MODELLING STUDY OF THE ENERGY PERFORMANCE OF GREEK EDUCATIONAL BUILDINGS

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Abstract

The requirements of the Energy Performance of Buildings Directive and the corresponding transposition into the Greek Building Regulations will have a significant impact on building design in Greece. In order to study the range of design options which may be applicable in the various climatic regions of Greece for reducing the energy consumption in buildings, a parametric analysis using simulation was undertaken of the standard building typologies typical of Greek construction.

The parametric analysis was focused on educational buildings, and was aimed at identifying benchmark performance and establishing guidelines and options for designers. In order to attain these benchmarks, different typologies of buildings in the respective climatic zones of the country were investigated.

The analysis made use of the ESP-r simulation program and considered the impact of the design changes not only on the energy usage, but also in terms of other performance criteria, particularly thermal comfort. The results of the study allowed some general conclusions to be reached on the energy and environment performance of various design options for educational buildings in different locations in Greece.

The analysis focused on the climate responsive aspects of the construction and design of the buildings. The design of educational buildings requires awareness by the architect for the materials needed for the construction of an energy efficient building. Design options such as insulation characteristics, building orientation and ventilation during the four seasons in scattered locations were considered. All these parameters were analyzed using ESP-r in order to identify which actions need to be taken into account when designing energy efficient educational buildings.

CONTENTS

1 Introduction

In the recent years there is an increasing need to find ways in order to improve the energy efficiency of buildings. In order to do this, governments are investing a lot in research in order to identify the benchmarks and therefore create a set of laws which are to be applied when constructing or renovating buildings. The EPBD (Energy Performance Building Directive) is an example of such laws which were assembled by several institutes. The EPBD is scheduled to be in force from January 2006 in Europe. This means that all countries should have to comply with these laws at all stages of a building's construction and operation.

Greece in order to assist EPBD to set the correct benchmarks in proportion to its geographic position and in accordance with the climatic conditions that affect the different regions is one of the countries that are investing in research which is intended to find the minimum requirements needed in order to identify these benchmarks. One of the areas of interest of CRES (Centre for Renewable Energy Sources) which is a government organization is in conducting research in order to identify the minimum requirements of building energy efficiency that should be applied in accordance with EPBD.

One of CRES's interests lies in educational buildings because it cooperates with OSK (Organization of School Buildings). This is because schools represent a large number of buildings within the country, they are public, and their contribution to energy consumption is very high due to their big capacity. The research that CRES is interested in conducting is in different building types (and specifically in educational buildings) focused in the identification of the building energy performance in different climatic zones with the use of different wall insulations and glazing types in different orientations in order to identify how all these parameters can affect the building's energy performance and therefore identify the correct criteria that should be followed and applied by designers.

Esp-r is a tool provided by the 'University of Strathclyde Research Centre (ESRU)' of the Mechanical Engineering Department which can be used in order to perform such parametric analysis. The software package is very reliable and accurate and compared to other packages it offers the ability to measure occupants comfort level which in combination with the results of energy performance can offer a complete outcome.

The aim of this thesis is to create a parametric analysis in two types of Greek educational buildings (Linear and L-shape) using esp-r software package in two climatic zones (Athens – Zone B, Thessaloniki – Zone C) and in different building orientations (eight orientations) using four different types of wall insulation and glazing (Case 1, Case 2, Case 3, Case 4). The results of this research will contribute to the efforts of CRES.

In detail, the current thesis includes the following chapters:

- Energy Use in Buildings: This chapter aims in providing a brief description of what EPBD is and what its main functionalities are, which is the current status of EPBD progress in Greece, and which are the factors that affect energy performance of buildings.

- Environmental Performance of School Buildings: This chapter intends to provide details of the analysis that has already been performed in Greek educational buildings in previous research studies and to list some technical criteria that need to be taken into consideration by designers.

- Climate: This chapter includes the details related to the climatic zones in Greece and provides data that need to be considered in the analysis.

- ESP-R Modelling and Methodology: This chapter includes the details related to the educational building types which were analyzed and the simulation strategies that were used during the analysis.

- Results Analysis: This chapters aims in illustrating the results obtained from the analysis performed on the two different educational building types.

- Conclusions and Recommendations: This chapter summarizes the main outcomes of this research and presents the main improvements that can be carried out in further research.

- Appendices: This chapter includes the additional information that supports the analysis. In addition, it also contains some standards which were used in the analysis.

2 Energy Use in Buildings

2.1 Introduction

Energy use in buildings accounts for almost half of all CO_2 emissions in the EU. Yet measures exist today that could slash this figure by one third [1]. The European Directive on the Energy Performance of Buildings (EPBD) (2002/91/EEC) is the most significant measure that has been adopted by the EU to reduce buffer gas emissions from buildings. The Directive's focus is on new buildings, whilst also proposing certain measures that encourage energy efficiency improvements for existing large buildings (greater than $1000m^2$) [1].

Although an important first step, the Directive only taps into a fraction of the potential that exists to reduce emissions. The new research demonstrates that 90% of the potential to reduce emissions from buildings lies outside the current EU rules. The findings show that the current legislation fails to cover four key aspects [1]:

- Although the EU Directive provides a good first framework for new and large buildings, most emissions come from existing small buildings – it is here that the real potential for significant emissions reductions must be seized.

- Energy efficiency in buildings is generally associated with heating, but as temperatures and incomes rise, so does the use of air conditioning – especially in central and southern Europe. Proper energy efficiency measures concerned with improving the building fabric can be used to combat the energy needed to cool homes.

- the warmer the climate, the more impact energy efficiency measures can have

- energy efficiency measures, in particular reducing heat load, can reduce the cooling demand of a building by up to 70%

That is why the Commission has to enact Article 11 of the Directive – which instructs Member States to recommend further upgrading measures. It should implement this article very swiftly.

2.2 EPBD - Energy Performance Building Directive

EPBD (Energy Performance Building Directive) represents a set of laws which aim to be applied to building designers when constructing or renovating buildings in order to manage better energy consumption. It is important to note that many challenges will have to be faced through EPBD. In detail, the future of the building sector will have to comply with the new rules for construction. Initially the challenges that have been addressed are the calculation concerns of estimating the ideal energy performance of a building and then implementing it. Therefore, the consideration of the country's approach of tackling those issues need to be mentioned. The following standards need to be considered [4]:

A. For Energy performance standardization (Standard procedure calculations)

1. Approach of focusing on total energy use
2. Specific attention for indoor climate
3. Performance orientated procedures
4. Procedures in line with EN standards
5. Attention for design component and execution performance
6. Designer orientated software support
7. Various levels of complexity and procedures

B. For Energy performance legislation (practical implementation)

1. Consultation with building sector
2. Correct boundary conditions for various actors

3. Easy access to reliable input data
4. Appropriate requirement levels
5. Legal framework on principle for equivalence
6. Clear procedures allowing effective control
7. Effective system for compliance checking
8. General awareness, training, etc.

In order to place in a framework the specific issues of the legal context that have been addressed four categories have been identified [4]:

1. Design Process – Concerns about the general information of the legal context
2. Construction of the building – Requirements and characteristics of EP (Energy Performance) during design phase
3. Delivery of the building – Construction phase
4. Operation of the building – “Upon delivery” and “after construction” phases

2.3 Implementation challenges of EPBD

The designer or the responsible engineer has to prepare a document to satisfy the specific requirements of the regulation [4]. This may involve energy calculations or specific estimations (U-values, shading values etc.). This document has to be submitted to an official authority in order to obtain the permission to build. During the construction or later the authority may check or not the compliance with the regularity [4].

1. For the existing buildings both residential and non-residential sectors must comply only in cases of major renovation
2. The architects and the engineers are responsible for the overall design of the building and should carry out calculations assisted by experts or not.
3. Energy performance calculations must be performed only by accredited experts
4. Calculations should be checked by the authorities.

