years for both building design studies, analysis of retrofit opportunities, and for developing and testing building energy standards in the U.S. and around the world. The private sector has adapted DOE-2.1E by creating more than 20 interfaces that make the program easier to use, [18].

2.7.5 ECOTECT

Ecotect is a highly visual architectural design and analysis tool that links a comprehensive 3D modeler with a wide range of performance analysis functions covering thermal, energy, lighting, shading, acoustics and cost aspects. The intent is to allow designers to take a holistic approach to the building design process, making it easy to create a truly low energy building. Whilst its modeling and analysis capabilities can handle geometry of any size and complexity, its main advantage is a focus on feedback at the earliest stages of the building design process.

In addition to standard graph and table-based reports, analysis results can be mapped over building surfaces or displayed directly within the spaces. This includes visualization of volumetric and spatial analysis results, including imported 3D CFD data. Real-time animation features are provided along with interactive acoustic and solar ray tracing that updates in real time with changes to building geometry and material properties, [19].

2.7.6 Ener-Win EC, Hourly Energy Simulation Program for Buildings

Ener-Win simulates hourly energy consumption in buildings, including annual and monthly energy consumption, peak demand charges, peak heating and cooling loads, solar heating fraction through glazing, daylighting contribution, and a life-cycle cost analysis. Design data, tabulated by zones, also show duct sizes and electric power requirements.

The Ener-Win software is composed of several modules - an interface module, a weather data retrieval module, a sketching module, and an energy simulation module. The interface module includes a rudimentary building sketching interface. Ener-Win requires only three basic inputs: the building type, the building's location, and the building's geometrical data, [20].

2.7.7 Energy Express

Energy Express is a design tool for estimating energy consumption and cost at the design stage. The user interface allows fast and accurate model creation and manipulation. Energy Express includes a dynamic multi-zone heat transfer model coupled to an integrated HVAC model so that zone temperatures are impacted by any HVAC shortcomings.

Energy Express for Architects provides graphic geometry input and editing, multiple report viewing, comparison of alternative designs and results, simplified HVAC model, and detailed online help.

Energy Express for Engineers provides those capabilities along with peak load estimating and detailed HVAC model, graphic editing of air handling system and thermal plant layouts.

Energy Express can be used for the analysis of alternative designs of new buildings and their mechanical and electrical systems, or in the assessment of retrofit options being considered for existing buildings, [21].

2.7.8 Energy-10

Energy-10 was designed to facilitate the analysis of buildings early in the design process with a focus on providing a comprehensive tool suited to the design team environment for smaller buildings. Rapid presentation of reference and low-energy cases is the hallmarks of Energy-10. Since Energy-10 evaluates one or two thermal zones, it is most suitable for smaller, 10000 ft^2 (1000 m^2) or less, simpler, commercial and residential buildings.

Energy-10 takes a baseline simulation and automatically applies a number of predefined strategies ranging from building envelope (insulation, glazing, shading, thermal mass, etc.) and system efficiency options (HVAC, lighting, daylighting, solar service hot water and integrated photovoltaic electricity generation). Full life-cycle costing is an integral part of the software, [22].

2.7.9 Energy Plus

Energy Plus is a modular, structured software tool based on the most popular features and capabilities of BLAST and DOE-2.1 E. It is a simulation engine with input and output of text files. Loads calculated (by a heat balance engine) at a user-specified time step (15-minute default) are passed to the building systems simulation module at the same time step.

The Energy Plus building systems simulation module, with a variable time step, calculates heating and cooling system and plant and electrical system response. This integrated solution provides more accurate space temperature prediction - crucial for system and plant sizing, occupant comfort and occupant health calculations. Integrated simulation also allows users to evaluate realistic system controls, moisture adsorption in building elements, radiant heating and cooling systems, and interzone air flow, [23].

2.7.10 eQUEST (the quick energy simulation tool)

eQUEST is a easy to use building energy use analysis tool which provides high quality results by combining a building creation wizard, an energy efficiency measure (EEM) wizard and a graphical results display module with an enhanced DOE-2.2-derived building energy use simulation program.

The building creation wizard walks a user through the process of creating a building model. With in eQUEST, DOE-2.2 performs an hourly simulation of the building based on walls, windows, glass, people, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices.

eQUEST allows users to create multiple simulations and view the alternative results in side-by-side graphics. It offers energy cost estimating, daylighting and lighting system control and automatic implementation of energy efficiency measures (by selecting preferred measures from a list), [24].

2.7.11 ESP-r

ESP is a general purpose, multi-domain-building thermal, inter-zone air flow, intra-zone air movement, HVAC systems and electrical power flow-simulation environment which has been under development for more than 25 years. It follows the pattern of “simulation follows description”, where additional technical domain solvers are invoked as the building and system description evolves. Users control the complexity of the geometric, environmental control and operations to match the requirements of particular projects. It supports an explicit energy balance in each zone and at each surface. ESP-r is distributed under a GPL license, [25].

2.7.12 HAP, Hourly Analysis Program

Hourly Analysis Program (HAP) provides two tools in one package: sizing commercial HVAC systems and simulating hourly building energy performance to derive annual energy use and energy costs. Input data and results from system design calculations can be used directly in energy studies.

HAP is designed for the practicing engineer, to facilitate the efficient day-to-day work of estimating loads, designing systems and evaluating energy performance. Tabular and graphical output reports provide both summaries of and detailed information about building, system and equipment performance.

HAP is suitable for a wide range of new design and retrofit applications. It provides extensive features for configuring and controlling air-side HVAC systems and terminal equipment, [26].

2.7.13 HEED, Home Efficient Energy Design

The objective of HEED is to combine a single-zone simulation engine with a user friendly interface. It is intended for use at the very beginning of the design process, when most of the decisions are made that ultimately impact the energy performance of envelope-dominated buildings.

HEED requires just four project inputs: floor area, number of stories, location (zip code), and building type. An expert system uses this information to design two base case buildings: scheme 1 meets California's Title 24 Energy Code, and a scheme 2which is 30% more energy efficient. HEED automatically manages up to 9 schemes for up to 25 different projects. HEED's strengths are ease of use, simplicity of input data, a wide array of graphic output displays, computational speed, and the ability to quickly compare multiple design alternatives, [27].

2.7.14 IDA, Indoor Climate and Energy (IDA ICE)

IDA Indoor Climate and Energy (IDA ICE) is based on a general simulation platform for modular systems, IDA Simulation Environment. Physical systems from several domains are in IDA described using symbolic equations, stated in either or both of the simulation languages Neutral Model Format (NMF) or Modelica. IDA ICE offers separated but integrated user interfaces to different user categories:

- Wizard interfaces lead the user through the steps of building a model for a specific type of study. The Internet browser based IDA Room wizard calculates heating and cooling load.
- Standard interface for users to formulate a simulation model using domain specific concepts and objects, such as zones, radiators and windows.
- Advanced level interface - where the user is able to browse and edit the mathematical model of the system.
- NMF and/or Modelica programming - for developers, [28].

2.7.15 IES <Virtual Environment>, (IES <VE>)

The IES <Virtual Environment> (IES <VE>) is an integrated suite of applications linked by a common user interface and a single integrated data model. <Virtual Environment> modules include:

- ModelIT – geometry creation and editing
- ApacheCalc – loads analysis
- ApacheSim – thermal
- MacroFlo – natural ventilation
- Apache HVAC – component based HVAC
- SunCast – shading visualization and analysis
- MicroFlo – 3D computational fluid dynamics
- FlucsPro/Radiance – lighting design
- DEFT – model optimization
- LifeCycle – life-cycle energy and cost analysis
- Simulex – building evacuation

The program provides an environment for the detailed evaluation of building and system designs, allowing them to be optimized with regard to comfort criteria and energy use, [29].

2.7.16 PowerDomus

PowerDomus is a whole-building simulation tool for analysis of both thermal comfort and energy use. It has been developed to model coupled heat and moisture transfer in buildings when subjected to any kind of climate conditions, i.e., considering both vapor diffusion and capillary migration. Its models predict temperature and moisture content profiles within multi-layer walls for any time step and temperature and relative humidity for each zone.

PowerDomus allows users to visualize the sun path and inter-buildings shading effects and provides reports with graphical results of zone temperature and relative humidity, PMV and PPD, thermal loads statistics, temperature and moisture content within user-selectable walls/roofs, surface vapor fluxes and daily-integrated moisture sorption/ desorption capacity, [30].

2.7.17 SUNREL

SUNREL is an hourly building energy simulation program that aids in the design of small energy efficient buildings where the loads are dominated by the dynamic interactions between the building's envelope, its environment, and its occupants.

SUNREL has a simplified multizone nodal airflow algorithm that can be used to calculate infiltration and natural ventilation. Windows can be modeled by one of two methods. Users can enter exact optical interactions of windows with identical layers of clear or tinted glass and no coatings on the layers. Thermal properties are modeled with a fixed U-value and fixed surface coefficients.

SUNREL only models idealized HVAC equipment. The equipment and loads calculations are solved simultaneously, and the equipment capacities can be set to unlimited. Fans move a schedulable fixed amount of air between zones or from outside, [31].

2.7.18 TAS

Tas is a suite of software products, which simulate the dynamic thermal performance of buildings and their systems. The main module is Tas Building Designer, which performs dynamic building simulation with integrated natural and forced airflow. It has a 3D graphics based geometry input that includes a CAD link. Tas Systems is a HVAC systems/controls simulator, which may be directly coupled with the building simulator. It performs automatic airflow and plant sizing and total energy demand. The third module, Tas Ambiens, is a robust and simple to use 2D CFD package which produces across section of micro climate variation in a space.

Tas combines dynamic thermal simulation of the building structure with natural ventilation calculations which include advanced control functions on aperture opening and the ability to simulate complex mixed mode systems. The software has heating and cooling plant sizing procedures, which include optimum start. Tas has 20 years of commercial use in the UK and around the world, [32].

2.7.19 TRACE 700

TRACE is divided into four distinct calculation phases: Design, System, Equipment and Economics. During the Design Phase the program first calculates building heat gains for conduction through building surfaces as well as heat gains from people, lights, and appliances and impact of ventilation and infiltration. Finally, the program sizes all coils and air handlers based on these maximum loads.

During the System Phase, the dynamic response of the building is simulated for an 8760-hour (or reduced) year by combining room load profiles with the characteristics of the selected airside system to predict the load imposed on the equipment.

The Equipment Phase uses the hourly coil loads from the System Phase to determine how the cooling, heating, and air moving equipment will consume energy.

The Economic Phase combines economic input supplied by the user with the energy usage from the Equipment Phase to calculate each alternative's utility cost, installed cost, maintenance cost and lifecycle cost, [33].

2.7.20 TRNSYS

TRNSYS is a transient system simulation program with a modular structure that was designed to solve complex energy system problems by breaking the problem down into a series of smaller components.

TRNSYS components (referred to as "Types") may be as simple as a pump or pipe, or as complicated as a multi-zone building model. The components are configured and assembled using a fully integrated visual interface known as the TRNSYS Simulation

Studio, and building input data is entered through a dedicated visual interface (TRNBuild). The simulation engine then solves the system of algebraic and differential equations that represent the whole system.

In building simulations, all HVAC-system components are solved simultaneously with the building envelope thermal balance and the air network at each time step. In addition to a detailed multizone building model, the TRNSYS library includes components for solar thermal and photovoltaic systems, low energy buildings and HVAC systems, renewable energy systems, cogeneration, fuel cells, etc.

The modular nature of TRNSYS facilitates the addition of new mathematical models to the program. In addition to the ability to develop new components in any programming language, the program allows to directly embed components implemented using other software (e.g. Matlab/Simulink, Excel/VBA, and EES). TRNSYS can also generate executables that allow non-expert to run parametric studies, [34].

Chapter 3

Building energy performance regulations in Southern Europe

3.1 Introduction

Building energy legislation is found in Directive 93/76/EEC on Limitation of the Carbon Dioxide Emissions through the Improvement of Energy Efficiency, in Directive 2002/91/EC on Energy Performance of buildings, in Directive 89/106/EEC on Construction Products, in Directive 92/42/EEC on Efficiency Requirements for new hot-water boilers fired with liquid or gaseous fuels, in Directive 2004/101/EC on a Scheme for Greenhouse Gas Emission Allowance Trading within the community in respect of the Kyoto Protocol's Project Mechanisms, in Directive 2004/8/EC on the Promotion of Cogeneration based on a useful heat demand in the internal energy market and amending Directive 93/42/EEC and in EU Green Paper, Towards an European Strategy for the Security of energy Supply.

Due to the lack of national building regulation regarding energy performance methodologies in Greece, Southern countries of Europe have been selected as index reference because of the similar climatic conditions and their geographical location for the implementation of energy performance calculations and energy rating procedures.

An analysis of the available energy performance procedures and methodologies through the stage of Directive's 2002/91/EC implementation in Southern Europe (Cyprus, Italy, Portugal and Spain), focusing on their future enforcement in Greece and more precisely on the island of Crete, as it represents an increased energy requirements site, is reported.

3.2 Mediterranean areas

Southern Europe's climate is that of the Mediterranean climate, which has become a typically known characteristic of the area, as most Southern European countries border the Mediterranean Sea. The area which is considered climatically Southern Europe is divided into the following countries or part of them:

- Albania
- Bosnia and Herzegovina (coasts)
- Croatia (coasts)
- Cyprus
- France (southeast coast, and the island of Corsica)
- Gibraltar
- Greece
- Italy (except the Po River plain and Alps region)
- Malta
- Monaco
- Montenegro
- Portugal (northeast and southern two-thirds)
- Serbia (south)
- Spain (southern half and eastern coast)

All regions with Mediterranean climates have relatively mild winters, but summer temperatures are variable depending on the region. Because all regions with a Mediterranean climate are near large bodies of water, temperatures are generally moderate with a comparatively small range of temperatures between the winter low and summer high (although the daily range of temperatures during the summer is large, except along the immediate coasts due to dry and clear conditions).

Temperatures during winter only occasionally reach freezing and snow only rarely occurs at sea level, but often in surrounding mountains due to wet conditions. In the summer, the temperatures range from mild to very warm, depending on distance from the Open Ocean, elevation, and latitude. Even in the warmest locations with a Mediterranean-type climate, however, temperatures usually don't reach the highest readings found in adjacent desert regions due to cooling from water bodies, although strong winds from inland desert regions can sometimes boost summer temperatures quickly resulting in a much increased forest fire risk, [35, 36].

3.3 Building code in Greece

In Greece, according to the President's Degree 362//4/7/79, the Building Thermal Insulation Regulation has been in use since 1981, setting the minimum requirements for thermal conductivity of the building envelope for different climatic zones.

In accordance to the General Building Regulation and the Common Ministerial Decision (OHJ 880/B/19-8-98), a new code was under development (Regulation on Rational Use and Energy Conservation in buildings) regarding the energy performance requirements of the Directive 2002/91/EC, [37].

Today, a new Law 3661/2008 (Measures for the reduction of energy consumption of the buildings) has been established in 19 May 2008. According to this Law, the Greek legislation is harmonized with Directive 2002/91 of the European Parliament & Council of 16th December 2002 "For the energy performance of buildings".

In accordance with the new Law in a time horizon of six months a regulation that is going to define the methodology of calculation of the energy performance of buildings will be approved.

In a recent Common Ministerial Decision (OHJ 1122/B/17-6-08) (Measures for the improvement of energy performance and energy saving in public sector) specifications and regulations for the control and maintenance of heating and cooling systems as well as specifications on indoor lighting and ventilation that must be applied in public buildings, are defined, [38].

More precisely, it is mandatory for public buildings (privately owned or rented) that are located in areas with an active natural gas main to submit an application for connection to the natural gas grid until 31/12/2008 .This obligation is also valid for every future extension of the existent natural gas main.

Moreover, appropriate equipment for the compensation of reactive load of buildings' electric consumptions in order to increase power coefficient (cos φ) at a level of at least 0.95 must be installed in every public building (privately owned or rented) until 31/12/2008.

A preventive maintenance of air-conditioning systems is going to be implemented at least once a year and the control table will be placed in a prominent place clearly visible to the public. The control concerns air-conditioning systems of offices, split or central and it is taken place in components that are inside or outside of the buildings (the cleaning of condenser, evaporator, fans, filters and the control of cooling system' leaks).

The classification of office buildings regarding the level of expectation is shown in Table 3.1, [38].

Table 3.1: Classification of office buildings, [38]

Category	Levels (explanation)
I	High level of expectation and is recommended for spaces occupied by very sensitive and fragile persons with special requirements like handicapped, sick, very young children and elderly persons.
II	Normal level of expectation and should be used for new buildings and renovations.
III	An acceptable, moderate level of expectation and may be used for existing buildings.
IV	Values outside the criteria for the above categories. This category should only be accepted for a limited part of the year .

Furthermore, the recommended indoor temperature for public buildings is defined at 27 ^{0}C for summer season and at 19 ^{0}C for winter season, respectively. The indoor temperatures for winter as well summer season concerning the type of building are represented in Table 3.2, [38].

Table 3.2: Indoor temperature of office buildings, [38]

Type of building/space	Category	Temperature for winter season (^{0}C)	Temperature for summer season (^{0}C)
Single office (cellular office) Sedentary activty 1,2 met	I	21	25
	II	20	26
	III	19	27
Landscaped office (open plan office) Sedentary activty 1,2 met	I	21	25
	II	20	26
	III	19	27
Conference room Sedentary activty 1,2 met	I	21	25
	II	20	26
	III	19	27
Auditorium Sedentary activty 1,2 met	I	21	25
	II	20	26
	III	19	27

The fresh air flow is indicated at 7 lt/sec/person and the ventilation rate at 0.4 lt/sec/m^2 as shown in Table 3.3.

Table 3.3: Ventilation rates in buildings, [38]

Category	Very low polluting building (lt/s,m2)	Low polluting building (lt/s,m2)	Non low polluting building (lt/s,m2)
I	0,5	1	2
II	0,35	0,7	1,4
III	0,3	0,4	0,8

The specifications are based on CEN Standard prEN15251. According to this standard, the total ventilation rate is given as following:

$$q_{tot} = n \cdot q_p + A \cdot q_B \tag{3.1}$$

Where

n: Number of persons

q_p: Ventilation rate for people (lt/sec/person)

A: Floor area (m^2)

q_B: Ventilation rate for building materials (lt/sec/m^2)

It is also mandatory in public sector the replacement of glow lamps or fluorescent lamps that are classified lower than category B of energy rating with fluorescent lamps of category A or B with choke coil and other specifications until 31/5/2009. Every new order before the appointed date is going to be effected in accordance to the new specifications. Furthermore, recommended levels of luminance are defined according to the type of building as represented in Table 3.4. These values are based on CEN Standard EN12464−1.

Table 3.4: Illumination levels for some buildings and spaces, [38]

Type of building	Space	Maintained luminance, Em (Lx)
Office buildings	Single offices	500
	Open plan offices	500
	Conference rooms	500
Educational buildings	Classrooms	300
	Classrooms for adult education	500
	Lecture hall	500
Hospitals	General ward lighting	100
	Simple examination	300
	Examination and treatment	1000
Hotels and restaurants	Restaurant, dining rooms	-
Sport facilities	Sports halls	300
Wholesale and retail premises	Sales area	300
	Till area	500
Circulation areas	Corridor	100
	Stairs	150

In case that in the existent buildings the level of lighting without day lighting differs more than 150 lux in accordance with the appointed, then the order of lamps must be changed.

For the further energy saving in public buildings, automation systems in corridors, circulation areas etc. are installed for the control of the operation (reduction of lightness or when lights are out) of lighting systems.

Moreover, the appliances that are going to be outfitted in public sector should read energy labeling and certificated indication of energy efficiency preparative to assure energy saving during operation. More precisely, air conditioners, refrigerators, freezer fridges and electric cookers will read at least energy labeling A, while visual display units, laptops, printers and telefax will read either certificated indication of energy efficiency "Energy Star" or will have to satisfy specifications of energy efficiency as district as those of "Energy Star".

Figure 3.1: Energy Star logo

In rented public buildings, when there is no concurrence of the owner for the total intervention of energy saving in the building, simple techniques and systems of energy saving at least are implemented. For instance, lime-cast placement with cold stains of high reflection to solar radiation in flat roof, the painting of exterior walls with cold colored or white stains, ceiling fans, night ventilation, free cooling during the intermediate periods of heating/cooling, systems of heat recuperation are recommended.

For every public building one at least qualified expert is designated, who can be qualified for more than one building and is chosen by the General Secretariat of the responsible Ministry or Region. Among the competences of the qualified expert is the data collection of electric energy, diesel, natural gas or other used fuel consumption, to keep energy consumption archives of every building, the composition of annual comprehensive energy record and control report, the record of energy elements in accordance with the building use which will include the association of energy consumptions with the function problems and the filing of comprehensive energy certification relative questionnaire.

It is also expected the transaction of temporal and economic planning of the necessary interferences for the improvement of energy performance as well as the composition of annual report that will be applied for evaluation in the Department of Renewable Energy and Energy Saving of Ministry of Development until the 31st March of every year. Moreover, they will check and inspect the right operation of central heating and cooling systems and will be responsible for their regular maintenance, [38].

3.4 Principle of Energy Performance Regulation

The principle of an Energy Performance (EP) regulation defines the regulation through the following formula:

$$EP \leq EP_{\max} \tag{3.2}$$

Where:

EP: an indicator which represents the calculated energy consumption or CO_2 emission of the building

EP_{max}: the maximum consumption or CO_2 emission not to be exceeded by the building

EP is calculated through a procedure which takes into account characteristics of the building and of its technical installations, defining the calculation procedure is a technical issue.

EP_{max} is defined in the regulation through a formula which can be simple or very complex, defining EP_{max} is an economical issue. EP_{max} shall take into account, at least, the size of the building, its shape and its use (school, house, office).

EP regulations differ from regulations, where requirements are specified for energy performance of individual components, and not on the overall energy performance of the building. In practice, global EP regulations and regulations dealing with components are not contradictory. Many countries have an EP regulation both for the building as well as specific requirements for components or systems, [39].

3.5 Stage of Directive’s 2002/91/EC implementation in Southern Europe

Information services for practitioners and consultants, experts in energy agencies, interest groups and national policy makers in the European Member States for helping the implementation of the European Energy Performance of Buildings Directive (EPBD) are provided by the EPBD Buildings Platform, a European Commission initiative in the framework of the Intelligent Energy - Europe (2003-2006) programme, [40].

Five countries of Southern Europe (Cyprus, Greece, Italy, Portugal and Spain) have been selected as index reference for the assessment of Directive’s 2002/91/EC implementation, because of their geographical position and common climatic conditions.

3.5.1 Cyprus

3.5.1.1 Legal context

The Ministry of Commerce, Industry & Tourism (MCIT) has the overall responsibility to ensure the implementation of the EPBD in Cyprus. Consequently, the MCIT is in close collaboration with the other governmental bodies involved (Ministry of Interior and Ministry of Communication and Works), as well as with private consulting firms, scientific institutions, engineering associations and land developers. All these organizations are represented by a joint Working Group, which was established to oversee the implementation of the EPBD in Cyprus.

For the transposition of the EPBD in Cyprus, three legal documents have been approved by the House of Representatives and published in the Government Official Gazette:

- The Law for the Regulation of the Energy Performance of Buildings of 2006, L.142 (I)/2006.

- The Amendment of the Law for the Regulation of Roads and Buildings, L.101 (I)/2006.
- The Roads and Buildings (Energy Performance of Buildings) Regulations, Κ.Δ.Π.429/2006.

For full implementation of all provisions of the EPBD the following secondary legislation documents need to be approved and published:

- The Energy Certification for Buildings Regulations of 2008.
- The Inspection and Maintenance of Boilers and Air-conditioning systems Regulations 2008.
- The Inspection and Maintenance of Boilers and Air-conditioning systems Ministerial order.

In planning the implementation of the EPBD the Working Group is guided by 2 sub-committees namely:

- Advisory Committee for the Methodology for Calculating the Energy Performance of Buildings and Setting the Minimum Requirements of Energy Performance of Buildings;
- Advisory Committee Overseeing the Implementation of the Directive.

The approval of the above legislation has been delayed, mostly due elections during 2006 and the resultant changes in the composition of the House of Representatives. However, the Government aims at full implementation of all provisions of the EPBD by 4/1/2009.

Members of the sub-committees are Governmental Departments or Services, Non Governmental Organizations (NGOs), the Technical Chamber, Associations and other parties involved in the building sector appointed by the Law for the Regulation of the Energy Performance of Buildings of 2006, L.142(I)/2006. Their duty is to advise the Minister of Commerce, Industry and Tourism for the preparation of the methodology for the calculation of the energy performance of buildings and its revisions, for the setting of the minimum requirements and their revisions and for the correct and proper implementation of the directive and its transposition to the national legislation.

Since the 21st of December, 2007 two ministerial orders regarding the methodology for the calculation of the energy performance of buildings and the minimum requirements for the energy performance of buildings have been published, enforcing part of the Law for the Regulation of the Energy Performance of Buildings of 2006, L.142(I)/2006.

As a first step, the minimum requirements set for the energy performance of buildings are restricted to the insulation of the envelope, and are shown in the table below.

Table 3.5: Minimum requirements for the energy performance of all new buildings and buildings exceeding 1000 m^2 of total useful floor area undergoing major renovation, [41]

Description	U-value (W/m^2K)	Comments
Horizontal structural elements of the shell.	<= 0.75	
Walls and structural elements of the shell.	<= 0.85	Not applied to passive systems
Windows	<= 3.8	Not applied to shop windows
Floor in contact with unheated spaces.	<= 2	

At this stage the above minimum requirements apply for all new buildings and buildings exceeding 1000 m^2 of total useful floor area undergoing major renovation regardless of their location.

3.5.1.2 Status of the implementation

The enactment of the legislation concerning the minimum energy requirements for all new buildings and existing buildings exceeding 1000 m^2 total useful floor area undergoing major renovation has been in force since the 21st of December 2007. Major renovations comprise those buildings where the total cost of the renovation related to the building shell and/or energy installations such us heating, hot water supply, air-conditioning, ventilation and lighting is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated, or those where more than 25% of the building shell undergoes renovation.

As a result of this enactment, the designer of a building, when submitting an application for a building permit, should submit to the local authorities a set of the energy performance calculations proving compliance with the minimum requirements published by the Minister.

For this purpose the MCIT has prepared a guidance document concerning the thermal insulation of buildings and developed a simple calculation tool for the calculation of the U values of the elements composing the building shell.

3.5.1.3 Calculation procedures

External technical assistance has been provided to the MCIT and a simple methodology and software has been developed for the calculation of energy performance of new residential buildings, based on the relevant EN standards. Furthermore, the MCIT is developing a new methodology and software that will perform the calculation of the energy performance for all types of buildings (new and existing, residential and non-residential). The methodology should be based on EN standards and comply with the requirements of the directive.

The MCIT has recently signed a contract with a local software company for the development of the methodology and user friendly software. According to the contract, the software should have been delivered to the Energy Service by the 13th of October 2008. The software will produce the certificate as well as the advisory report. It should also take into account within the calculation procedure any form of energy that the building will use (e.g. RES).

3.5.1.4 Certification of buildings

The proposed regulations regarding the energy performance certification of buildings have been drafted under the guidance of the Advisory Committee overseeing the implementation of the Directive and forwarded to the Attorney General office for legal vetting.

The energy performance certificate is intended to be issued by experts registered under the authority of the Energy Service for the purposes of building construction, sale or rent. Experts can be any Architect, Civil, Mechanical or Electrical engineer registered in the Technical Chamber of Cyprus who have 3 years experience in the related fields for residential buildings, and 6 years for non residential buildings and have a certificate for the successful completion of the training course related to the knowledge of the methodology, software and legislation. More details concerning the training scheme are not yet available.

The certificate should be produced by the software which the experts will use for calculating the energy performance of buildings and it should contain an advisory report with comments and suggestions for the improvement of the building's energy performance. The quality and validity of the issued certificate will be checked by the Energy Service. The cost of the certificate depends upon the type of building and will not be restricted by the law. The advisory report will be issued by the software based on a standard check of some of the results and there will be an option for the expert to add more comments and advice.

3.5.1.5 Inspection of boilers and air conditioning systems

The inspection and maintenance of boilers, central heating systems and air-conditioning systems are included in "The Law for the Regulation of the Energy Performance of Buildings of 2006, L.142(I)/2006" and will not become mandatory until the 4th of January 2009. At present the regulations concerning the above subjects are being prepared by the relevant sub-committee. On completion of the proposed regulations expected by the end of July 2008 they will be sent to the Attorney General's office for legal vetting, [41].

3.5.2 Greece

3.5.2.1 Legal context

The implementation of the EPBD in Greece is the responsibility of the Ministry of Development and the Ministry of Environment. The country has delayed in transposing the EPBD. At this stage the draft law has been prepared. The draft has been analyzed during a 3 day discussion of the appropriate Energy Committee of the Greek Parliament, where major consumer and technical advisory groups were consulted and the final text was agreed, [42].

The Law passed through the Parliament and has officially been incorporated in the Greek legal system since May 2008. The execution orders are the responsibility of the Ministries of Development and Environment, their formation has been assigned to CRES and they are expected to be published by Nov. of 2008.

3.5.2.2 Calculation procedures

Greece is in the process of setting the regulations for the EPBD (general design/inspection principles and minimum requirements for the building cell, lighting, boiler/heating system, air conditioning etc). The country is planning to form the calculation procedures (art. 3) in parallel to the regulations. It was foreseen that they will be adopted by the Government within 2007. There will be specific procedures for dwellings and for other buildings.

Software tools are expected to be developed by the market and verified by appropriate government bodies thereafter.

3.5.2.3 Requirements for new buildings

The Government of Greece is completing a study on minimum requirements for all new buildings. The task is being undertaken by the Ministry of Development with the help of the Regulatory Authority for Energy. The requirements will come into force for building permits requested after 1 January 2009.

The type and level of requirements are function of the type of building (dwellings, office buildings, schools etc) and may cover:

- Maximum U-value
- Requirement on average insulation level
- Maximum primary energy consumption per m^2 of floor area
- Boiler and air conditioner efficiencies

New buildings should produce an energy study for the building permit to be issued. The proof of compliance must be made after completion of the building. It is foreseen that control of the regulation is the responsibility of the Regional Authorities (the existing Building Permit Offices) where the building is located.

3.5.2.4 Requirements for existing buildings

The procedure followed for new buildings covers also existing buildings. The ongoing studies examine minimum requirements for new building components when building renovation is done and for extensions to existing buildings. The requirements will be formally adopted on 1 January 2009.

3.5.2.5 Certification of buildings

The requirements regarding the certification of buildings will be adopted by the Government 6 months after the Law has been passed by the parliament (i.e. end 2008). The general certificate model to be used will be the A-G label. There are considerations, however to allow for more categories above the B level (e.g. A+, A, A- etc.), to stimulate competition towards more efficient building design in the future. Certification, accompanied by a building permit, will be obligatory for new buildings after 1 January 2009. There is an ongoing debate as to whether the certificate will be obligatory for buildings to be rented or sold. The main argument against this requirement is the large number of inspectors needed in the early stages of implementation.

3.5.2.6 Evaluation of building shell

A study was undertaken to define the steps required for the evaluation and inspection of the building envelope. The study examined every stage starting from an inspection contract agreement to collection of data (suggesting a standardized questionnaire) and issuing and registering the certificate. The procedure was defined, in accordance with the EPBD and the existing Greek law of building insulation.

3.5.2.7 Inspection of boilers and air conditioning

The plan for Inspection of boilers has been prepared and is under review by the Ministries of Development and Environment, [43]. It will replace existing boiler inspection procedures undertaken by the Ministry of Environment.

A study was undertaken, utilizing the databases of Eurovent - Certification, to examine state of the art air-conditioning equipment in the European market. The study concluded that only A class small air-conditioners could be used, while for larger machinery A & B class would be acceptable.

Indicative graphs depicting the energy category of small and large air-conditioning equipment for thousands of machines currently available across the EU, used to define acceptable systems, are given below.