5. The final energy consumption as well as the performance of some building components has to be calculated.
6. An energy certification scheme based on the calculated energy consumption of the building is in force.
7. Mandatory or voluntary control during the construction phase is applied
8. The building office is authorized to check the compliance of the building at any time from representative of states or local municipalities.
9. The builder owner or his representative are ordered to change the parts which are sub-standards
10. Responsibility of the owner in case of non-compliance with EP regulations
11. Certification schemes during the after construction stages applies as function of energy
12. The building may be inspected by the state upon delivery
13. The building may be inspected after its construction

2.4 Current Status

Considerable work, towards the calculation and certification of energy performance of buildings, has been completed in Greece over the past six years. The national compliance act with the SAVE 93/76 Directive has instituted [6]:

- The elaboration of a new Regulation for Energy Efficiency in Buildings, which has been already drafted,

- The implementation of energy auditing activities for buildings, according to another act, the Regulation for Energy Audits, issued in 1999. Furthermore, the authorization process for potential energy auditors has been prescribed to form a separate legal act. The above framework is pending minor upgrading, review and official approval by the governmental authorities, to follow the mandates of EPBD and is expected to be contained within the forthcoming national legislation of compliance with the Directive.

- Within the framework of the EPBD implementation, work is proceeding in the following areas: The Ministry of Development has formed a committee having as tasks to steer the application of the Directive issues, to produce and assess supporting regulatory documentation and to make summary proposals to the government in order to structure the new legal system of compliance with EPBD. During regular weekly meetings the committee analyzes topics of performance calculation methodology, energy certification procedures and energy experts-auditors-HVAC equipment inspectors.

2.5 EPBD legal context

Concerning the applications of the EP regulations to buildings subject to renovation Greece requires from the building owners to comply, both residential and non-residential buildings with EP regulations, only in cases of major renovation.

The Architects and engineers are responsible for the overall design of the building and should carry out the EP calculations assisted or not by experts. In Greece energy performance calculations, should be performed only by accredited experts. These should be checked by the authorities. The final annual energy consumption as well as the performance of some building components has to be calculated. The following standards should be met [4]:

1. An index in the range 1 to 120 based on the costs per unit floor area per year, for space and water heating, and

2. An index in the range 0.0 to10.0, based on the CO2 emissions per unit floor area per year, attributable to space and water heating (for standard occupancy and heating level).

In Greece an energy certification scheme based on the calculated energy consumption of the building is in force.

The following legal aspects and the current condition in Greece have been addressed. These involve the construction phase, delivery phase, after construction phase, energy performance requirements, and minimum energy requirements for new and existing buildings [4].

2.5.1 Legal Aspects during the Construction Phase

The main legal aspects considered for the construction phase of a building, deal with possible inspections and the characteristics of these inspections, possible penalties or sanctions applied in the case of non compliance with the EP legislation, as well as with aspects related to the legal responsibility during construction.

Regarding possible inspections during the construction phase, three specific legislative conditions have been identified. These are: a) countries, which apply a self control procedure, b) countries that apply a mandatory or voluntary control procedure and finally c) countries applying a non control procedure [4].

Mandatory or voluntary control during the construction phase is applied in Greece. Most of the time there is no inspection during the construction of a building and there is no predetermined procedure – it depends on the controller. Officials can inspect the construction site or the finished building at any time up to 5 years after submittance of the dossier-as-built. In principle anything that enters the EP calculation may be checked. However, It is voluntary to have a quality assurance.

A self control approach is also applied for large projects. The control procedures concern mainly water and sewage systems, ventilation systems and thermal insulation, but not components such as heating systems. The control is made mainly in those points, in which security and healthy considerations must be taken into account. The control is made for designing the final systems and structures and also for some intermediate constructions. A self control approach is also applied [4].

In Greece, the building office is authorised to check the compliance of the building with the regulations at any time. It checks the thickness of insulation, the type of boiler, etc. Moreover, the builder-owner or his representative is ordered to change the part which is sub-standard otherwise the construction may stop. Regarding possible responsibility of the individuals in case of non compliance with the EP regulations, in Greece the responsibility is with the owner.

2.5.2 Legal aspects upon delivery phase

The main legal aspects considered for the upon delivery phase of a building, deal with possible inspections and the characteristics of these inspections, possible penalties or sanctions applied in the case of non compliance with the EP legislation, as well as with aspects related to the legal responsibility upon delivery of the building, and the application of certification schemes during this phase [4].

- In Greece the building control office is authorised to check the compliance of the building with the regulation at any time. However the procedure has not yet been applied. Inspections are preformed by representatives of the states or of the local municipality.

- Regarding possible sanctions in Greece the owner has to change parts that do not comply with the regulation or in case of a serious bias.

- Regarding responsibility in Greece, it is with the owner.

- Regarding certification schemes they are applied during the upon delivery phase.

2.5.3 Legal aspects during the after construction Phase

The main legal aspects considered for the “after construction” phase of a building deal with possible inspections and the characteristics of these inspections, the system to be inspected, possible penalties or sanctions applied in the case of non compliance with the EP legislation, as well as with aspects related to the legal responsibility after construction and the application of certification schemes during this phase. Concerning [4]:

- inspections and controls during the 'after construction' phase, the building control office is authorised to check the compliance of the building with the regulations at any time. However the procedure has not yet been applied.

- the systems and components to be controlled, all parameters related to the EP may be controlled

- possible sanctions or penalties, the owner has to change the parts that do not comply with the regulations.

- the responsibility for non compliance with the EP regulations, the responsibility is with the owner

- application of certification schemes during the after construction phase, a certifications scheme applies as function of the energy.

In Greece the new methodology according to EPD is almost ready. The existing methodology does not correspond to the requirements of the EPD and is based just on the U value of the building. A new methodology that fits perfectly with the requirements of EPD has been prepared and is expected to be applied.

2.5.4 Energy Performance requirements

According to article 4 of the EPD:

'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 technical progress in the building sector. The energy performance requirements shall be applied in accordance with Article 5 and 6.3. Member States may decide not to set or apply the requirements referred to in paragraph 1 for the following categories of buildings [4]:

- 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 workship and 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 that four months of the year,

Stand-alone buildings with total useful area less than 50 m^2 are part of a renovation to be carried out within limited time period, with the abovementioned objective of improving the overall energy performance of the building".

In Greece no minimum requirements exist but have been prepared. The new regulations include the minimum requirements according to the EPD.

2.5.5 Minimum energy requirements for new building

According to article 5 of the EPD:

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

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

Are considered and are taken into account before construction starts.

Requirements referred to article 5 are not satisfied by the present regulation. Alternative energy systems are not considered as well. In Greece the new regulations will comply with the Directive. Also the new regulation offers credit to solar systems but not to district energy systems

2.5.6 Minimum Energy Requirements for Existing Buildings

According to the article 6 of the EPD:

‘Member States shall take the necessary measures to ensure that when buildings with total useful floor area over 1000 m^2 undergo major renovation, their energy performance is upgraded in order to meet minimum requirements so as to be 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 for the renovated systems or components when these are part of a renovation to be carried out within limited time periods, with abovementioned objective of improving the overall energy performance of the building.’

In Greece the actual legislation does not comply with Article 6, but the developed new legislations satisfy the requirements.

2.6 Energy Efficiency

The European Union is a region with over 454 million inhabitants, now that it has expanded by adding 10 new Member States. Europeans occupy and use a wide array of building types and with an equally wide range of thermal qualities and each year the building stock increases significantly. The 25 Member States have all publicly stated their priority to energy efficiency and buildings represent the largest share of energy consumption [7].