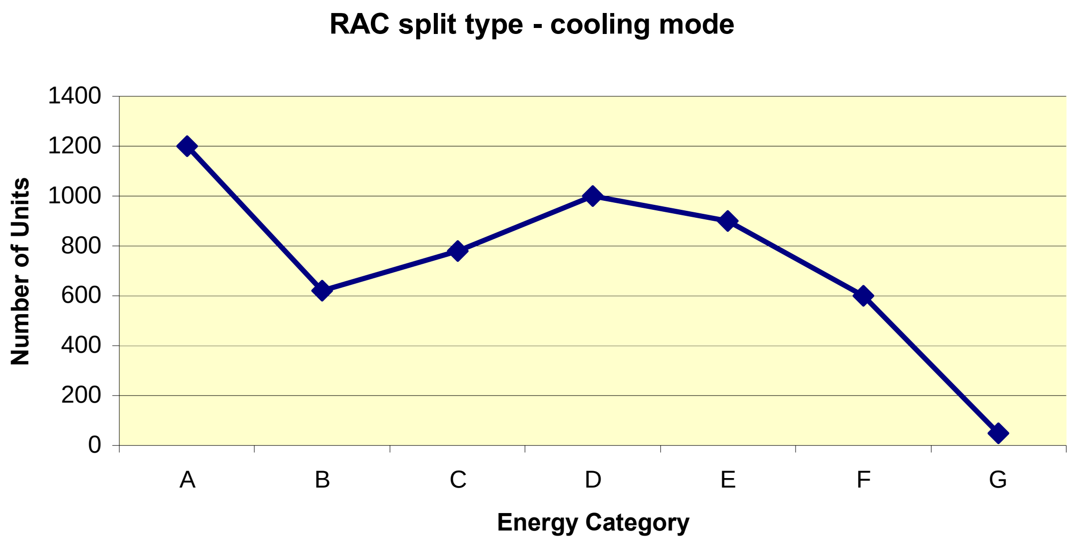

Figure 3.1: Energy category of small AC equipment, [44]

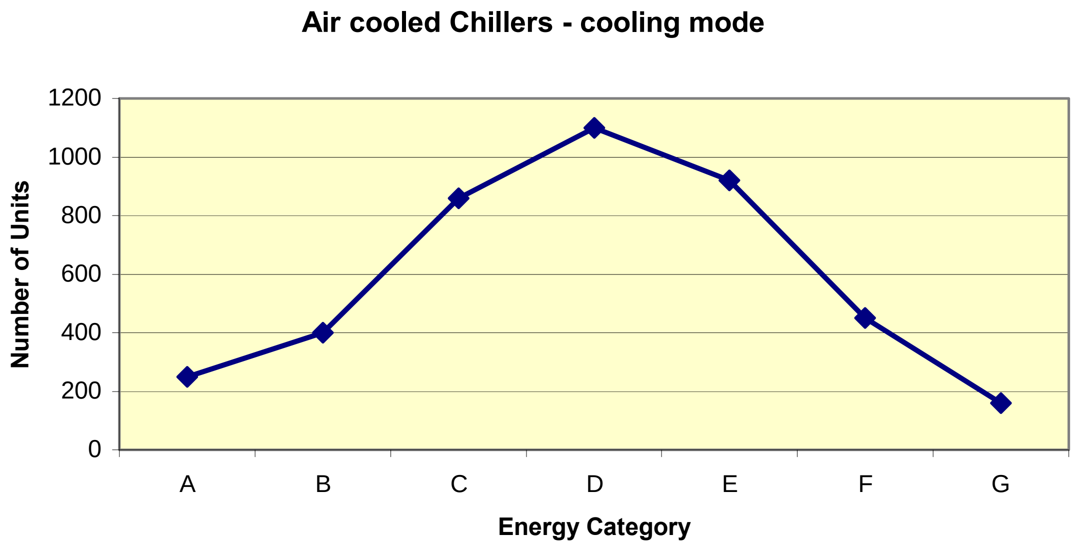

Figure 3.2: Energy category of large AC equipment, [44]

A general framework of evaluation of air conditioners has been produced. Significant attention will be paid on defining a standard methodology on the regular servicing of air-conditioning equipment. The Common Ministerial Decision (OHJ 1122/B/17-6-08, Measures for the improvement of energy performance and energy saving in public sector) sets minimum requirements on lighting fixtures available in the country, air-conditioning used in public buildings, as mentioned in section 2.2. It is in general more stringent than the EPBD and is prior to the full implementation of the EPBD, as it was signed in June 2008.

3.5.2.8 Energy design and inspection rates

The Technical Chamber of Greece has also financed a study which attempts to give a definition of the elements/steps necessary for the energy design of a building and the suggested (economic) rates for evaluators and inspectors. Such rates are in general within the range of 100-150 € for average buildings, boilers and air-conditioners and are increasing by m^2 or 100's kW for larger installations. For new buildings, the rates are expressed as a percentage (within 10-20%) of the architectural and mechanical engineering studies of energy consuming equipment, [44].

3.5.3 Italy

The implementation of the EPBD in Italy is the responsibility of the Ministry of Economic Development, in collaboration with the Ministry of Environment and the Ministry of Infrastructures. Before approval, the opinion of the Committee of Regions is compulsory, through the Conference State-Regions.

According to the modification of the Italian Constitution, Part V, the energy policy is partially delegated to the Regions and autonomous provinces, leaving the drafting of the general framework to the central government, while the regions have the final right to adapt it to their individual requirements. Some regions, in anticipation of the long delayed national guidelines, have developed their own procedures on minimum requirements and the certification of buildings. Three regions now have an official certification scheme already available.

Furthermore, some local authorities, municipalities especially, have introduced in their own Building Regulations compulsory criteria for energy certification.

3.5.3.1 Legal context

On 19 August 2005 the Council of Ministers approved a first Legislative Decree (D. Lgsl. n. 192/2005), representing a general framework for the transposition of all

EPBD articles in the national legislation, [45]. The only exception concerns art. 9 - inspection of air conditioners where three year delay was requested.

On 29 December 2006, the Council of Ministers has adopted a new Legislative Decree (D.Lgsl.n.311/2006) regarding modifications and extensions of the articles included in the previous D. Lgsl. 192/2005. The following implementation decrees are the responsibility of the Ministry of Economic Development.

The next stage has been the recent transposition of Directive 32/2006/EC on energy end-use efficiency and energy service, approved as Legislative Decree n.115 on the 30th of May, 2008 by the President of the Republic, and published in the Official Gazette n. 154 of the 3rd of July, 2008, where Annex III stipulates the updated methods of calculation and the requisites of assessors for building energy certification, [47].

The expected national guidelines on energy certification, together with the corresponding Decree of the President of the Republic (DPR) on the calculation methodologies and the minimum requirements for cooling systems, will complete the transposition, after the necessary consensus of the co-ordination table between the State and the Regions.

At the time of printing, these documents had already obtained the agreement of the Regions and only some formal parameters are missing from the publication. This legislation represents a general framework, within which the regions, based on their specific features, can define their policies for improved energy efficiency.

3.5.3.2 Calculation procedures

Calculation procedures have been adopted by the same Lgsl. D. n.311/2006, article 4, and listed in Annex M, based on the existing national standards. Several CEN documents have been adopted in 2008 as Italian standards, primarily concerning the various methodologies for building heating performance calculation and heating system efficiency. Annex III of the D. Lgsl. 115/2008 adopted a recently published series of technical specifications, UNI TS 11300, which contain details for the use of the previous standards, simplified calculations, simplified input sets for existing buildings, criteria for treating standard cases etc. All the technical standards are available from the Italian Standard Organization UNI, [48].

A simplified reference calculation tool, named DOCET, was developed by the ENEA, together with ITC-CNR, being a reference energy performance calculation method for existing residential buildings, [49]. The Italian Thermo-technical Committee (CTI), in charge of technical standards for the HVAC sector, has to produce a national reference tool, based on the UNI TS 11300 series.

All commercial software tools which will be made available on the market, must comply with the CTI reference tool, keeping the difference in energy performance result to less than 5%, and the validation has to be approved by CTI or UNI.

3.5.3.3 Requirements for new buildings

On 29 December 2006, the Government of Italy revised the minimum requirements for all new buildings. The Energy Performance (EP) requirements are implemented in three stages, corresponding to buildings, whose permit requests are required respectively after 1st January 2006, 1st January 2008 and 1st January 2010.

The type and level of EP requirements for heating differ according to the function of the building: residential (except community buildings), which expresses the EP in kWh/m^2, and the non-residential, which expresses the EP in kWh/m^3. All EP values are expressed as a function of the climatic zone, identified by the number of heating degree days (DD), and of the shape factor, represented by the ratio S/V, i.e. (envelope surface)/(building volume). Italy is divided into six climatic zones according to the DD. The EP limit values for residential and non-residential buildings are represented in Table 3.6 and 3.7, correspondingly.

Table 3.6: Energy Performance (EP) limits for residential buildings expressed in kWh/m^2 starting 1st January 2010, [56]

Building form factor S/V	Climatic Zones									
	A	B		C		D		E		F
	Up to 600 DD	From 601 DD	To 900 DD	From 901 DD	To 1400 DD	From 1401 DD	To 2100 DD	From 2101 DD	To 3000 DD	Beyond 3000 DD
<= 0.2	8.5	8.5	12.8	12.8	21.3	21.3	34	34	46.8	46.8
>= 0.9	36	36	48	48	68	68	88	88	116	116

Table 3.7: Energy performance (EP) limits for non-residential buildings expressed in kWh/m^3 starting 1st January 2010, [56]

Building form factor S/V	Climatic Zones									
	A	B		C		D		E		F
	Up to 600 DD	From 601 DD	To 900 DD	From 901 DD	To 1400 DD	From 1401 DD	To 2100 DD	From 2101 DD	To 3000 DD	Beyond 3000 DD
<= 0.2	2..0	2.0	3.6	3.6	6	6	9.6	9.6	12.7	12.7
>= 0.9	8.2	8.2	12.8	12.8	17.3	17.3	22.5	22.5	31	31

A proof of compliance must be made after completion of the building, under legal responsibility of the director of works. Control of the regulation is the responsibility of the Municipality where the building is located.

3.5.3.4 Requirements for existing buildings

For buildings undergoing major renovation, the Italian Government gradually adopted the same EP minimum requirements as those for new buildings:

a) Integral application to the whole building in case of:

- Total renovation of the building envelope elements for existing buildings having a useful (heated) floor area of more than 1000 m^2.
- Demolition and reconstruction of existing buildings having a useful (heated) floor area of more than 1000 m^2.

b) Integral application limited to the new part of the building if this exceeds more than 20% the original volume.

c) Application limited to the compliance of single parameters, performance levels and prescriptions when the renovation of an existing building comprises:

- The total or partial renovation or extensive maintenance of the envelope, except in the case of total renovation of the building envelope elements for existing buildings having a useful (heated) floor area of more than 1000 m^2.
- The installation of new heating systems or heating system renovation in existing buildings.
- The replacement of heat generators.

The following parameters must be followed for all renovations (whatever the size or extent, even the replacement of a single window, the wall insulation, a boiler, etc.)

The maximum U-value of vertical or inclined opaque walls, horizontal surfaces (roofs and floors) and transparent glazing, to be introduced in three stages, corresponding to the three dates of implementation: 1st January 2006, 1st January 2008 and 1st January 2010 are shown in Table 3.8 to 3.11.

Table 3.8: Limit values of the thermal transmittance of opaque vertical surfaces, [56]

Climatic zones	From 1st January 2006 U (W/m^2K)	From 1st January 2008 U (W/m^2K)	From 1st January 2010 U (W/m^2K)
A	0.85	0.72	0.62
B	0.64	0.54	0.48
C	0.57	0.46	0.40
D	0.50	0.40	0.36
E	0.46	0.37	0.34
F	0.44	0.35	0.33

Table 3.9: Limit values of the thermal transmittance of roofs, [56]

Climatic zones	From 1st January 2006 U (W/m^2K)	From 1st January 2008 U (W/m^2K)	From 1st January 2010 U (W/m^2K)
A	0.80	0.42	0.38
B	0.60	0.42	0.38
C	0.55	0.42	0.38
D	0.46	0.35	0.32
E	0.43	0.32	0.30
F	0.41	0.31	0.29

Table 3.10: Limit values of the thermal transmittance of basement, [56]

Climatic zones	From 1st January 2006 U (W/m^2K)	From 1st January 2008 U (W/m^2K)	From 1st January 2010 U (W/m^2K)
A	0.80	0.74	0.65
B	0.60	0.55	0.49
C	0.55	0.49	0.42
D	0.46	0.41	0.36
E	0.43	0.38	0.33
F	0.41	0.36	0.32

Table 3.11: Limit values of the thermal transmittance of vertical windows (frame and panes), [56]

Climatic zones	From 1st January 2006 U (W/m^2K)	From 1st January 2008 U (W/m^2K)	From 1st January 2010 U (W/m^2K)
A	5.5	5.0	4.6
B	4.0	3.6	3.0
C	3.3	3.0	2.6
D	3.1	2.8	2.4
E	2.8	2.4	2.2
F	2.4	2.2	2.0

In case of system renovation, the average global seasonal efficiency ηg of the thermal system shall be higher (75 + 3 log Pn) %, where Pn is the base 10 logarithm of the generator power.

In case of simple substitution of a fuel fed generator, the minimum instantaneous efficiency, at 100% load, shall be 90 + 2 log Pn, in case of heat pumps the limit, in terms of primary energy, is 90 + 3 log Pn, where Pn is the base 10 logarithm of the generator power in kW. All these requirements came into force on 1 January 2006.

These implementations are now supported by new public incentives, namely a 55% tax credit, to be spread over a maximum of ten fiscal years, up to 2010 by the Financial Law 2008, for the following building efficiency measures:

- Electric, absorption cycle and geothermal heat pumps, condensing boilers, solar thermal collectors.
- Retrofitting of building envelope elements satisfying the minimum requirements coming into force in 2010.
- Small building renovations, with a building performance of less than 20% of the EP values in force.

The production of the documents necessary to obtain the fiscal funding allows the control of the minimum requirements by the local authorities, together with compulsory certification.

Table 3.12: Impact results 2007 and 2008 (MSE data until March 8th - extrapolation from the first 59.000 received applications on a total of 120.000), [56]

Primary energy saved	975.171,66	MWh
Net intervention costs	1.582.635.777,82	Euro
Basis for incentive calculation	1.600.124.682,48	Euro
Professional costs	80.390.015,84	Euro
Income tax detraction	880.068.575,36	Euro

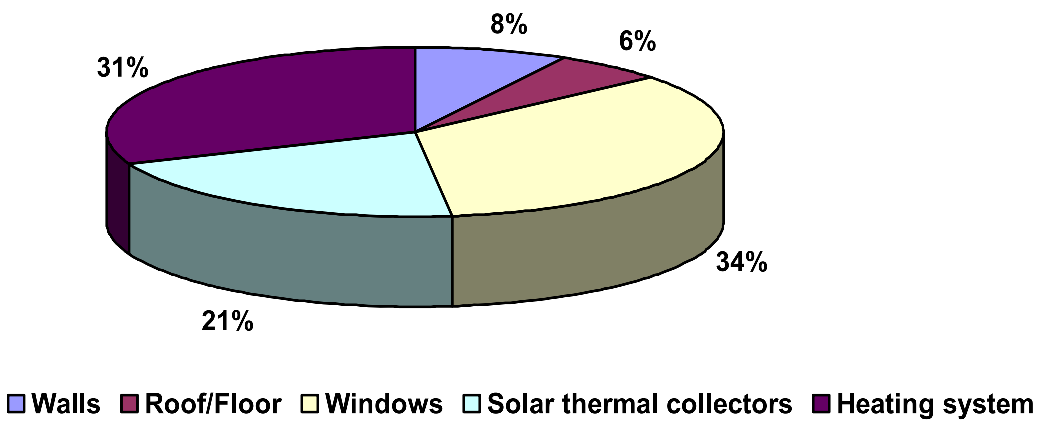

Figure 3.3: Breakdown of the results obtained by the 55% tax credit system after 15 months application, [56]

3.5.3.5 Certification of buildings

The requirements regarding the certification of buildings were adopted by the Government by the D. Lgsl. 311/2006, article 6. The certification of new buildings started 30 days after the publication of the new Decree (1st February 2007), using the existing methods (limited to heating and DHW, the new methods for cooling and artificial lighting will come later) to express the numerical value of the EP, which is the responsibility of the building designer, confirmed by the works director, until the new governmental guidelines on certification come into force.

The certification will gradually become mandatory for all buildings, when the property is transferred, in three stages: July 2007 for buildings above 1000 m^2 useful surface; July 2008 for buildings below 1000 m^2 (excluding single flats), and July 2009 for all apartments.

Since 1 January 2007, energy certification is required in order to have access to any type of public incentives for improving energy performance such as:

- The previously mentioned 55% fiscal tax credit, for building efficiency measures, introduced by the financial law 2008.
- The Decree of 22 December 2006 by the Ministry for Economic Development, assigning 8 million Euro for energy audits, certification and final design of energy renovation for public buildings (the implementation is committed to the Regions).
- The new premium rate programme for Photovoltaic plants, providing improved rates when an energy certification of the building, demonstrating at least a 10% energy reduction in respect to the initial situation, is provided.

Up to March 2008, building energy certificates have been issued throughout the whole Country:

- In new buildings (number of equivalent flats): 700000
- In property transfer of existing buildings, in terms of medium-big size buildings: 10000
- in terms of equivalent apartments: 110000

Several Municipalities are also introducing incentives for those new buildings which satisfy the best energy classes, based on a partial reduction of the contributions due to the administration for the provision of urban infrastructures.

The most relevant schemes on energy certification of buildings are being implemented in the different Italian regions, as follows:

The first and most popular case concerns the initiative launched by the Bolzano Province which initiated a voluntary scheme to award a “CASACLIMA” brand. This scheme was established before the Decree n 192/05, and takes into account the quality of the building envelope and also the heating system, [50]. More than 88 assessors are now accredited by CasaClima. The energy classes of Casaclima certificate are depicted in Figure 3.4.

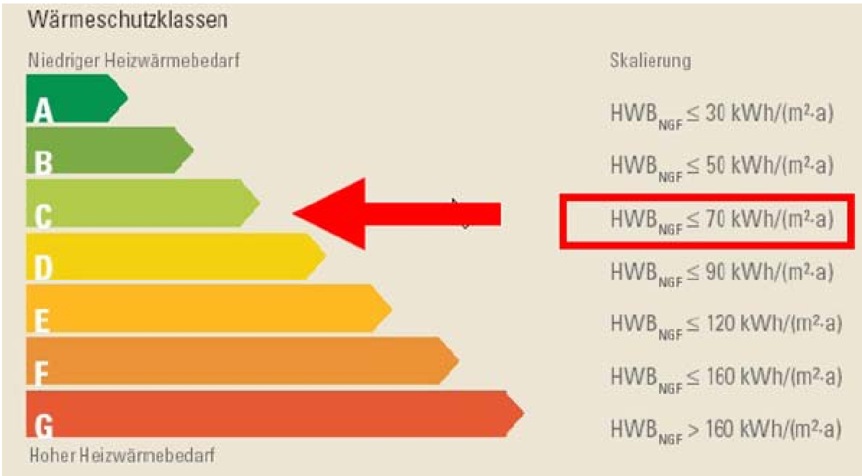

Figure 3.4: Energy classes of CasaClima certificate, [50, 56]

The Lombardy Region has enacted the regional guidelines, exercising the powers allowed by the Reform of the Title V of the Italian Constitution. In connection with this, the accreditation system for the building certification, named CENED, was set up. It aims at proposing certification procedures and defining the calculation methodology. More than 6600 assessors have already been accredited in the Region.

Figure 3.5: CENED energy certification, [56]

Other Regions or Autonomous Provinces launching new project-schemes on energy certification are:

- Marche (protocol on bio-architecture, named ITACA).
- Liguria – Regional regulation n. 6 of the 8th November 2007, implementing art. 29 of the regional law n. 22 of the 29th May 2007 "Norms on energy matters", [51].
- Piedmont (Law on energy performance of buildings - LR 28/05/2007 n.13).
- Emilia Romagna Region official decree approving the guidelines related to energy certification of buildings 4th of March, 2008, [52].
- Trento Province: methodology through Deliberation Act n. 2167 on 20/10/06, [53].

It is interesting to note that in some regions, differences are relevant. For example, the ranging of the minimum requirements according to the form factor S/V (envelope surface divided by volume) is adopted by all regions, while only a few use it for the certification classes. Some Provinces are also introducing their own voluntary schemes/tools, such as:

- Milano Province: guidelines and certification scheme SACERT, [54].
- Reggio Emilia Province, Reggio Emilia Municipality and ACER (social housing company of Reggio Emilia): ECOABITA scheme.
- Vicenza Province: Ecodomus.vi scheme for energy certification, [55].

3.5.3.6 Inspection of boilers and air conditioning

Inspection of boilers was introduced in Italy through the Law n. 10/1991 and following implementation decrees. The Legs. D. 311/2006 modified some procedures, giving more responsibility to the regions and allowing for a longer maximum interval (up to 4 years) for the maintenance and control of small gas boilers.

The procedures for inspection of air conditioning systems are still under discussion, as the EC has granted the request for a three-year delay.

3.5.3.7 Qualified experts

The Ministry Decree 30-05-2008 authorizes the following criteria for the accreditation of building energy performance assessors:

- Professionals, registered at the official association, demonstrating suitable design or energy auditing experience.
- Any person having a technical-scientific background, attending a specific training course, with final examination.
- The background qualification diplomas have to be recognised by the regions and autonomous provinces.
- The training courses have to be organised or authorised by the regions and autonomous provinces.

These general principles, stated at national level, can be slightly modified to suit the regional conditions: in Emilia-Romagna and Lombardy, for example, skilled HVAC designers or building energy auditors, demonstrating long term experience, do not require attending a training course.

Before signing a certificate, in order to guarantee an unbiased approach to the evaluation procedure, the assessors have to declare:

a) For new buildings, the absence of any conflict of interest, namely the absence of direct or indirect involvement in the design or construction process, the suppliers of the materials and components, or in respect of any advantage to the owner.

b) For existing buildings, the absence of any conflict of interest, namely the absence of direct or indirect involvement with the suppliers of the materials and components, or in respect of any advantage to the owner.

This declaration is not necessary for assessors employed by public administrations or other public organizations dealing with energy and buildings. When a simple boiler is replaced the certificate can be issued by a technician of the boiler supplier or installer, [56].

3.5.4 Portugal

Portugal has adopted appropriate measures to implement the directive: on 4 April 2006, the Government adopted three Decrees that, together, constitute the transposition of the EPBD into national law. Certification of new buildings started in July 2007 and about 1500 certificates have already been issued by qualified experts by the end of January 2008.

3.5.4.1 Legal context

On 4 April 2006, the Official Journal published three Decrees regarding the transposition of the EPBD into national law, [57]:

- Decree 78/2006 creates and defines the operational rules for the System for Energy and Indoor Air Quality Certification of Buildings (SCE) - articles 7 & 10.
- Decree 79/2006 establishes the new revision of the Regulations for HVAC systems, including requirements for regular inspection of boilers and air-conditioners (RSECE) - articles 8 & 9.
- Decree 80/2006 establishes the new revision of the Thermal Regulations for Buildings (RCCTE) - articles 3 to 6.

More recently, two other legislative documents were published: Portaria nº 461/2007 (5 June 2007) which establishes the timetable for implementation of the certification process and Portaria nº 835/2007 (7 August 2007) which defines the fee to be paid to SCE for the central registration and validation of certificates issued by qualified experts.

In Portugal, the implementation of the EPBD is the overall responsibility of the Ministry of the Economy together with the Ministry of Environment. The direct responsibility for the two regulations belongs to the Ministry of Public Works.

3.5.4.2 Calculation procedures

The calculation procedures (art. 3) are defined in the Building regulations for residential buildings and in the HVAC regulations for non-residential buildings.

A software tool, produced by INETI for the Energy Certification System (SCE) for both residential and small non-residential buildings, became available in September 2006. For residential buildings, however, the calculations can be performed by hand, on a spreadsheet, or using any other commercial software package that became available in the meantime, offering enhanced interfaces and databases of materials, construction details, etc.

For large non-residential buildings, commercial software tools complying with accuracy requirements based on ASHRAE standard 140-2004 (based on IEA's BESTEST criteria, the same list of software recognized by the US DOE, currently including about twenty American and EU based software packages) must be used to calculate energy consumption, using detailed hourly simulations on a yearly basis. National databases of hourly annual typical climates were prepared and published for every municipality in Portugal, and they must be used for demonstrating building compliance, to eliminate any uncertainties derived from the use of different climatic datasets.

3.5.4.3 Requirements for new buildings and major renovations

The new requirements are mandatory for building permits requested after 3 July 2006. The type and level of requirements depend on the type of building (dwellings, office buildings, schools, etc.) and cover:

- Maximum Heating and Cooling needs per m² of floor area (residential and small non-residential buildings only).
- Maximum U-value, as shown in Table 3.13.
- Minimum shading requirements for all windows.
- Minimum requirements for thermal bridges.
- Maximum consumption for production of domestic hot water, including mandatory installation of collectors for solar hot water (all residential buildings as well as large non-residential buildings with significant hot water use, e.g., hotels, hospitals, etc.).
- Maximum primary energy consumption per m² of floor area (all buildings).
- Minimum efficiency and quality requirements for heating and cooling systems components (non-residential buildings).

Table 3.13: Reference U-values required for compliance with building regulations (indicative values- W/m^2.K), [58]

<table>
<tr><th rowspan="2" colspan="2">Envelope</th><th colspan="4">Climatic region</th></tr>
<tr><th>I1</th><th>I2</th><th>I3</th><th>Islands</th></tr>
<tr><td rowspan="2">Exterior</td><td>Walls</td><td>0.7</td><td>0.6</td><td>0.5</td><td>1.4</td></tr>
<tr><td>Roofs</td><td>0.5</td><td>0.45</td><td>0.4</td><td>0.8</td></tr>
<tr><td rowspan="2">Partions to unheated spaces</td><td>Walls</td><td>1.4</td><td>1.2</td><td>1.0</td><td>2.0</td></tr>
<tr><td>Roofs</td><td>1.0</td><td>0.9</td><td>0.8</td><td>1.25</td></tr>
<tr><td colspan="2">Windows</td><td>4.3</td><td>3.3</td><td>3.3</td><td>4.3</td></tr>
</table>

The proof of compliance must be made at two stages:

a) When requesting the building permit.

b) And after completion of the building.

Control of the regulation is the responsibility of the Municipality where the building is located, based on a Declaration of Compliance with the building regulations issued by an accredited expert registered in the SCE (Building Certification System).

3.5.4.4 Requirements for existing non-residential buildings larger than 1000 m^2

If the primary energy consumption of an existing building, based on actual fuel bills and covering all types of energy usage, exceeds a certain level fixed by the HVAC regulations, an energy efficiency plan must be prepared and all measures with payback shorter than 8 years must be implemented over a three year period. This threshold level corresponds to the currently 40% worst performers of their typology, as determined by extensive building energy consumption surveys ordered by the national government in preparation of the new regulations. This threshold level that triggers an energy efficiency plan should be regularly reduced over the years, to include an increasing number of buildings.

This requirement does not apply to smaller non-residential buildings or to any residential building.

3.5.4.5 Certification of buildings

The National System for Energy and Indoor Air Quality Certification of Buildings (SCE) came into force on 1 July 2007. This milestone started a new phase in the current legislation on energy efficiency of buildings in Portugal since it was published in 4 April 2006.

The SCE aims to achieve two primary objectives: save energy, while ensuring comfortable conditions and acceptable indoor air quality. ADENE, the Portuguese Energy Agency, is the managing body for this process, under the shared supervision of the Directorate-General of Energy and Geology and the Portuguese Environmental Agency.

The timetable to implement the SCE in various types of buildings is divided into three phases until its full implementation in January 2009, when all the required buildings will be included in the certification system: new buildings, major renovations, public buildings and all buildings when sold or rented. In the first phase, certification is only required for all new residential and non-residential buildings with a floor area larger than 1000 m^2 and requesting a construction permit after July 1, 2007. The second phase includes all new buildings, regardless of their floor area, when they request a construction permit after 1 July 2008, [58].

The system operates in conjunction with two sets of building regulations applied to construction, the Regulations on Thermal Behavior of Buildings (RCCTE) and the Regulations on HVAC Systems in Buildings (RSECE).

The implementation of these regulations is checked by qualified experts at several stages throughout a building’s lifetime. The Energy Certificate is the most visible aspect of the SCE. This document will assign an energy performance label to residential and nonresidential buildings and it may list measures for improving their energy performance.

The energy label classifies the buildings on an efficiency scale ranging from A+ (high energy efficiency) to G (poor efficiency). This is similar to the scale currently used for some domestic appliances and equipment (although classes A and B are evenly subdivided in to classes A+, A, B, B-, to improve the distinction among new buildings - all new buildings must be in the A+ to B- classes)and it allows for easy reading and interpretation by the consumer.

Until the end of January 2008, there are more than 1500 Energy Certificates registered on a web based central registration system that qualified experts must access and use to issue certificates. This way, a national database of certified buildings is being updated with information that will be useful to monitor progress of different aspects of the implementation of the directive, from basic statistics such as the number of certified buildings to producing studies for the future possible tightening of minimum requirements that the EPBD demands on a periodic basis.

Moreover in Portugal, the definition of public building includes every non-residential building, owned by private or government bodies. Every non-residential building larger than 1000 m^2 shall be required to prominently display an energy certificate at the main entrance.

Certificates are based on calculated energy ratings, and must be periodically renewed once every 6 years. Indoor Air quality certificates must be renewed every two or three years, depending on building typology.

Certificates must include a list of recommended energy improvement measures based on actual consumption (energy bills). A detailed energy and indoor air quality audit is thus required periodically. When the actual energy consumption is above a certain threshold, an energy plan is required.

3.5.4.6 Inspections of boilers and air-conditioning

Inspections of boilers and air-conditioners are covered by the HVAC regulations adopted by the Government on 4 April 2006 and shall become mandatory from 1 January 2009. The procedures for inspection of boilers and air conditioning systems are still under discussion. In the case of nonresidential buildings, inspections will be a required part of the HVAC maintenance plan and their execution will be subject to verification by qualified experts when performing periodic audits of the building, once every 2 or 3 years.

3.5.4.7 Indoor air quality

The non-residential regulations (RSECE) also specify stringent indoor air quality requirements for new and existing buildings. In new buildings, HVAC systems must be designed to guarantee a minimum intake of fresh air, according to the type and use of the space. In existing non residential buildings, indoor air quality must be periodically monitored (every 2 or 3 years, depending on building type) and corrective measures must be taken if pollutant levels are above certain limits, [58].

3.5.4.8 Qualified experts

Qualified experts are the only persons permitted to issue Certificates and carry out inspections. They must be recognized architects or engineers with at least five years' experience, on the basis of peer-analysis of their CVs carried out by elected boards by their professional associations.

In addition, qualified experts must attend recognized courses and pass a demanding national examination that evaluates their knowledge about the technical requirements of the building regulations and the details of the certification system itself. ADENE co-ordinates the training of qualified experts and is responsible for the Energy Certification module in all courses.

These courses are available in the three areas covered by the system and award different qualifications: RCCTE (residential and small non-residential) and RSECE (large non-residential). For the large non-residential buildings, experts can be qualified in one or two areas: Energy and Indoor Air Quality (RSECE-E and RSECE-QAI). A professional license, valid for 5 years, is issued to Qualified Experts, and it is subject to renewal pending proof of continued training and lack of malpractice.

Qualified experts can act on an individual basis or integrated in public or private organizations. The first group of qualified experts, consisting of about 200 experts, has been given the additional qualification for training new experts. Recognized courses are already offered by more than 40 universities or accredited training institutions, and more than 700 candidates are undergoing training as of January 2008. The goal is to have 2000 qualified experts by 2009.

3.5.4.9 Quality control

The quality of the certificates will be controlled by periodic checks of the work of the qualified experts. At least once every 5 years, each expert will be audited by ADENE to evaluate his correct use of methodologies and tools. About 10% of the certificates will be subjected to this analysis. This control will be financed by the fee paid for the registration of each certificate (45 € per certificate in residential buildings and 250 € per certificate in non-residential buildings), [57, 58].

3.5.5 Spain

The existing Spanish legislation regarding energy saving in buildings dates from 1979 while the last regulation on thermal building installations from 1998. Both needed extensive reviewing and updating. The EPBD gave the Spanish Government the chance to include more stringent energy criteria into this review, not just for the fulfillment of the EU obligations but also for the implementation of other National Energy Policies such as the Energy Strategy E4 and the Renewable Energy Plan.

3.5.5.1 Legal context

The EPBD was transposed in Spain by means of three royal decrees:

- Royal Decree approving the 'Technical Code of Buildings (CTE)'. It was approved by the Council of Ministers on 17th of March 2006 and published in the Official Gazette on 28th March 2006.