From all indications, there is high cost-effective potential for energy savings in buildings. The Council Resolution of 7 December 1998 on energy efficiency (98/C 394/01) stated that meeting the indicative target of a 1 per cent improvement in energy intensity above the current trend would result in avoiding energy consumption of 55 Mtoe in buildings. This represents about 20 per cent of the Kyoto Protocol target. Most recent analysis is provided in the original proposal prepared by the EC on the Directive on the Energy Performance of Buildings. The global potential is about 22 per cent reduction of present consumption that can be realised by 2010. This consumption is for heating, hot water, air conditioning and lighting [7].

Yet, much of that cost-effective potential will not be achieved, in part, because of various market barriers that government policy is trying to address. Achieving the economic potential for energy efficiency is complex. Market players have different approaches and different priorities. Energy efficiency per se is usually not a major consideration in investment decisions, except during periods of crisis when it is often too late.

In a crisis, demand can be reduced by restricting services virtually overnight. But, improved energy efficiency at a regional or national level has to occur through a thoughtful, planned approach over a fairly long period. Due consideration to the factors that are hindering the market from functioning properly need to be examined. And governments have to continually assess whether their measures are properly targeting those barriers.

2.7 Improved Energy Efficiency in Buildings

While many experts and the energy service industry have made the arguments for improved energy efficiency in buildings at both the national and international levels, there has often been some misunderstanding about what is energy efficiency and what it means in day-to-day activities. While there are many definitions of energy efficiency, this one is representative:

An improvement in energy efficiency is regarded as any action undertaken by a producer or a consumer of energy products that reduces energy use per unit of output, without affecting the level of service provided. Energy efficiency improvements can therefore be considered at all stages of the various fuel cycles. Greater energy efficiency can be brought about through hardware improvements, such as technological enhancements; software changes, such as improved energy management and better operational practices; or a combination of both.

Energy efficiency is a stated energy policy objective in all European countries. It is now and has been for many years, even decades. The arguments for improved energy efficiency in buildings focus on [7]:

- Reduced energy costs to consumers, which for many the reduction is important in avoiding “fuel poverty” (where energy costs represent a disproportionate and unsustainable share of disposable income);
- Security of energy supply:
- Cheaper than investing in increased energy capacity;
- Improved comfort;
- Lower GHG emissions, which means a major contribution to climate change strategies and helping to achieve the Kyoto Protocol targets;
- Contribution to the rehabilitation of certain building types in the new Member States of Central and Eastern Europe;
- A major contribution to the objective of sustainable development, which all European countries have committed themselves toward;
- Improving energy efficiency in buildings is important to the buildings energy service industries that are important employers in Europe.

2.8 The Major Barriers to Achieving the Economic Potential

Achieving the economic potential for energy efficiency is complex. Market players have different approaches and different priorities. Energy efficiency per se is usually not a major consideration in investment decisions, except during periods of crisis when it is often too late. In a crisis, demand can be reduced by restricting services virtually overnight. But, improved energy efficiency at a regional or national level has to occur through a thoughtful, planned approach over a fairly long period.

With the high dependence on imports, energy security remains an important policy objective of the European Union. Energy efficiency has been identified as one of the major policy options to reduce risk. As a secondary benefit, energy efficiency programs create employment and the EC recently funded a study showing the employment effects of the various policy measures. Energy efficiency is generally more labour intensive than many other energy policy options and policymakers in Europe are interested in implementing new energy efficiency measures if they increase employment. Such jobs are frequently local, semi-skilled and cost-effective [7].

According to most analysts [7], there is still a great need for more information on cost-effective opportunities such as: how improved energy efficiency can contribute to reducing buffer gas emissions, the impact of new emerging technologies and innovative financing approaches (such as third-party financing).

Many countries have improved their training schemes and introduced energy management into higher education. However, there are not many examples where EU-wide funds for training are being used to improve the quality of the energy service sector.

2.9 Technological Aspects

Buildings use energy for heating, cooling and lighting, contributing to the problems of exhaustion of fossil fuel supplies and environmental pollution. In order to make buildings more energy-efficient an extensive set of ‘energy saving building components’ has been developed that contributes to minimizing the energy need of buildings, that helps them to access renewable energy sources, and helps them to utilize fossil fuels as efficiently as possible [8]. Examples of such energy saving building components are heat pumps, sunspaces, advanced glazing systems, thermal insulation layers, etc.

Building simulation tools appear to be a suitable instrument to support decisions regarding the selection and integration of energy saving building components: they can provide detailed information on the thermal performance of buildings that have not yet been built, thereby allowing objective comparison of different design options under identical conditions. However, in general the actual use of simulation tools to provide information to support the selection of energy saving building components does not live up to this expectation. The development of new building energy simulation tools shows a continuous increase of capabilities and complexity. This trend increases the dependency on adequate modelling and expertise, and thereby increases the barriers to integration of building design process and building simulation even further.

3 Environmental performance of school buildings

OSK (Organisation of school buildings) is responsible for the development of Specifications in order to guide school building designers in Greece. These specifications refer to the design brief, and to visual and thermal requirements for the school operation.

The instruction guide given to the designer incorporates explicit drawings describing the results of modifications of the typical classroom drawings with respect to **daylight**, **insolation, solar protection** and **ventilation**. In particular, they illustrate the effect of site location, aperture position, room height, shape and dimension of side fins and overhangs on the distribution and the behaviour of each of the above parameters.

Schools thermal performance presents particularities because of their use, typology and construction. Those characteristics are summarised as follows [9]:

- **Operation**: schools operate usually during the morning. In big cities due to lack of buildings they operate until evening. The same building houses more than one school and operates in two shifts. Furthermore, most schools are used for other educational and creative activities until late the afternoon.

- **Typology**: the school typology and the classroom orientation determine the building thermal behaviour and the possibility to apply passive or active solar techniques. The basic building types are described below:

    - Linear educational building: is represented by linear arrangement of classrooms, with a corridor in between them.

    - L-shape educational building: When the school becomes bigger the number of classrooms increase. The school design becomes an L shape in order to fit in the available site. The result of this L shape is that one wing classrooms are normal to the other with diverting orientations.

- **Construction**: the modern building's material are concrete – brick – metal frames – flat concrete roof.

3.1 Daylight

It is often necessary to provide a room with natural light from the sun or the sky. The quantities of this natural light may be thought desirable for a pleasant environment or they may be needed to perform certain tasks, such as exacting work with colour. The natural light can be used as the sole source of the interior or can be combined with artificial light.

Daylight is usually admitted into a building by means of windows, or skylights; but these windows also transmit heat, sound and perhaps air. So the design of windows for a building, called fenestration, affects almost all the environmental variables. The provision of natural lighting in a building must not be designed without also considering questions of artificial lighting, heating, ventilation and sound control [14].

The quantity of natural light inside a room is governed by the factors listed below. By analysing these factors it is possible to describe daylight numerically and to predict its effects in a room.

- The nature and brightness of the sky
- The size, shape and position of the windows
- Reflections from surfaces inside the room
- Reflections and obstructions from the objects outside the room.

3.2 Indoor and Outdoor Air Pollution

Air pollution – both indoor and outdoor – is a major environment-related health threat, causing a range of respiratory and cardiovascular ailments. Unhealthy air is breathed by an estimated 1.1 billion people and claims 3 million lives a year [20].

Indoor air pollution occur when fossil or biomass fuels are used for cooking and heating in crowded and poorly ventilated settings. Of all forms of air pollution worldwide, indoor air pollution from open fires or inefficient stoves is the single greatest cause of ill-health.

Indoor air contamination is also caused by biological particles, such as pollen, mould, the droppings of mites, insects, micro organisms, as well as the non-biological particles, such as lead, carbon monoxide, asbestos and synthetic chemicals. Women and children, who spend the most time indoors, are the prime victims of the resulting indoor air pollution. These dust particles contain irritants and infectious agents that can cause or worsen ARI. Another very important source of indoor air pollution is tobacco smoke.

Outdoor air pollution is a particularly serious threat to the swelling populations of the world's cities. With the increased combustion of fossil fuels, industrial processes and growing car use, urban populations are exposed to a long list of pollutants that include sulphur dioxide, nitrogen oxide, nitrogen dioxide, carbon monoxide, ozone, lead, dioxins, suspended particulate matter and a host of volatile organic compounds [20]. Open burning of urban waste with high components of plastics like polyvinyl chloride (PVC) is also a significant source of dioxins, furans and heavy metals in many communities. People who are poor often live close to these sites or work in them.

3.3 Insolation – Solar protection

The heat gained in a building by radiation from the Sun depends upon the following factors [14]:

- The geographical latitude of the site, which determines the height upon the Sun in the sky
- The orientation of the building on the site, such as whether rooms are facing south or north
- The season of the year, which also affects the height of the Sun in the sky
- The local cloud conditions, which can block solar radiation
- The angles between the Sun and the building surfaces, because maximum gain
- occurs when surfaces are at right angles to the rays from the Sun
- The nature of the window glass and whether it absorbs or reflects any radiation
- The nature of the roof and walls, because heavyweight materials behave differently to lightweight materials.

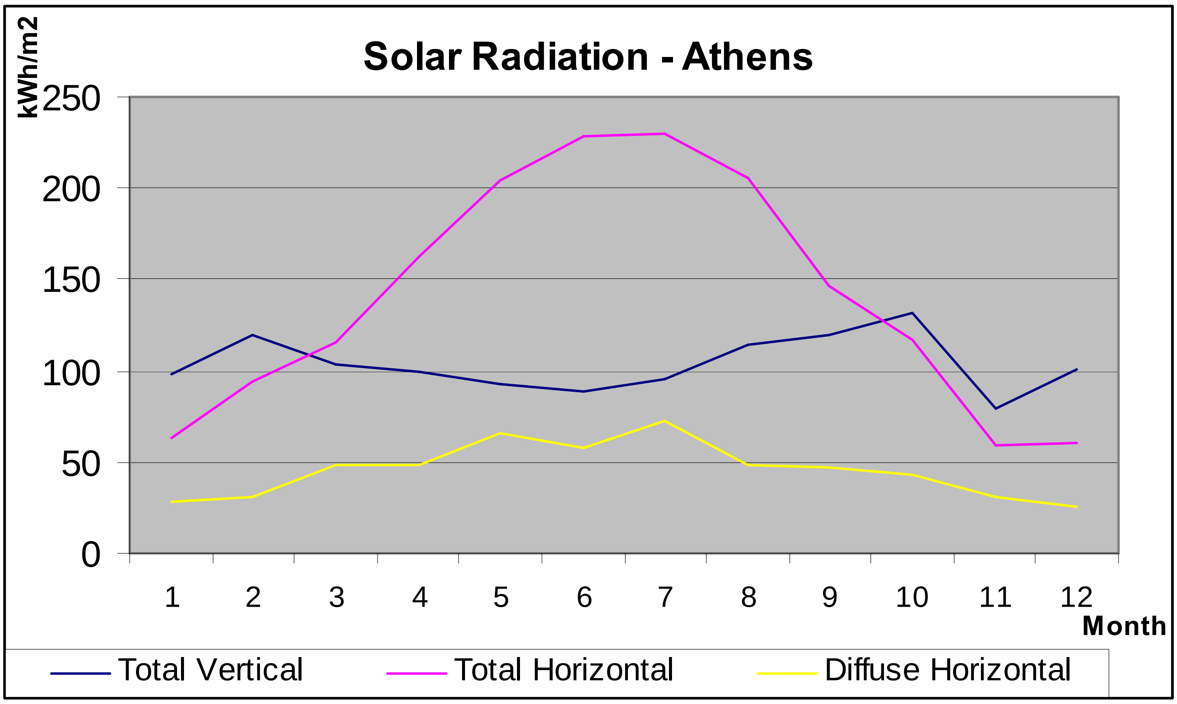


Figure 1: Annual solar radiation in Athens - CRES

The rate at which, heat from the Sun falls on a surface varies throughout the day and the year. Most solar and heat gain to buildings in Greece is by direct radiation through windows. The maximum gains through south-facing windows tend to occur in spring and autumn when the lower angle of the Sun causes radiation to fall more directly onto vertical surfaces. This heat gain via windows can, if used correctly, be useful for winter heating.

The solar heat gains for a particular building at a specific time are relatively complicated to calculate, although it is important to do so when predicting summer heat gains in commercial buildings. For winter calculations however, it is useful to consider the total solar gain over an average heating season.

3.4 Sound Insulation

Noise may penetrate the classroom from the yard, the spots fields, the space outside the school (streets, neighbouring buildings) and the environment (wind rain). The appropriate sealing of the cracks contributes to the noise reduction.

Ventilation of the classrooms is necessary during the hours of school operation, so in areas with an intense noise problem, several techniques can be used for its reduction.

Other techniques are applied in the surroundings and other on the building envelope. Systems of ventilation with sound absorbers can be placed between the perimeter of the frames and the walls. This is a rather expensive solution which also presupposes the replacement of the frames.

3.5 Sun control

Sun controls are parts of a building that help prevent excessive heat gain and glare caused by direct sunshine. The main types of device are described below [14]:

- External controls are the most effective form of Sun control because they minimise the radiant heat reaching the fabric of the building. Examples include external shutters, awnings, projecting eaves or floor slabs.

- Internal controls such as blinds give protection against glare and direct radiation. The system is less effective than effective controls outside the glass because blind will absorb some solar heat and re-emit this heat into the room. Examples include curtains, blinds, and internal shutters.

- Special glasses are available which prevent the transmission of most heat radiation with only some loss of light transmission. A similar effect is given by special film which sticks onto plain glass.

3.6 Ventilation

Ventilation in building is the process of changing the air in a room or other internal space. This process should be continuous with new air taken from a clean source. Although we require oxygen for life, a build-up of carbon dioxide is more lifethreatening and a general build-up of odours will be more critical long before there is danger to life. In addition to the comfort of the occupants the ventilation of a building has other objectives, such as those included below [14]:

- Supply of oxygen
- Removal of carbon dioxide
- Control of humidity for human comfort
- Control of air velocity for human comfort
- Removal of odours
- Removal of micro-organisms, mites, moulds, fungi
- Removal of heat
- Removal of water vapour to help prevent condensation
- Removal of particles such as smoke and dust
- Removal of organic vapours from sources such as cleaning solvents, furniture, and building products
- Removal of combustion products from heating and cooking
- Removal of ozone gas from photocopiers and laser printers
- Removal of methane gas and decay products from ground conditions

The ‘old’ air being replaced has often been heated and, to conserve energy, the rate of ventilation may be limited or heat may be recovered from the extracted air.

Other factors to consider in the provision of ventilation include the following [14]:

- Control of fire
- Conservation of energy
- Noise from the system

Natural ventilation is a most common technique in Greece, which is practiced in two different ways [14]:

- cross ventilation (between openings) or vertical draught and warm air removal (chimney effect)

- mechanical ventilation with use of 100% fresh air

Even though natural ventilation has never been mandatory with relevant codes, it has always been practiced in the wider sense and is promoted for cooling benefits and reduction of cooling loads, as well as, air quality. Specifically for the latter factor, particular standards may be applied for different building uses (such as school buildings, where a standard for 5ach is applied for fresh air renewal in the classrooms).

Natural ventilation is mostly promoted within the new code for cooling loads reduction and thermal comfort benefits. In the domestic sector, ventilation standards (either: natural, hybrid or mechanical) require one air change per hour (1 ach), whilst in the non-domestic ventilation varies between 2ach and 6ach (mechanical ventilation) [9].