- Royal Decree approving the review of the current 'Regulations for thermal installations on Buildings (RITE)', approved by the Council of Ministers on 20th of July 2007 and published in the official Gazette on29th August 2007.
- Royal Decree on the Basic Procedure for Energy Performance Certification of new buildings approved by the Council of Ministers on 17th January 2007, and published in the Official Gazette on 31st January 2007.

All of these are the responsibilities of the Ministry of Housing, and the revised RITE and Energy Certification is the responsibility of the Ministry of Industry, Tourisms and Trade also.

3.5.5.2 Calculation procedures

The calculation procedure for the buildings energy efficiency (named "Energy Efficiency qualification") is expressed by the estimated energy consumption necessary to satisfy the building energy demand in occupational and standard running conditions.

This can be calculated by a simplified prescriptive option or by a general option, described in the following section, using an official software tool or by any alternative method validated by the Government. More information about the technical specification of the calculation procedure for the energy efficiency qualification is found in the Annex I of the Royal Decree 47/2007, dated 19th January, by which the Basic Procedure for the new buildings Energy Efficiency Certification is approved.

3.5.5.3 Requirements for new buildings

The Building Code (CTE) has set minimum energy requirements for new buildings. The requirements come into force for building permits requested after 17th September of 2006.

The type and level of performance requirements depend on the climatic zone (in total, there are 12 in all the Spanish territory) where there is building work, and they cover:

- Maximum U-values for different building elements.
- Solar factor for windows, roof lights, etc.
- Minimum Efficiency performance for thermal installations.
- Minimum Efficiency performance for lighting installations.
- Minimum natural lightning contribution.
- Minimum solar contribution to Domestic Hot Water.
- Minimum photovoltaic contribution to electric power.

The compliance with requirements on 'Energy demand limitation' (HE1) could be checked using a simplified procedure, (for each orientation, the real values are compared with the limit values for the roof, facade walls and floors in contact with ground) or by using a complex procedure.

The complex procedure requires the use of software tools. LIDER is the official one, which has been developed by the Government and is available for free, [59].

More information about these two procedures are found in the Section HE1 "Limits for the Energy Demand" of the Basic Document DB-HE Energy Saving of the Building Code approved by the Royal Decree 314/2006, on 28th of March.

3.5.5.4 Requirements for existing buildings

Existing buildings must comply with the same minimum requirement as new ones when building rehabilitation, enlargement or renovation is carried out: also large buildings (floor area over 1000 m^2) where more than 25 % of the building envelope undergoes renovation.

For new buildings, these requirements must also have been implemented by 17th September 2006.

3.5.5.5 Certification for buildings

Provisions regarding the energy performance certification of new buildings have been adopted at national level by the Government as the ‘National Basic Procedure for energy certification’ by means of the Royal Decree 47/2007, of 17th January, published on 31st of January 2007. The fact that it is a ‘Basic procedure’ means that other authorities having jurisdiction, such as the Autonomous Communities, can regulate and complete the National system giving more detail provisions of the control and inspections. The cooperation between all interested parties and administrations involved will be realized through a National Advisory Commission set by the Decree.

Certification will be obligatory for every type of new buildings for which a building permit is requested by Local Authorities after 31st October 2007.

As for the calculation of energy demand, the ‘National Basic Procedure’ for energy certification foresees two possible ways: a simplified one (that includes any validated procedure approved by the Certification Commission added to the already existing simplified methodology for dwellings based in 12 tables for different climatic areas) and another complex one. The last one requires the use of a software tool, ‘CALENER’ being the official one.

So far, there are two different versions of CALENER: CALENER_VYP (for dwellings and small tertiary sector buildings) and CALENER_GT (for big tertiary sector buildings), [60, 61].

For existing buildings, another Royal Decree is under preparation. A ‘Basic procedure” for the certification of existing buildings is expected to be ready and mandatory from 2009.

3.5.5.6 Inspection of boilers and air-conditioning

Inspection of boilers is already covered by the Regulation on thermal installations on Buildings (RITE) since its first version was approved in 1982, revised in 1986 and currently applicable since 1998. This current RITE version has been recently revised and approved by the Council of Ministers on 20th of July 2007.

The technical procedures for HVAC systems are included in this revised version of RITE.

Chapter 4

Application of computational energy saving methodologies in Crete

4.1 Introduction

Regarding the increasing energy demand in the island of Crete, the estimation of energy saving in buildings for the island of Crete is implemented. More precisely, a simulation of an office building in the city of Iraklion (Crete) was implemented using TRNSYS program. Various energy saving measures were tested and compared to a reference case. Moreover, the record of electric energy consumption of office buildings in correspondence with their requirements in the four Prefectures of Crete is reported.

4.2 Energy saving in an office building using TRNSYS simulation program

In Greece, the Building Thermal Insulation Regulation has been in use since 1981, setting the minimum requirements for thermal conductivity of the building envelope for different climatic zones, as mentioned in previous chapter.

4.2.1 Determination of Heating and Cooling Degree Days

In accordance to the "Regulation on Rational Use and Energy Conservation in buildings", regarding the energy performance requirements of the Directive 2002/91/EC, four different climatic zones are defined based on Heating Degree Days (HDDs), [62]:

- Climatic Zone A: 601-1100
- Climatic Zone B: 1101-1600
- Climatic Zone C: 1601-2200
- Climatic Zone D: 2201-2620

In addition, the great majority of Hellenic building stock is not thermally insulated, despite the fact that HDDs range reach over 2600 HDD in Northern Greece due to local weather conditions, [63].

According to the classification of Greece in four climatic zones, Crete falls into climatic zone A which is characterized by mild winter and mild humid summer, [64].

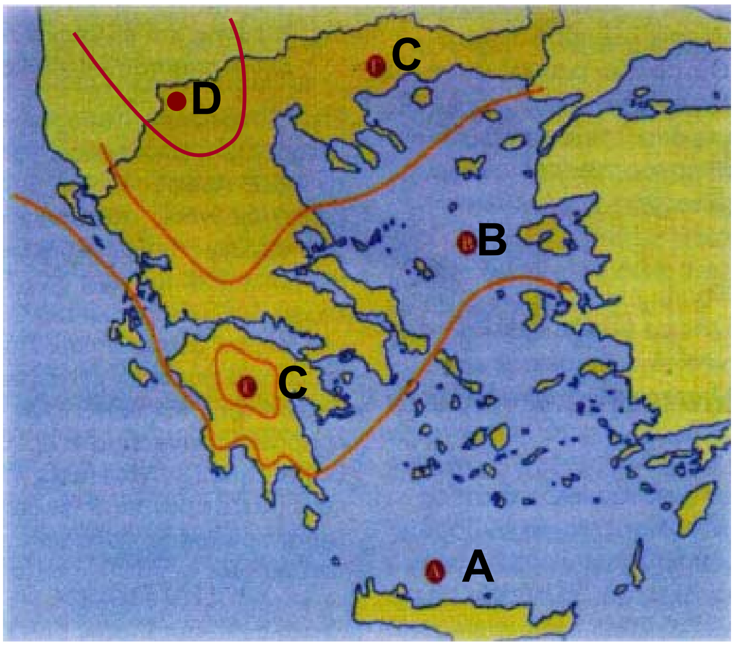

Figure 4.1: Climatic zones in Greece

The existing building stock in Crete enumerates about 288.000 buildings, whereas only 28.4 % was constructed before 1981 when Building Thermal Insulation Regulation came into force.

A simplified method is applied in order to determine the heating and cooling degree days (which actually provide an estimation of the heating and cooling loads of a building) for the city of Iraklio, knowing the mean hourly temperature for one year and assuming the balance temperature at 18 ^{0}C, [65]. As a result, the degree days of heating and cooling were estimated to be equal to 910 and 1100 respectively.

4.2.2 Energy saving in heating and cooling

For the improvement of building envelope, the assessment of building thermal loads is required. The envelope transmission loads are dominant as their losses affect the total energy efficiency of the building. In order to characterize the heat transfer, a thermal resistance R value or a U Value must be defined.

According to the Building Thermal Insulation Regulation (BTIR) and the Regulation on Rational Use and Energy Conservation (RRUEC) in buildings, the indicative U Values for climatic zone A are defined in Table 4.1.

Table 4.1: U Values in climatic zone A

U Values	***BTIR***	***RRUEC***
	W/m^2.K	W/m^2.K
Outer walls,U_W	0.7	0.55
Outer horizontal surface,U_D	0.5	0.4
Floor on no heating space,U_G	3	1.3
Internal partitions, U_{DL}	3	1.3

The estimated energy use saving for heating and cooling was calculated by the following equation, [65]:

$$\Delta E = \frac{24.\left(BLC_E - BLC_R\right).DD_s(T_b,_E)}{\eta} \tag{4.1}$$

Where:

BLC_E - BLC_R: Difference in U Values (UBTIR-URRUEC)

DDs: Degree days of heating or cooling, correspondingly

T_b: Balance temperature (assumed to be 18 °C) η: System efficiency (set to be one)

The energy saving in heating & cooling based on the difference in U Values of the two regulations as well as the calculated degree days of heating and cooling, are represented in Table 4.2.

Table 4.2: Energy saving in heating and cooling

Energy saving	Heating	Cooling
	$kWh/m^2.yr$	$kWh/m^2.yr$
ΔE_W	3.28	3.96
ΔE_D	2.18	2.64
ΔE_G	37.13	44.88
ΔE_{DL}	37.13	44.88

4.2.3 Application of TRNSYS simulation program

TRNSYS is a transient system simulation program with a modular structure that was designed to solve complex energy system problems, as the ones in buildings. In building simulations, all HVAC-system components are solved simultaneously with the building envelope thermal balance and the air network at each time step, [66].

A simulation of a not thermally insulated office (270 m^2 surface area) in Iraklio was implemented, in order to estimate the energy saving in heating and cooling. The office was divided in six thermal zones based on the thermal (heating and cooling) loads. More precisely, the office under investigation is consisted of nine rooms equipped by twenty nine electrical devices such as PC, plotter, fax. The heating is provided in the office by district heating as well as ten space heaters. On the other hand, cooling is provided by ten air conditioning systems.

At first, the total energy load of the building was calculated as base case. Hereupon, four different scenarios concerning energy saving were examined:

- Insulation (25 mm)
- Side fins (top bottom extension 0.5 m and the left , right gap 0.3 m)

- Overhangs (located 0.5 m above the window and extend 1 m both sides of the window) & side fins
- Venetian blinds

4.2.4 Results

The appraisal results are depicted in Figure 4.1.

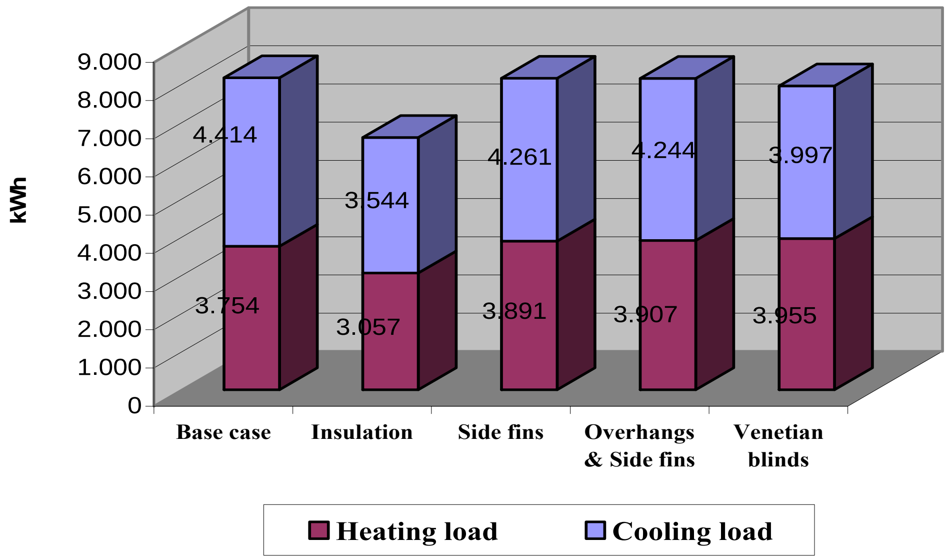

Figure 4.1: Loads calculation per scenario

According to the results of the simulation, the energy saving for each individual scenario is shown in Table 4.3.

Table 4.3: Energy saving per scenario

	Normalised energy consumption (kWh/m^2)	Energy Savings (%)
Base case	30.25	
Insulation	24.45	19.18
Side fins	30.19	0.2
Overhangs & Side fins	30.18	0.24
Venetian blinds	29.45	2.64

The evaluation of energy use savings in an office in the city of Iraklio, region of Crete was implemented comparing four different scenarios. In accordance with the applied scenarios, the highest energy use saving is accomplished by adding insulation at external walls. As a consequence, the building incurs lower energy losses and thus higher savings improving the energy efficiency of the building. Furthermore, energy use saving is also observed at the other scenarios both of external (side fins, overhangs and side fins) and internal (Venetian blinds) shading.

According to the current state of building sector in the region of Crete, where the majority of buildings are not insulated, the addition of thermal insulation as well as external and internal shading can lead to the reduction of energy losses (estimate of saving), improving at the same time the energy efficiency of buildings.

4.3 Electric energy consumption of office buildings in Crete

A research for the record of electric energy consumption of office buildings in the four Prefectures of Crete was implemented through the filling of a questionnaire. The general characteristics of office buildings (region, Prefecture, Municipality, location, activity, floor area, floor, number of rooms, positions and occupants and office hours) were itemized in the questionnaire.

The questionnaire was divided in five categories regarding lighting, heating, cooling, indoor environment and equipment, as presented in Annex II. Every category includes four sub-categories of either qualitative or quantitative data with corresponding scale from 0 to 4 regarding techniques of energy saving and electric energy consumption, respectively.

The total amount of the office buildings under research is 100, classified in accordance to population's concentration in the four Prefectures of Crete, as shown in Figure 4.2.

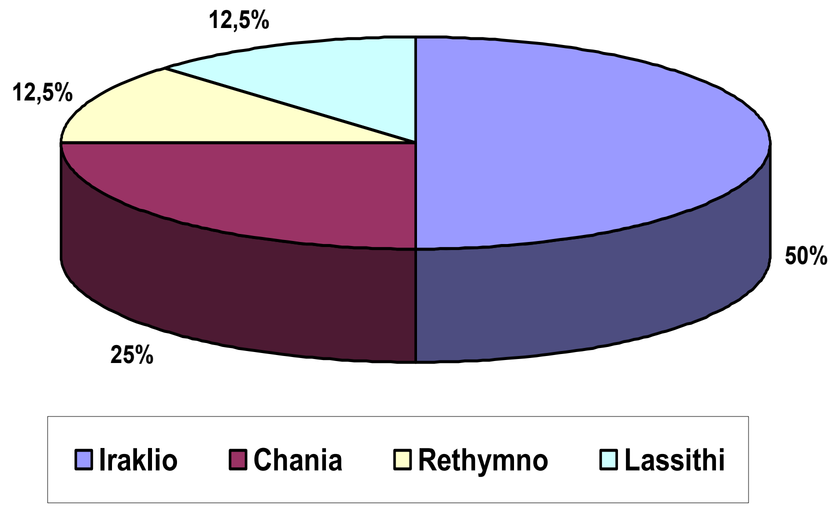

Figure 4.2: Population's concentration of the four Prefectures in Crete

4.3.1 Calculation of electric energy consumption

For the calculation of electric energy consumptions of office buildings, 260 days of the year were assumed as working days leaving out Feast days and weekends. For the category of lighting, offices' function hours were divided by two according to the office requirements for lighting during the day. Furthermore, for the category of equipment a use percentage of 30% was taken into account. For the category of heating and cooling four months of the year were taken into account for the calculation of their consumptions and 1 kcal equal to 1,163 Wh as well as 1 btu equal to 0,293 Wh were presupposed.

According to the appraised calculations, the distribution of offices' electric energy consumption for each category is represented in the following Figures 3.3 to 3.6. More precisely, for the category of lighting, 16% of offices consume 5 kWh/m^2/yr, 31% of offices consume 10 kWh/m^2/yr, 26% of offices consume 15 kWh/m^2/yr, 18% of offices consume 25 kWh/m^2/yr and just 1 to 2% of offices consume 30 to 45 kWh/m^2/yr, as shown in Figure 4.3.