Natural ventilation via cross or vertical air flow (for natural cooling) is totally applied in domestic buildings with considerable benefits, as Greek buildings employ heavy construction with significant thermal mass. In contrary, due to the lighter constructions of tertiary buildings and other finishing and covering materials (wall-to-wall carpeting), only bioclimatic tertiary buildings apply natural ventilation for cooling; in most non-domestic buildings, natural ventilation is applied in conjunction with HVAC for fresh air and hygiene purposes (smoke air removal).

Another factor that discourages the implementation of natural cooling in buildings via ventilation is pollution, which dominates the urban centres. Either pollution comes from emissions (cars and buildings) or noise; it creates hindrances for natural ventilation and demands mechanical ventilation.

3.7 Thermal Insulation

In order to maintain a constant temperature within a building it is necessary to restrict the rate at which heat energy is exchanged with the surroundings. Keeping heat inside a building for as long as possible conserves energy and reduces heating costs.

Thermal insulation is the major factor in reducing the loss of heat from buildings. Adequate insulation should be a feature of good initial design but insulation can also be added to existing buildings. The relatively small cost of extra insulating materials is quickly paid for by the reduction in the size of the heating plant required and by the annual savings in the amount of fuel needed [14]. These fuel savings continue throughout the life of the building.

One of the other benefits of good thermal insulation is that the risk of surface condensation is reduced because of the warmer internal surfaces. Good insulation can also reduce the time taken for a room to heat up to a comfortable temperature; in a room that is occupied during the day, for example.

It is useful to remember that good thermal insulation will also reduce the flow of heat into a building, when temperature outside is greater than the temperature inside. In other words, a well –insulated structure will, if ventilation is controlled, stay cooler in the summer than a poorly-insulated structure. In a large building this insulation will give savings in the energy needed to run the cooling plant. Dependent on insulation levels, some office buildings may use more energy for summer cooling than for winter heating [14].

The Thermal insulation installed in a building affects the rate at which the building loses heat energy which is measured by the U-value. The thermal performance of the building also depends upon the thermal capacity of the insulating material, which affects the times taken to heat or cool the structure, and the position of the insulation, which affects the temperature in the structural element [14]. The following table (Table 1) represents the minimum requirements for the U-values for different construction elements of the building.

Construction elements	U-value (W/m²K)
1. External walls including all layers	0,7
2. Horizontal surfaces and roofs	0,5
3. Floors laid in the ground or floors next to unheated basement or semi basement	
Climatic zone A	3,0
Climatic zone B	1,9
Climatic zone C	0,7
4. Partition walls next to unheated spaces	
Climatic zone A	3,0
Climatic zone B	1,9
Climatic zone C	0,7

Table 1: Construction elements and their minimum U-values [13]

3.8 Prediction of PPD value

In order to obtain the PPD value which is a number measured in percentage (%) and represents the occupant dissatisfaction within a building it is necessary to understand the meaning of PMV.

3.8.1 Determination Predicted mean vote (PMV)

The PMV is an index that predicts the mean value of the votes of a large group of persons on the following 7-point thermal sensation scale [17]:

+ 3 hot
+ 2 warm
+ 1 slightly warm
0 neutral
– 1 slightly cool
– 2 cool
– 3 cold

The PMV index can be determined when the activity (metabolic rate) and the clothing (thermal resistance) are estimated, and the following environmental parameters are measured: air temperature, mean radiant temperature, relative air velocity and partial water vapor pressure. The PMV index is based on heat balance of the human body.

Man is in thermal balance when the internal heat production in the body is equal to the loss of heat to the environment. In a moderate environment, man’s thermoregulatory system will automatically try to modify the skin temperature and the sweat secretion to maintain heat balance. In the PMV index the physiological response of the thermoregulatory system has been related statistically to thermal sensation votes collected. The PMV can be calculated for different combinations of metabolic rate, clothing, air temperature, mean radiant temperature, air velocity and air humidity [17].

The PMV index is derived for steady-state conditions but can be applied with good approximation during minor fluctuations of one or more of the variables, provided that time-weighted averages of the variables during the previous 1 h period are applied.

It is recommended to use the PMV index only for values of PMV between – 2 and + 2. Furthermore, it is recommended to use the PMV index when the six main parameters are inside the following intervals [17]:

M = 46 W/m2 to 232 W/m2 (0,8 met to 4 met)
*I*cl = 0 m2·°C/W to 0,310 m2·°C/W (0 clo to 2 clo)
*t*a = 10 °C to 30 °C
= 10 °C to 40 °C
*v*ar = 0 m/s to 1 m/s

3.8.2 Predicted percentage of dissatisfied (PPD)

The PMV index predicts the mean value of the thermal votes of a large group of people exposed to the same environment. But individual votes are scattered around this mean value and it is useful to predict the number of people likely to feel uncomfortably warm or cool. The PPD index establishes a quantitative prediction of the number of thermally dissatisfied people. The PPD predicts the percentage of a large group of people likely to feel too warm or cool, i.e. voting hot (+ 3), warm (+ 2), cool (– 2) or cold (– 3) on the 7-point thermal sensation scale.

When the PMV value has been determined, the PPD can be found from the equation [17]:

$$PPD = 100 - 95 \times e^{-(0{,}033\,53 \times PMV^4 + 0{,}217\,9 \times PMV^2)}$$

The PPD-index predicts the number of thermally dissatisfied persons among a large group of people. The rest of the group will feel thermally neutral, slightly warm, or slightly cool.

4 Climate

A fundamental reason for the existence of a building is to provide shelter from the climate, such as cold and the heat, the wind and the rain. The climate for a building is the set of environmental conditions which surround a building and links to the inside of a building by means of heat transfer.

Climate has important effects on the energy performance of buildings, in both winter and summer, and on the durability of the building fabric. Climates which are favourable to energy use and durability also make the external environment of a building attractive and useful for recreation.

Although the overall features of the climate are beyond our control, the design of a building can have a significant influence on the climatic behaviour of the building. The following measures can be used to enhance the interaction between buildings and climate [14]:

- Selection of site to avoid heights and hollows
- Orientation of buildings to maximise or minimise solar gains
- Spacing of building to avoid unwanted wind and shade effects
- Design of windows to allow maximum daylight buildings
- Design of shade and windows to prevent solar overheating
- Selection of trees and wall surfaces to shelter buildings from driving rain and snow
- Selection of ground surfaces for dryness

4.1 Climate types

The large-scale climate of the Earth consists of interlinked physical systems powered by the energy of the Sun. The build environment generally involves the study of smaller systems for which the following terms are used [14]:

- **Macroclimate:** The climate of a larger area, such as a region or a country

- **Microclimate:** The climate around a building and upon its surfaces.

A building site may have natural microclimate caused by the presence of hills, valleys, slopes, streams, and other features. Buildings themselves create further microclimates by shading the ground, by drying the ground, parts of the same building, such as parapets and corners, which receive unequal exposure to sun, wind and rain.

4.2 Climatic zones

Law “Regulation for Thermal Insulation” (1979) imposed thermal protection of the building shell as mandatory depending on the climate region (Greece is divided in four climatic zones - Figure 2 - depending on external temperature during winter and the duration of heating period) and the size of the building. Table 5 presents the maximum overall U-values for construction elements.

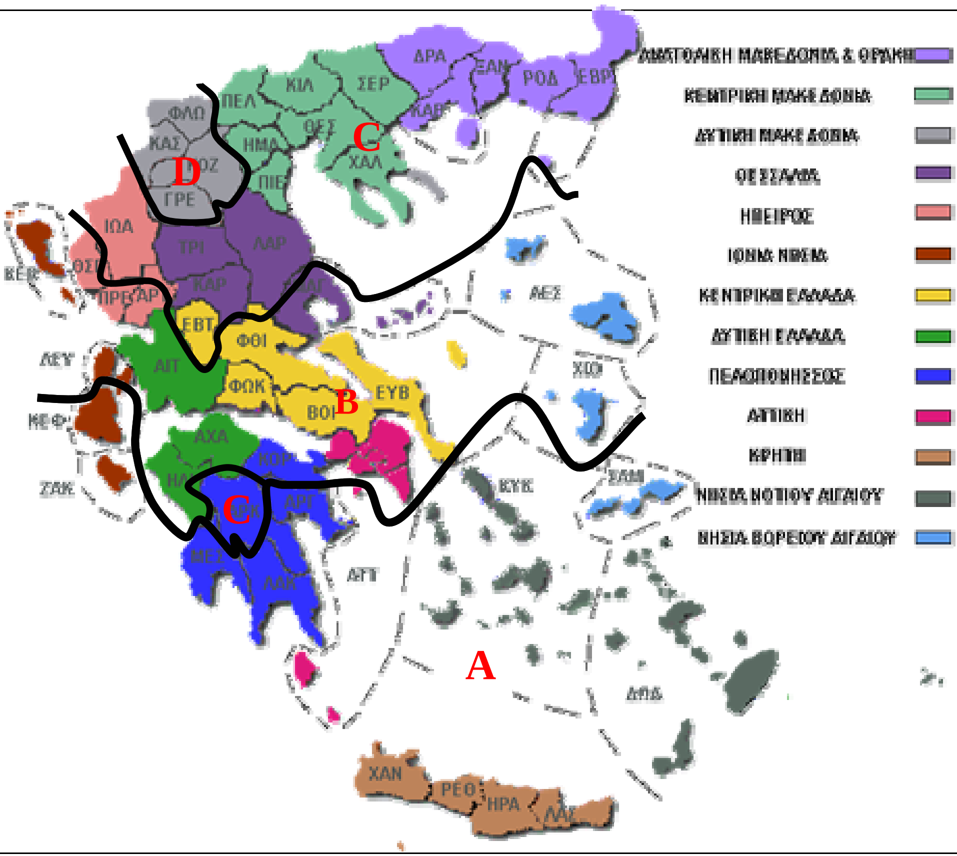


Figure 2: Four climatic zones of Greece [13]

According to the new Building Energy Code (Regulation on Rational Use and Energy Conservation) which will replace the existing “Regulation for Thermal Insulation” and will set as obligatory the energy design of all buildings will be based on specific energy consumption limits (per building type and climatic zone-four climatic zones depending on the Degree Days for Heating), properties and performance of materials, as also, on specific calculation methodologies (heating/cooling/lighting) enabling the application of bioclimatic strategies and energy saving technologies in the electromechanical installations [13].

For the analysis of the current thesis two zones have been used because of the available climatic data provided from energy plus (Energy +). These two climatic zones are the B – Athens and C – Thessaloniki. The remaining two zones A – Chania and D – Florina are not in scope of the current thesis due to lack of information.

4.3 Effects of microclimate

An improved microclimate around a building brings the following types of benefits [9]:

- Lower heating costs in winter
- Reduction of overheating in summertime
- Longer life for building materials
- Better growth for plants and trees
- Increased user satisfaction and value

4.4 Climatic data

In order to design a building which is appropriate for its site, the climate of that site needs to be studied and predicted. In order to do this the following climatic factors have to be considered [15]:

- Temperature
- Humidity
- Precipitation of rain and snow
- Wind speed and direction
- Sunshine hours and solar radiation
- Atmospheric pollution

These factors can vary by the hour, by the day, and the season. Some of the variations will cycle in a predictable manner like the Sun, but others such as wind and cloud cover will be less predictable in the short term. Information about aspects of climatic factors is collected over time and made available in a variety of data forms including the following:

- Maximum or minimum values
- Average values

- Probabilities or frequencies

Climatic Zone B - Athens					
	Horizontal Diffuse W/ m^2	Air Temperature (C)	Total Horizontal W/ m^2	Wind Speed m/s	Absolute Humidity (%)
Mean	228.30	17.71	675.66	0.62	17.85
Max	878.40	30.40	3186.00	0.70	25.70
Min	0.00	7.70	0.00	0.50	10.90

Table 2: Characteristics of climatic zone B [9]

Climatic Zone C – Thessaloniki					
	Horizontal Diffuse W/ m^2	Air Temperature (C)	Total Horizontal W/ m^2	Wind Speed m/s	Absolute Humidity (%)
Mean	257.17	14.80	595.79	1.83	69
Max	1580.40	30.30	2894.40	2.20	85
Min	0.00	3.10	0.00	0.80	38

Table 3: Characteristics of climatic zone C [9]

The type of climatic data that is chosen depends upon design requirements. Peak values of maximum or minimum are needed for some purposes, such as sizing heating plant or designing wind loads. Longer term averages, such as seasonal information, are needed for prediction of energy consumption.

4.4.1 Zone B – Athens

The climate of zone B (Athens) is mild in winter and summer. In the following figures and tables the annual meteorological data is given for Athens which is classified in zone B.

In Athens during winter the average mean hourly temperature fluctuates between 10 C – 13 C (January) whereas average relative humidity is 69%. Both temperature and humidity values are high. Therefore the heating is necessary during early morning and night hours [9]. Heating loads may be partially covered by solar gains from south oriented classrooms. An auxiliary heating system is necessary.

During summer for June and September – average hourly temperature values are mainly in the ventilation, shading and large thermal mass zone. Consequently, in order to assure thermal comfort inside the classrooms, the following measures should be applied [9]:

- External shading devices for the windows with south, east and west orientations
- Cross ventilation in order to reject overheating produced from students
- Night ventilation is necessary in order to cool the massive structural building elements, such as walls, floors and roofs
- Massive elements in the building structure are necessary in order to absorb and store the heat surplus. Night ventilation may cool down those elements rejecting the heat surplus to the exterior. School typology and orientation determine the building energy loads and the modifications proposed. The latitude, the location of the building in the site, and the climatic data contribute to the absorption and storage of the heat within the structure.