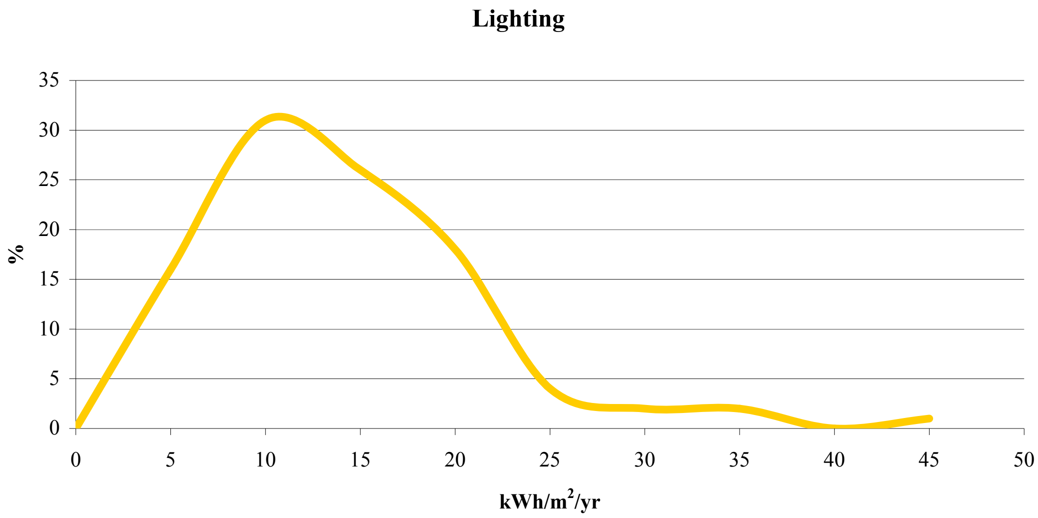

Figure 4.3: Electric energy consumption for lighting

The electric energy consumption of offices for heating is represented in Figure 4.4. In particular, 14% of offices consume 80 kWh/m^2/yr, 33% of offices consume 160 kWh/m^2/yr, 29% of offices consume 240 kWh/m^2/yr, 12% of offices consume 320 kWh/m^2/yr and just 1 to 2% of offices consume 480 to 720 kWh/m^2/yr.

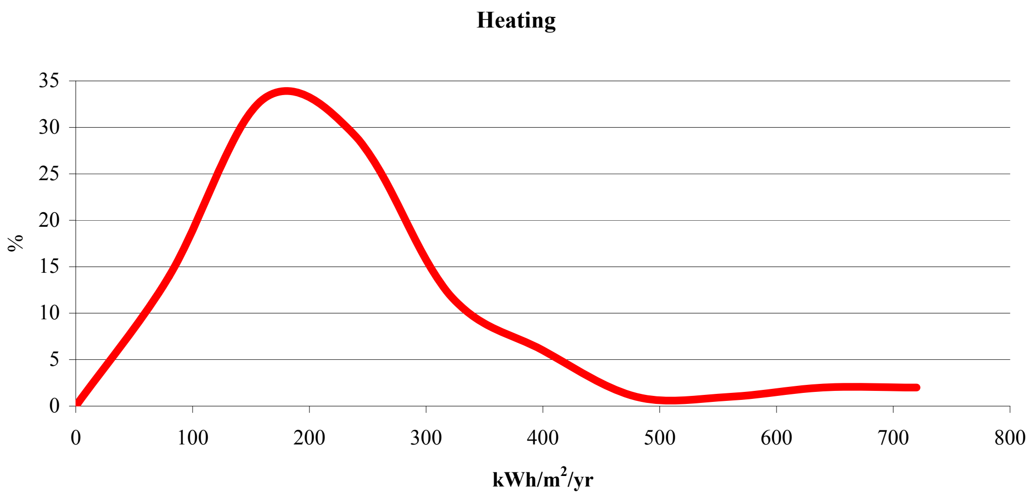

Figure 4.4: Electric energy consumption for heating

The electric energy consumption for cooling, as depicted in Figure 4.5, was calculated at 40 kWh/m^2/yr for 15% of offices, 80 kWh/m^2/yr for 16% of offices, 120 kWh/m^2/yr for 17% of offices, 160 kWh/m^2/yr for 22% of offices, 200 kWh/m^2/yr for 17% of offices and 240 to 360 kWh/m^2/yr for 2 to 5% of offices.

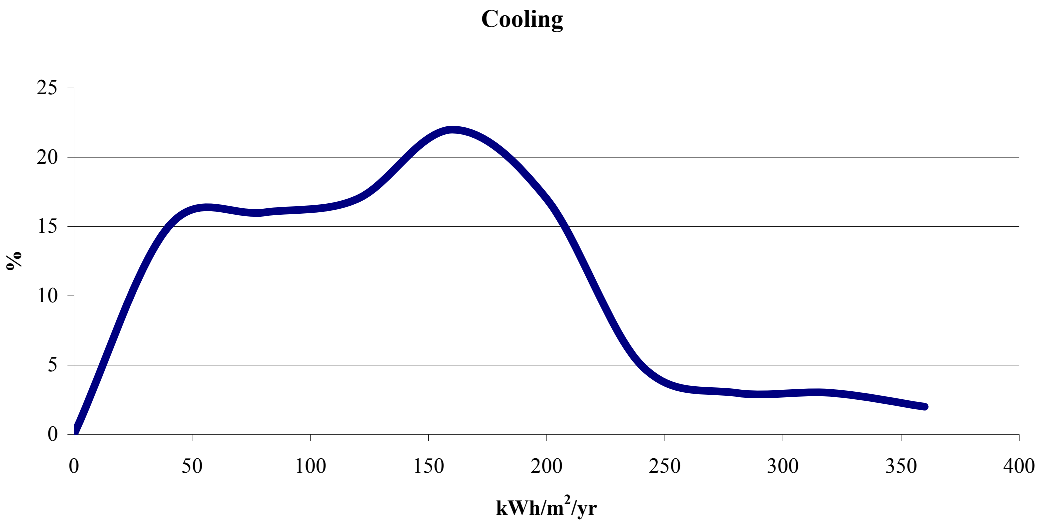

Figure 4.5: Electric energy consumption for cooling

At Figure 4.6, the equipment's electric energy consumption of offices is represented. Hereupon, 24% of offices consume 40 kWh/m^2/yr, 46% of offices consume 80 kWh/m^2/yr, 23% of offices consume 120 kWh/m^2/yr and 1 to 4% of offices consume 160 to 320 kWh/m^2/yr.

Figure 4.6: Electric energy consumption for equipment

The electric energy consumption's distribution per category is represented in the following Figure 4.7, while the additive distribution per category is represented in Figure 4.8. The electric energy consumption's maximum value that is observed for the category of lighting is 10 kWh/m^2/yr for the 30% of offices, for the category of equipment 80 kWh/m^2/yr for the 46% of offices, for the category of heating 180 kWh/m^2/yr for the 34% of offices and for the category of cooling 160 kWh/m^2/yr for the 22% of offices, as depicted in Figure 4.7. In the Figure 4.7, the maximum value of electric energy consumption for every category by the top of each curve, as well as the total electric energy consumption of every category by the range of each curve is observed.

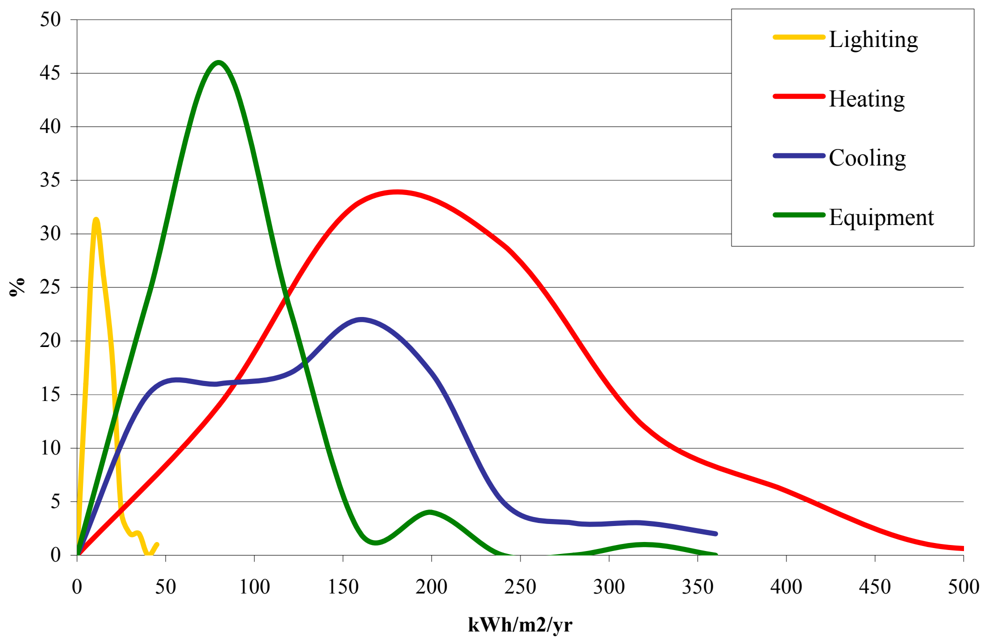

Figure 4.7: Distribution of electric energy consumption per category

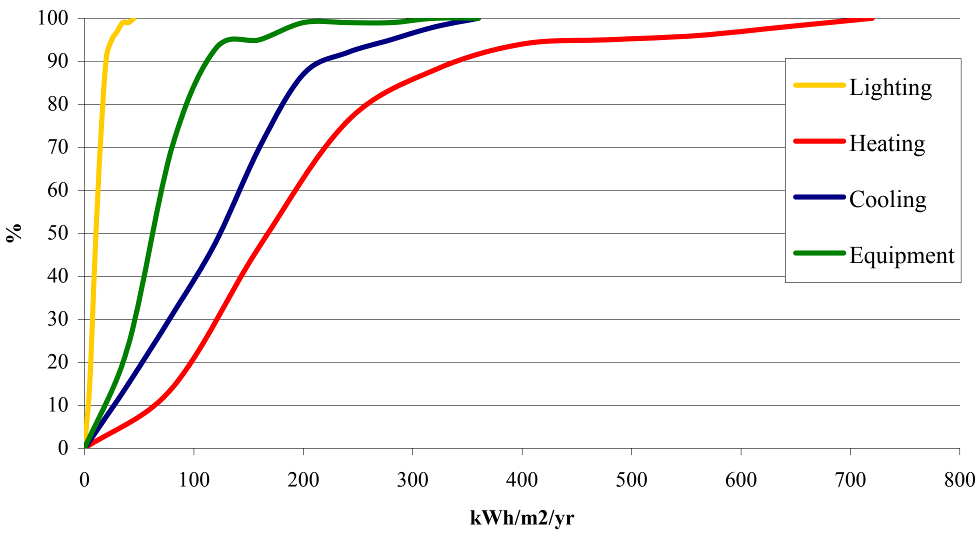

Figure 4.8: Additive distribution of electric energy consumption per category

The total electric energy consumption regarding all mentioned categories is shown in Figure 4.9. Hereupon, 12% of offices consume 150 kWh/m^2/yr, 23% of offices consume 300 kWh/m^2/yr, 30% of offices consume 450 kWh/m^2/yr, 21% of offices consume 600 kWh/m^2/yr, 8% of offices consume 750 kWh/m^2/yr and 2% to 4% of offices consume 900 to 1050 kWh/m^2/yr.

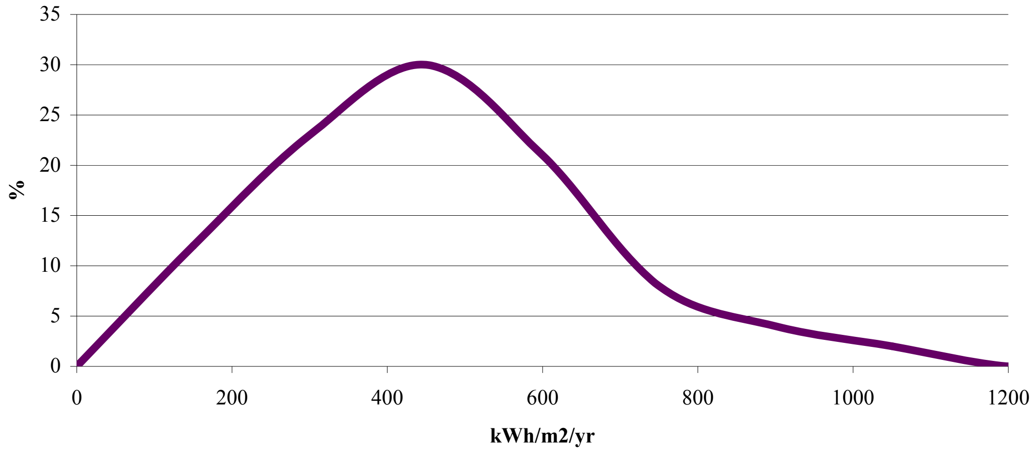

Figure 4.9: Total electric energy consumption of offices

The usage percentage for every office is represented in the following Figure 4.10. As depicted in the Figure, the usage percentage of offices varies between 7 to 25%.

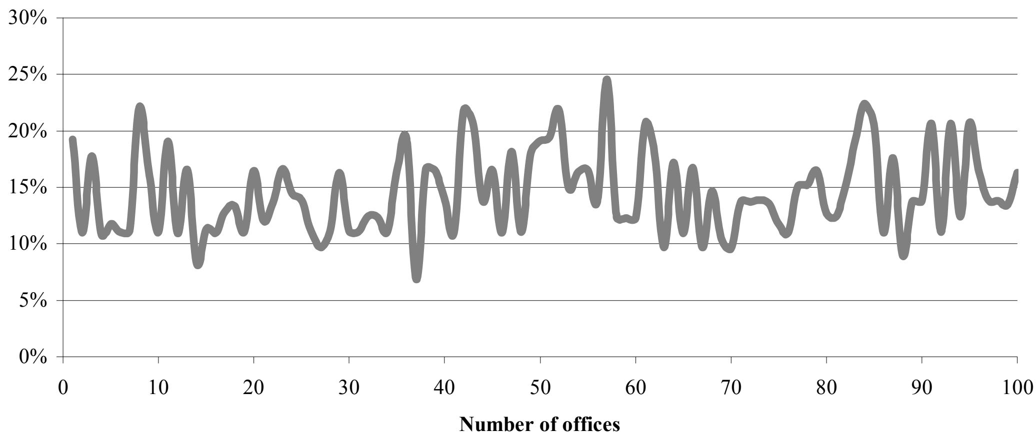

Figure 4.10: The usage percentage of offices

Chapter 5

Classification of office buildings by an advanced edition of Matrix tool "Matool"

5.1 Introduction

Matrix tool "Matool" has been developed in the framework of the SAVE Program:" SMART Accelerate-Acceleration of SMART Buildings technologies and market penetration", [67]. An advanced edition of Matool (Matool, v.2) has been developed in order to classify office buildings by their energy performance including not only qualitative characteristics but quantitative as well.

5.2 Description of Matool, v.2

Matool, v.2 is an easy to handle software developed in Visual Basic 6. Matool interface is shown in Figure 5.1. The Matool, v.2 includes the following categories as performance indicators:

- Lighting
- Heating
- Cooling
- Indoor environment
- Equipment

These five performance indicators are divided in either qualitative or quantitative sub-performance indicators. Each of the performance indicators has a value ranging from

0 to 4, with 4 indicating the best and 0 indicating the worst (see Annex B). The two first sub-performance indicators for lighting are represented in Figure 5.2.

The maximum value for each performance indicator is 16 and the total 80. The rating is accordingly specified as follows:

- Bad: <12
- Pass: 13-25
- Good: 26-38
- Very good: 39-51
- Excellent: 52-80

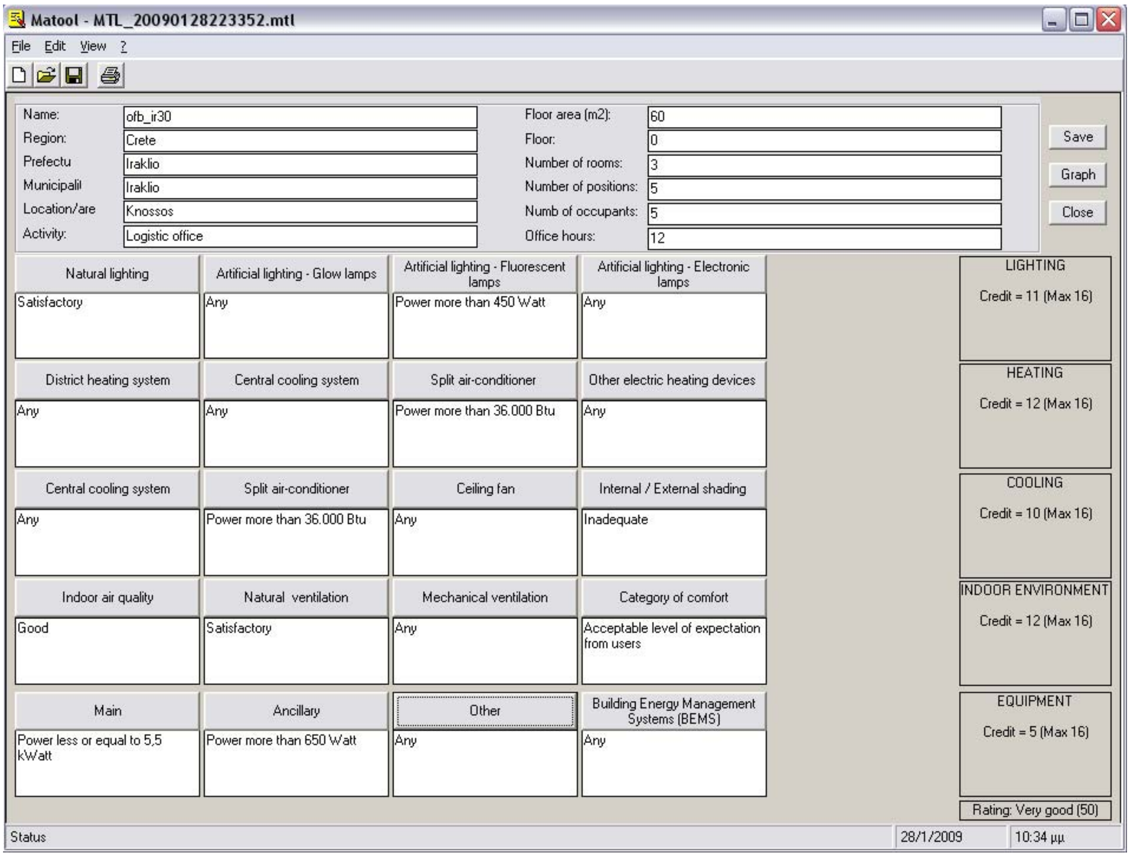

Figure 5.1: Matool interface

The building is assessed using the developed questionnaire (see Annex B). The building features directly influence each individual performance indicator and the overall performance of a building. The tool assists in the identification of building's weak points that are illustrated in graphics.

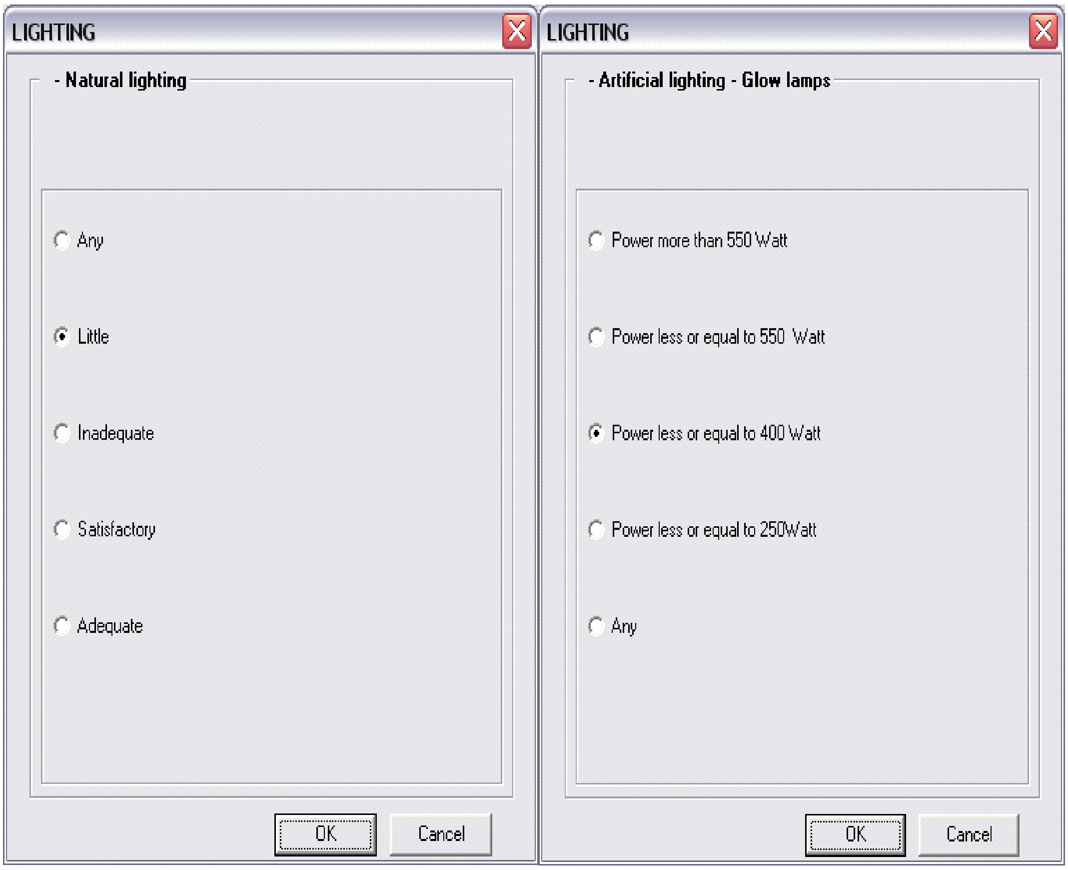

Figure 5.2: Sub-performance indicators for lighting

5.3 Survey results

Matool, v.2 has been applied in 10 office buildings as index reference, concerning the population concentration in the four Prefectures of Crete. Hereupon, the survey results of five case studies in the Prefecture of Iraklio are represented, the survey results of 3 case studies in the Prefecture of Chania and 1 case study for the Prefecture of Rethymno and Lassithi, respectively.

5.3.1 Case study 1

This office building is located in the area of Estavromenos in the city of Iraklio. It is a ground floor engineer technical office of 100 m^2 floor area. It has achieved an overall score of 47 out of a maximum 80, which rates the office in the very good category. More precisely, it has scored 10 credits in lighting and cooling, 14 in heating, 7 in indoor environment and 6 in equipment, as shown in Figure 5.3. According to the survey results, enhancement in the indoor environment and reduction in the electric energy consumption of the equipment is suggested.

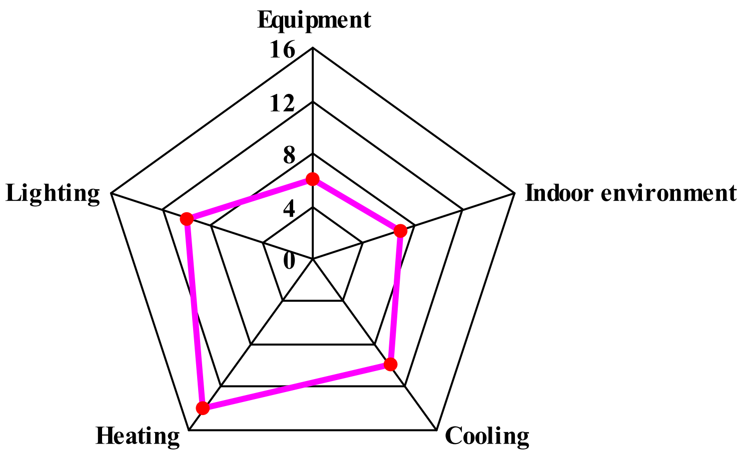

Figure 5.3: Case study 1 survey results

5.3.2 Case study 2

The following office building is located in the centre of the city of Iraklio. It is a law office of 35 m^2 floor area in the 4th floor of the building. It has achieved an overall score of 66 out of a maximum 80, which rates the office in the excellent category. More precisely, it has scored 14 credits in lighting, heating and cooling, 13 in indoor environment and 11 in equipment, as shown in Figure 5.4. In accordance with the survey results, the office building has a very good performance as it is classified in the excellent category.

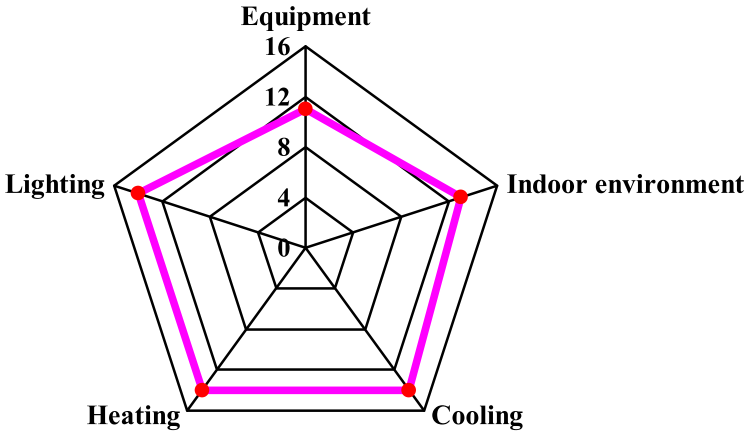

Figure 5.4: Case study 2 survey results

5.3.3 Case study 3

The next office building is located in the area of Gazi in the city of Iraklio. It is a ground floor civil engineering office of 70 m^2 floor area. Overall, this building has achieved a score of 44 out of a maximum 80.This suggests that this office building is classified in the very good category. It has scored in particular 10 credits in lighting, 12 in heating and in indoor environment, 8 in cooling and 2 in equipment, as shown in Figure 5.5. According to the survey results, a reduction in the electric energy consumption of the equipment as well as the cooling should be achieved in order to improve the energy performance of the building.

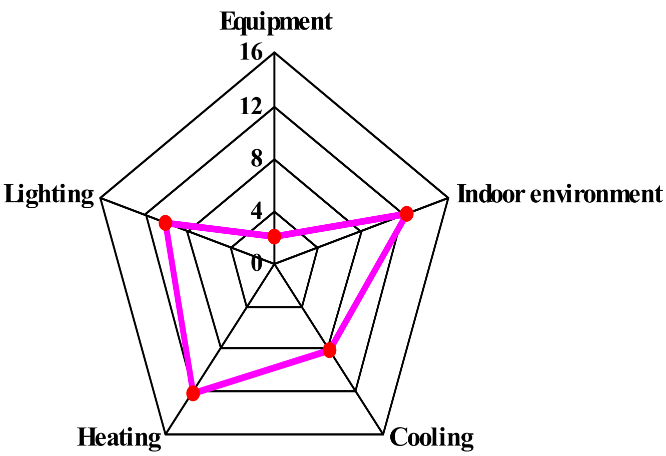

Figure 5.5: Case study 3 survey results

5.3.4 Case study 4

The following office building is located in the centre of the city of Iraklio. It is an engineer technical office of 90 m^2 floor area in the 1st floor of the building. It has achieved an overall score of 28 out of a maximum 80, which rates the office in the good category. It has scored specifically 5 credits in lighting and in cooling, 4 in heating, 8 in indoor environment and 6 in equipment, as shown in Figure 5.6. In accordance with the survey results, this office building has achieved low credits in all performance indicators. Hereupon, reduction in the electric energy consumption of lighting, heating, cooling and equipment as well as enhancement in indoor environment should be accomplished.

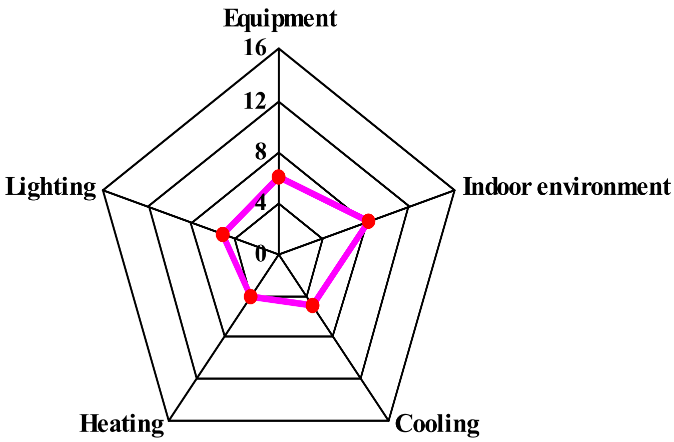

Figure 5.6: Case study 4 survey results

5.3.5 Case study 5

This office building is located in the centre of the city of Iraklio. It is a ground floor architectural office of 100 m^2 floor area. It has achieved an overall score of 39 out of a maximum 80, which rates the office in the very good category. More precisely, it has scored 6 credits in lighting, 4 in heating, 9 in cooling, 12 in indoor environment and 8 in equipment, as shown in Figure 5.7. According to the survey results, a reduction in the electric energy consumption of lighting, heating, cooling and equipment should be considered.

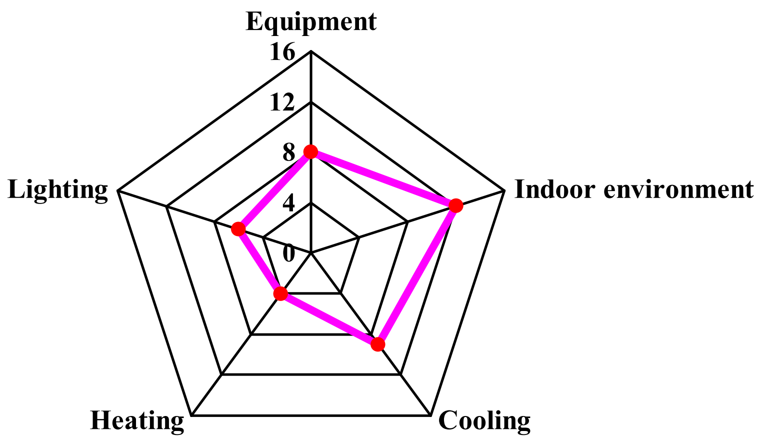

Figure 5.7: Case study 5 survey results

5.3.6 Case study 6

The following office building is located in the centre of the city of Chania. It is a ground floor real estate office of 35 m^2 floor area. It has achieved an overall score of 70 out of a maximum 80, which rates the office in the excellent category. More precisely, it has scored 13 credits in lighting, 16 in heating, 15 in cooling and in indoor environment and 11 in equipment, as shown in Figure 5.8. According to the survey results, the office building has a very good performance as it is classified in the excellent category.

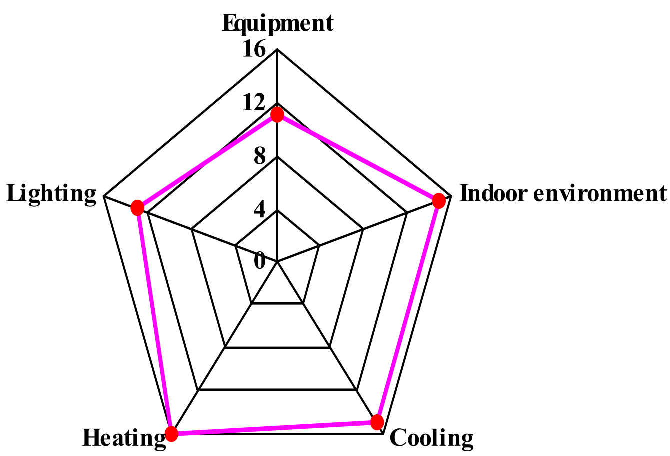

Figure 5.8: Case study 6 survey results

5.3.7 Case study 7

The following office building is located in the centre of the city of Chania. It is a logistic office of 90 m^2 floor area in 5^{th} floor. It has achieved an overall score of 49 out of a maximum 80, which rates the office in the very good category. More precisely, it has scored 10 credits in lighting, 14 in heating, 13 in cooling, 9 in indoor environment and 3 in equipment, as shown in Figure 5.9. In accordance with the survey results, reduction in the electric energy consumption of equipment is suggested.