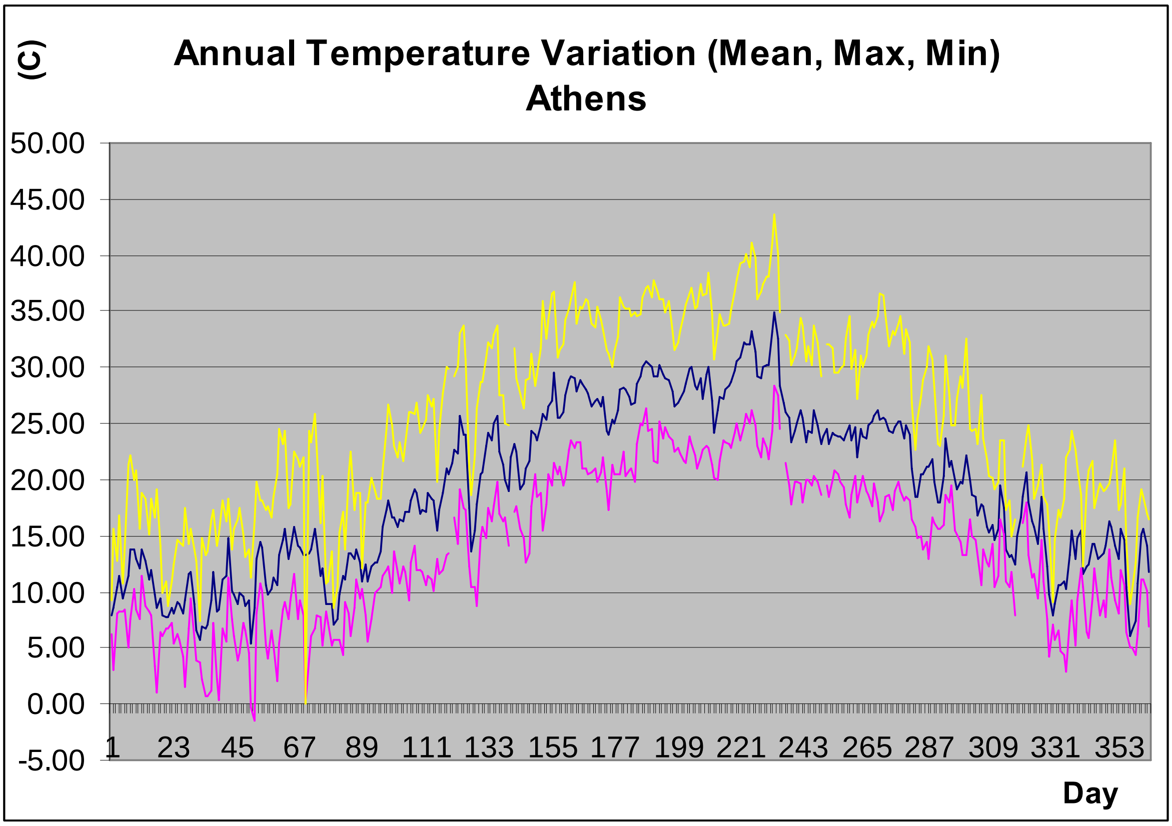


Figure 3: Annual temperature Variation – Athens, CRES

4.4.2 Zone C – Thessaloniki

The climate of zone C is cold during the winter and hot during summer, with high levels of relative humidity for both seasons.

In Thessaloniki for the winter (January) average hourly temperatures fluctuate from 5 C to 9 C and the average relative humidity value is about 76%. The building requires auxiliary heating in order to cover energy requirements. A significant amount of energy – nearly 50% - can be covered from the available solar energy [9], if the classroom orientation is south or +/- 30 degrees diverging eastward or westward from the south. With the installation of passive solar systems the average hourly temperatures which are within the comfort zone may have an increase of significance only in the month of June. However the building requires ventilation during afternoon in order for the heat stored in the building's internal surfaces to be rejected to the exterior. Thermal comfort in the interior requires window external shading. The guidelines for the efficient school design are as follows [9]:

- Windows with south, east, and west or in between orientations require external shading. Planting or external shading devices, fixed or movable may shade the facades.
- Space ventilation is necessary in order to discharge the heat surplus, caused by students or by high external temperatures during afternoon. Night ventilation is also necessary in order to cool the building elements, such as walls, floors, roofs.
- Increased thermal building inertia means that structural elements such as walls, floors, roofs have big thermal capacity in order to absorb heat surplus and maintain comfort conditions. During night the heat absorber by all structural elements may be discharged to the exterior by ventilation.

4.5 Degree-days, Accumulated Temperature Difference

The method of degree days or Accumulated Temperature Difference, ATD, is based on the fact that the indoor temperature of an unheated building is, on average, higher than the outdoor. In order to maintain an internal design temperature of 19 C, for example, the building only needs heating when the outdoor temperature falls below 15 C. This base temperature is used as a reference for counting the degree days of outside temperature drop and the number of days for which such a drop occurs.

Climatic zone	Degree Days for Heating
A	601-1100
B	1101-1600
C	1601-2200
D	>2201

Table 5: Degree Days for Heating – Greece [13]

5 ESP-r Modelling and Methodology

ESP-r is a transient energy simulation system which is capable of modelling the energy and fluid flows within combined building and plant systems when constrained to conform to control action. The package comprises a number of interrelating program modules addressing project management, simulation, results recovery and display, database management and report writing.

One or more zones within a building are defined in terms of geometry, construction and usage profiles. These zones are then inter-locked to form a building, in whole or in part, and, optionally, the leakage distribution is defined to enable air-flow simulation. The plant network is then defined by connecting individual components. And, finally the multi-zone building and multi-component plant are connected and subjected to simulation processing against user-define control. The entire data preparation exercise is achieved interactively, and with the aid of pre-existing databases which contain standard (or user-defined) constructions, event profiles and plant components. Additional modules exist to permit an increase in simulation rigour if the related data is available [15].

The dominant shapes used for the educational buildings are the linear and the L-shape. These two shapes have been modelled using esp-r. The construction elements used for L-shape and Linear models can be viewed in Table 6 below. The variable U-values are achieved by increasing or decreasing the thickness of polystyrene for the wall and air gap of the windows.

TYPE	ELEMENTS USED
WINDOW	4MM GLASS, 17MM AIR, 4MM GLASS
WALL	2MM PLASTER, 90MM BRICK, 5MM POLYSTYRENE, 90MM BRICK, 2MM PLASTER
METALLIC DOORS	2MM METAL, 40MM AIR, 2MM METAL
FLOOR	30MM CERAMIC, 25MM MORTAR, 150MM CONCRETE, 10MM PLASTER
FLOOR UNDER OPEN AREA	30MM CERAMIC, 25MM MORTAR, 150MM CONCRETE, 50MM POLYSTYRENE, 2MM PLASTER.
ROOF	30MM CERAMIC, 25MM MORTAR, 5MM POLYSTYRENE, 180MM LIGHTWEIGHT CONCRETE, 150MM CONCRETE, 10MM PLASTER

Table 6: Analysis of construction elements of educational buildings [9]

5.1 ESP-r Models

L-shape and Linear models share the same basic construction characteristics, with the main differences in the shape and size of the building. The following table (Table 7) shows the minimum standard requirements for Elementary and High-School buildings per room type.

There are also differences in the models. In detail, except from the shape of the building, L-shape educational building model has external shading devices in all external walls with the shading devices being of 1.0 m wide while the Linear educational building model does not have any external shading.

Elementary – High School (Gymnasium) – Lyceum					
Use	Classroom	Laboratory	Multi Purpose Hall	Library	WC
Area (m^2)	51-56	78	230-350	26-52	-
m^2/student	1.7	2.6	-	1.86	-
Space height (m)	3	3	3.5	3	2.4
m^3/student	4	4	4	4	4
Artificial Lighting (lux)	300-325	300-325	300-325	300-325	300-325
Ventilation (ach)	6	6	6	6	-
Design Temperature (C)	18	18	18	18	-