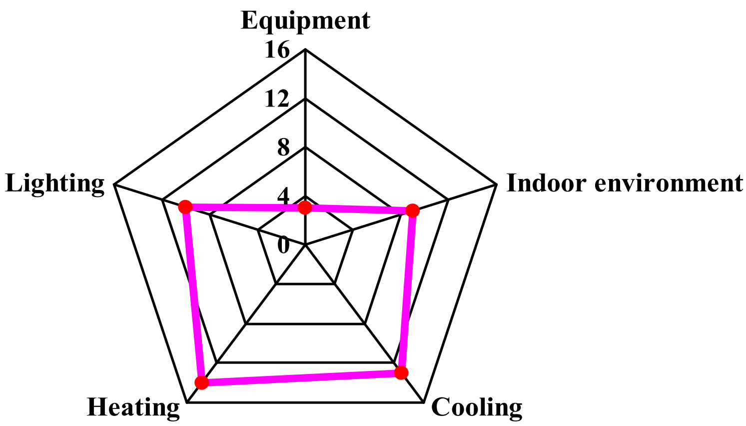

Figure 5.9: Case study 7 survey results

5.3.8 Case study 8

The following office building is located in the centre of the city of Chania. It is an engineer technical office of 110 m^2 floor area in 5^{th} floor. This office building has achieved an overall score of 34 out of a maximum 80. This credit rates the office building in the good category. More precisely, it has scored 12 credits in lighting, 4 in heating and in cooling, 10 in indoor environment and 4 in equipment, as shown in Figure 5.10. According to the survey results, reduction in the electric energy consumption of heating, cooling and equipment should be achieved.

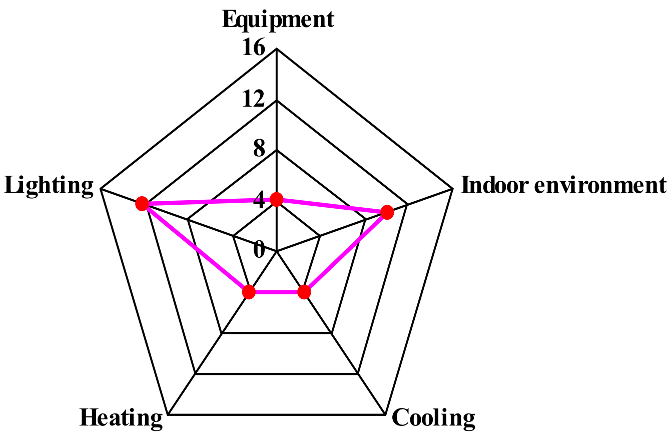

Figure 5.10: Case study 8 survey results

5.3.9 Case study 9

The following office building is located in the centre of the city of Rethymno. It is an engineer technical office of 60 m^2 floor area in 1st floor. It has achieved an overall score of 51 out of a maximum 80, which rates the office in the very good category. It has scored in particular 11 credits in lighting, in cooling and in indoor environment, 12 in heating, and 6 in equipment, as shown in Figure 5.11. According to the survey results, reduction in the electric energy consumption of equipment is suggested.

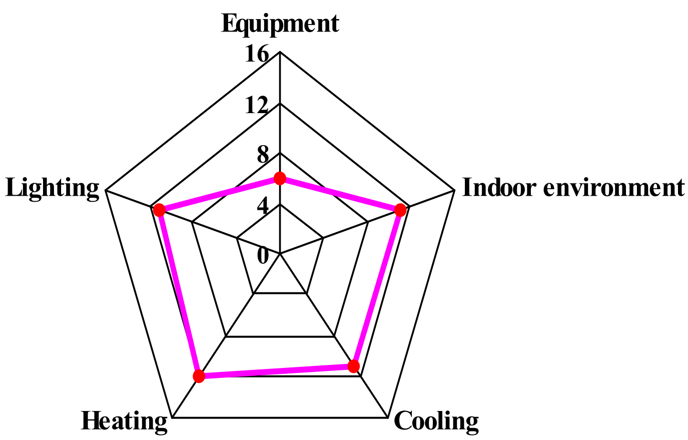

Figure 5.11: Case study 9 survey results

5.3.10 Case study 10

The following office building is located in the centre of the city of Ierapetra. It is a ground floor engineer technical office of 45 m^2 floor area. It has achieved an overall score of 58 out of a maximum 80, which rates the office in the excellent category. More precisely, it has scored 11 credits in lighting, 15 in heating, 12 in cooling, 10 in indoor environment and in equipment, as shown in Figure 5.12. According to the survey results, the office building has a very good performance as it is classified in the excellent category.

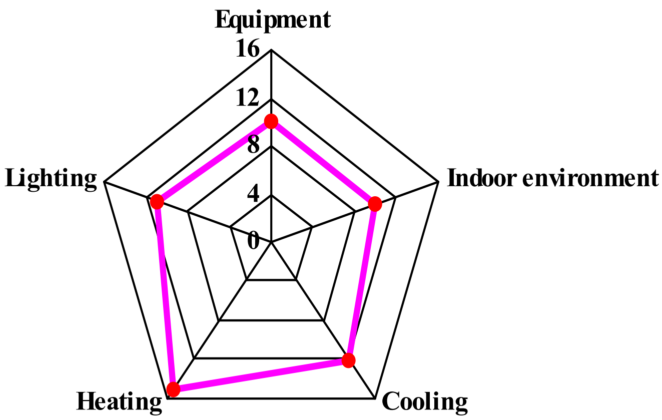

Figure 5.12: Case study 10 survey results

Chapter 6

Conclusions and future work

6.1 Conclusions of the thesis

In conformance with the recent Common Ministerial Decision (OHJ 1122/B/17-6-08) “Measures for the improvement of energy performance and energy saving in public sector”, the classification of office buildings regarding the level of expectation is implemented. According to category III “An acceptable, moderate level of expectation and may be used for existing buildings”, the recommended indoor temperature concerning office buildings is defined at 27 ^{0}C for summer season and at 19 ^{0}C for winter season, respectively as mentioned in section 3.2.

Hereupon, according to the recommended indoor temperatures for summer and winter season and the average hourly temperatures for one year of the city of Iraklion, the requirements for heating and cooling were calculated (see chapter 4).

Therefore, heating requirements were appraised to be 80%, while the electric energy consumption of heating was calculated almost at 50% of the offices’ total electric energy consumption. On the other hand, the requirements for cooling were appraised to be almost 20%, whereas the electric energy consumption of cooling was calculated at 30%.

It is observed a noticeable difference in the appraised requirements of heating by 30% in accordance with its consumption and in consumption of cooling by 10% in accordance with its appraised requirements. As a result, measures for energy saving in cooling should be into effect in order to reduce the consumption of cooling and therefore the total consumption of offices in the island of Crete.

Furthermore, in accordance with the survey results of the selected office buildings in Chapter 5, high electric energy consumption in the category of equipment, cooling and heating is observed. For this reason, technologies of energy saving should be applied in order to reduce electric energy consumption and at the same time increase energy performance of office buildings.

Energy saving for the category of equipment in particular may be obtained by increasing efficiency, while energy saving for the category of cooling and heating by adding insulation as well as internal and external shading.

It is also of great significance, the observance of temperature limit values for winter and summer season by the occupants, in order to achieve the conservation of energy in buildings.

6.2 Future work

The building sector in Greece consumes high electric energy, due to the fact that the great majority of Hellenic building stock is not thermally insulated.

Knowing the u values, which are available in the Building Thermal Insulation Regulation and the Regulation on Rational Use and Energy Conservation in buildings and heating degree days regarding the classification of Greece in four different climatic zones, energy use saving of heating and cooling in office buildings in Greece can be implemented, in order to reduce electric energy consumption and at the same time the carbon dioxide emissions in the environment.

Different scenarios of energy saving can be applied in order the higher energy saving to be accomplished. Furthermore, the classification of office buildings in Greece by their energy performance can be considered.

As a result, Greece is going to implement more easily the requirements set by Directive 2002/91/EC on Energy Performance of buildings, as well as by Kyoto Protocol.

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Annex A

Nr.	Work Item (WI)	Technical Commitee (TC)	prEN
GENERAL STANDARDS GROUP			
Group 1: Standards dealing with the calculation of total energy in buildings			
1+3	Energy performance of buildings - Methods of expressing energy performance and for energy certification of buildings.	TC 89	prEN15217
2	Energy performance of buildings - Overall energy use, primary energy and CO_2 emissions.	TC 228	prEN15315
4	Energy performance of buildings - Assessment of energy use and definition of ratings.	TC 89	prEN15203
Group 2: Standards dealing with observation and control of total performance of buildings			
5	Energy performance of buildings - Inspection of boilers and heating systems.	TC 228	prEN15378
6	Ventilation for Buildings - Energy performance of buildings - Guidelines for the inspection of air-conditioning systems.	TC 156	prEN15240
30	Guidelines for inspection of ventilation systems.	TC 156	prEN15239
COMPUTATIONAL STANDARDS GROUP			
Group 3: Standards dealing with the calculation of energy consumption in buildings			
7	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 1: General	TC 228	prEN15316 - 1
8	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2.1: Space heating emission systems.	TC 228	prEN15216 - 2-1
9	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2.2: Space heating generation systems: Part 2.2.1. Combustion systems (Boilers). Part 2.2.2. Heat pump systems. Part 2.2.3. Thermal Solar systems (including DHW). Part 2.2.4 The performance and quality of CHP electricity and heat (incl. on-site and micro-CHP). Part 2.2.5. The performance of quality district heating and large volume systems. Part 2.2.6. The performance of other renewable heat and electricity. Part 2.2.7. Biomass combustion systems.	TC 228	prEN15216 - 4-1 4-2 4-3 4-4 4-5 4-6 4-7
10	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 2.3: Space heating distribution systems.	TC 228	prEN15316 - 2-3
11	Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 3: Domestic hot water systems: 3.1 Characterisation of needs (tapping requirements) 3.2 Distribution 3.3 Generation	TC 228	prEN15316 - 3-1 3-2 3-3
12	Ventilation for Buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems.	TC 156	prEN15243
13	Energy performance of buildings - Energy requirements for lighting - Part1 : Lighting energy estimation.	TC 169	prEN15193 - 1
14	Energy performance of buildings - Calculation of energy use for space heating and cooling - (with extension of scope of EN ISO 13790).	TC 89	EN ISO13790
15	Thermal performance of buildings - Calculation of energy use for space heating - Simplified method.	TC 89	EN ISO13790

Group 4: Standards dealing with the calculation of building energy requirements			
16	Thermal performance of buildings - Sensible room cooling load calculation - General criteria and validation procedures.	TC 89	prEN15255
17	Thermal performance of buildings - Calculation of energy use for space heating and cooling - General criteria and validation procedures.	TC 89	prEN15265
18+19	Ventilation for buildings - Calculation methods for the determination of air flow rates in dwellings of buildings including infiltration.	TC 156	prEN15242
20+21	Ventilation for buildings - Calculation methods for energy requirements due to ventilation systems in dwellings of buildings.	TC 156	prEN15241
22	Calculation methods for energy efficiency improvements by the application of integrated building automation systems.	TC 247	prEN15232
Group 5: Supporting standards			
23	Review of standards dealing with calculation of heat transmission in buildings – 1st set - Thermal performance of building components - Dynamic thermal characteristics - Calculation methods - Thermal performance of buildings - Transmission and ventilation heat transfer coefficients - Calculation method - Thermal performance of windows, doors and shutters - Calculation of transmittance Part 1 : General	TC 89	prEN-ISO 13786 13789 10077-1
24	Review of standards dealing with calculation of heat transmission in buildings – 2nd set - Building material and products - Hygrothermal prperties - Tabulated design thermal values and procedures for determining declared and design values - Heat transfer via the ground - Calculation methods - Thermal bridges - Heat flows and surface temperatures - Detailed calculations - Thermal bridges - Linear transmittance - Simplified methods and default values - Thermal resistance and thermal transmittance - Calculation method	TC 89	prEN-ISO 10456 13370 10211 14683 6946
25	Ventilation for non residential buildings - Performance requirements for ventilation and room conditioning systems.	TC 156	prEN13779
26	Design of Embedded water based surface heating and cooling systems: Part 1: Determination of the design heating and cooling capacity. Part 2: Design, Dimensioning and Installation. Part 3: Optimizing for use of renewable energy sources.	TC 228	prEN15377 -1 -2 -3
27	Performance requirements for temperature calculation procedure without mechanical cooling.	TC 89	prEN13791
28	Thermal performance of buildings - Calculation of internal temperatures of a room in summer without mechanical cooling - Simplified method.	TC 89	prEN13792
29	Data requirements for standard economic evaluation procedures related to energy systems in buildings, including renewable energy sources.	TC 228	prEN15459
31	Criteria for the indoor environment, including thermal, indoor air quality, light and noise.	TC 156	prEN15251

Annex B

<u>Questionnaire</u>

General characteristics of office buildings

Region:…………………………………………………………………………
Prefecture:…………………………………………………………………………
Municipality:………………………………………………………………
Location/area:………………………………………………………………
Activity:……………………………………………………………………………
Floor area (m^2):…………………………………………………………………...
Floor:……………………………………………………………………………
Number of rooms:……………………………………………………………………………
Number of positions:…………………………………………………………..........................
Number of occupants:………………………………………………………………………
Office hours:………………………………………………………………………..

Category 1 : Lighting

1.1

Natural lighting	
Any	0
Little	1
Inadequate	2
Satisfactory	3
Adequate	4

1.2

Artificial lighting – Glow lamps	
Power more than 550 Watt	0
Power less or equal to 550 Watt	1
Power less or equal to 400 Watt	2
Power less or equal to 250Watt	3
Any	4

1.3

Artificial lighting – Fluorescent lamps	
Power more than 450 Watt	0
Power less or equal to 450 Watt	1
Power less or equal to 300 Watt	2
Power less or equal to 150Watt	3
Any	4

1.4

Artificial lighting – Electronic lamps	
Power more than 110 Watt	0
Power less or equal to 110 Watt	1
Power less or equal to 80 Watt	2
Power less or equal to 50 Watt	3
Any	4

Category 2 : Heating

2.1

District heating system	
Power boiler more than 150 kcal	0
Power boiler less or equal to 150 kcal	1
Power boiler less or equal to 80 kcal	2
Power boiler less or equal to 40 kcal	3
Any	4

2.2

Central cooling system	
Power more than 36.000 Btu	0
Power less or equal to 36.000 Btu	1
Power less or equal to 24.000 Btu	2
Power less or equal to 12.000 Btu	3
Any	4

2.3

Split air-conditioner	
Power more than 36.000 Btu	0
Power less or equal to 36.000 Btu	1
Power less or equal to 24.000 Btu	2
Power less or equal to 12.000 Btu	3
Any	4

2.4

Other electric heating devices	
Power more than 4,5 kWatt	0
Power less or equal to 4,5 kWatt	1
Power less or equal to 3 kWatt	2
Power less or equal to 1,5 kWatt	3
Any	4

Category 3 : Cooling

3.1

Central cooling system	
Power more than 36.000 Btu	0
Power less or equal to 36.000 Btu	1
Power less or equal to 24.000 Btu	2
Power less or equal to 12.000 Btu	3
Any	4

3.2

Split air-conditioner	
Power more than 36.000 Btu	0
Power less or equal to 36.000 Btu	1
Power less or equal to 24.000 Btu	2
Power less or equal to 12.000 Btu	3
Any	4

3.3

Ceiling fan	
Power more than 180 Watt	0
Power less or equal to 180 Watt	1
Power less or equal to 120 Watt	2
Power less or equal to 60 Watt	3
Any	4

3.4

Internal / External shading	
Any	0
Little	1
Inadequate	2
Satisfactory	3
Adequate	4

Category 4 : Indoor environment

4.1

Indoor air quality	
Bad	0
Normal	1
Good	2
Very good	3
Excellent	4

4.2

Natural ventilation	
Any	0
Little	1
Inadequate	2
Satisfactory	3
Adequate	4

4.3

Mechanical ventilation	
Power more than 75 Watt	0
Power less or equal to 75 Watt	1
Power less or equal to 45 Watt	2
Power less or equal to 30 Watt	3
Any	4

4.4

Category of comfort	
No level of expectation from users	0
No acceptable level of expectation from users	1
Normal level of expectation from users	2
Acceptable level of expectation from users	3
High level of expectation from users	4

Category 5 : Equipment

5.1

Main	
Power more than 5,5 kWatt	0
Power less or equal to 5,5 kWatt	1
Power less or equal to 4 kWatt	2
Power less or equal to 2 kWatt	3
Any	4

5.2

Ancillary	
Power more than 650 Watt	0
Power less or equal to 650 Watt	1
Power less or equal to 500 Watt	2
Power less or equal to 350 Watt	3
Any	4

5.3

Other	
Power more than 1 kWatt	0
Power less or equal to 1 kWatt	1
Power less or equal to 700 Watt	2
Power less or equal to 400 Watt	3
Any	4

5.4

Building Energy Management Systems (BEMS)	
Any	0
Little	1
Inadequate	2
Satisfactory	3
Adequate	4