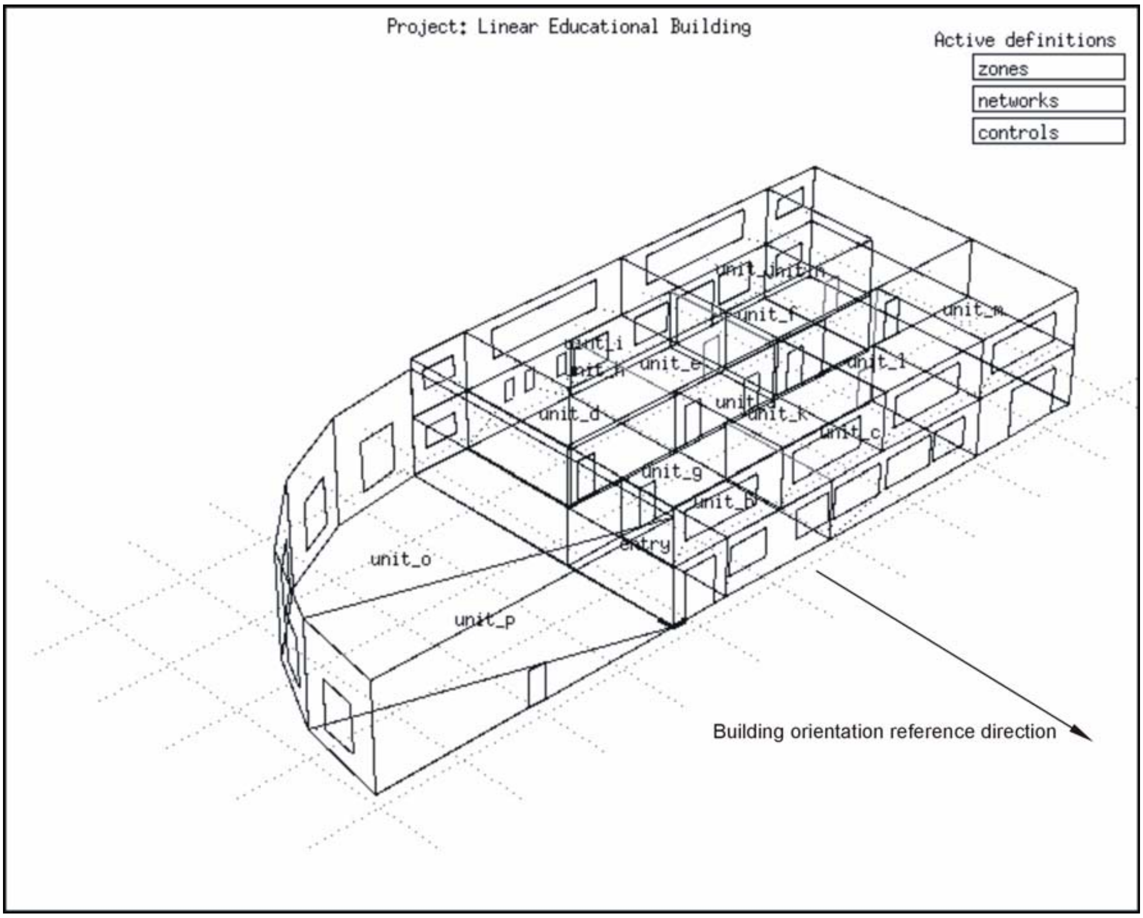
Table 7: Design details for educational buildings [9]

No internal blinds have been considered in the analysis of neither of the two models. The benefit of internal blinds has not been tested due to the time constrains of the project. Further research can be carried out in order to evaluate the energy performance of L-shape and Linear buildings including these in the analysis.

5.1.1 Linear educational building

The following figure shows the Linear educational building as it has been modelled in esp-r according to OSK design specifications [10]. This is a two level building (ground and first floor) with six classrooms in operation plus a computer lab and a library. Also a common activities area exists and is used a few hours of the normal operational hours of the school. These represent the heated/cooling areas of the building (controlled zones). In addition to those the building consists of the following: a) toilettes, b) corridors, c) storage rooms, d) stairwell and e) boiler room. These represent the free floating areas of the building (uncontrolled zones).

The building's direction reference (represented by the arrow) is used as reference point for the simulation and analysis steps of the thesis.



Model 1: Linear Educational Building

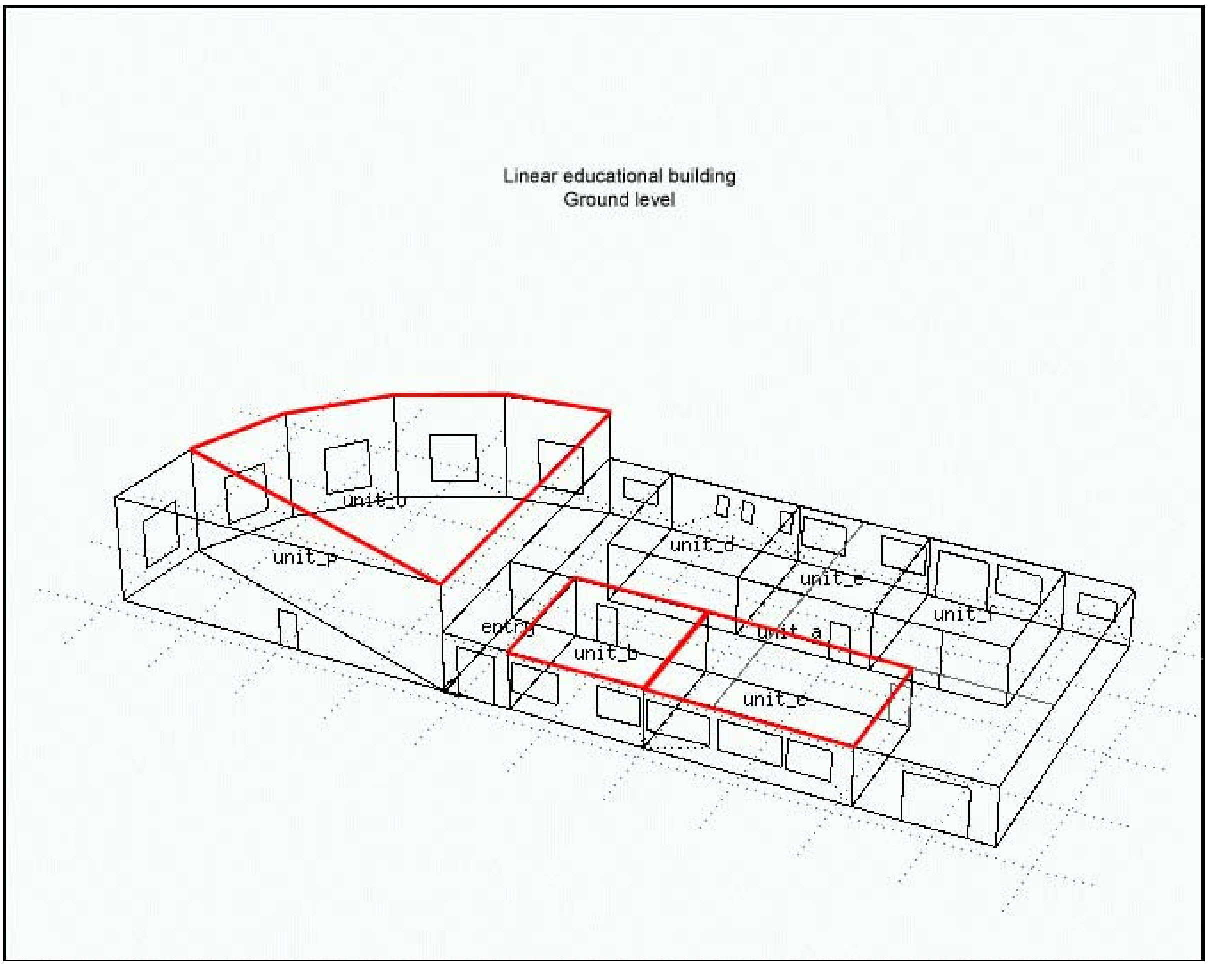
The total area of the linear educational building is 1983 m^2 out of which the heated/cooling area is 1355 m^2 (controlled zones) while the remaining 628 m^2 are not heated/cooling areas (uncontrolled zones). All results have been converted to square meter of heated/cooled area.

In the following figures (Model 1a and 1b) the controlled zones for heating and cooling are highlighted in red. The remaining zones represent the uncontrolled zones. Table 7 below lists al zone details:

ZONES	OPERATION STATUS	AREA (M^2)
UNIT_A	UNCONTROLLED	213
UNIT_B	CONTROLLED	51.8
UNIT_C	CONTROLLED	102
UNIT_D	UNCONTROLLED	54.7
UNIT_E	UNCONTROLLED	54.7
UNIT_F	UNCONTROLLED	54.7
UNIT_G	CONTROLLED	207
UNIT_H	UNCONTROLLED	81.5
UNIT_I	CONTROLLED	82.1
UNIT_J	CONTROLLED	82.1
ENTRY	UNCONTROLLED	38.2
UNIT_K	CONTROLLED	207
UNIT_L	CONTROLLED	207
UNIT_M	CONTROLLED	207
UNIT_N	UNCONTROLLED	79.2
UNIT_O	CONTROLLED	209
UNIT_P	UNCONTROLLED	52.4

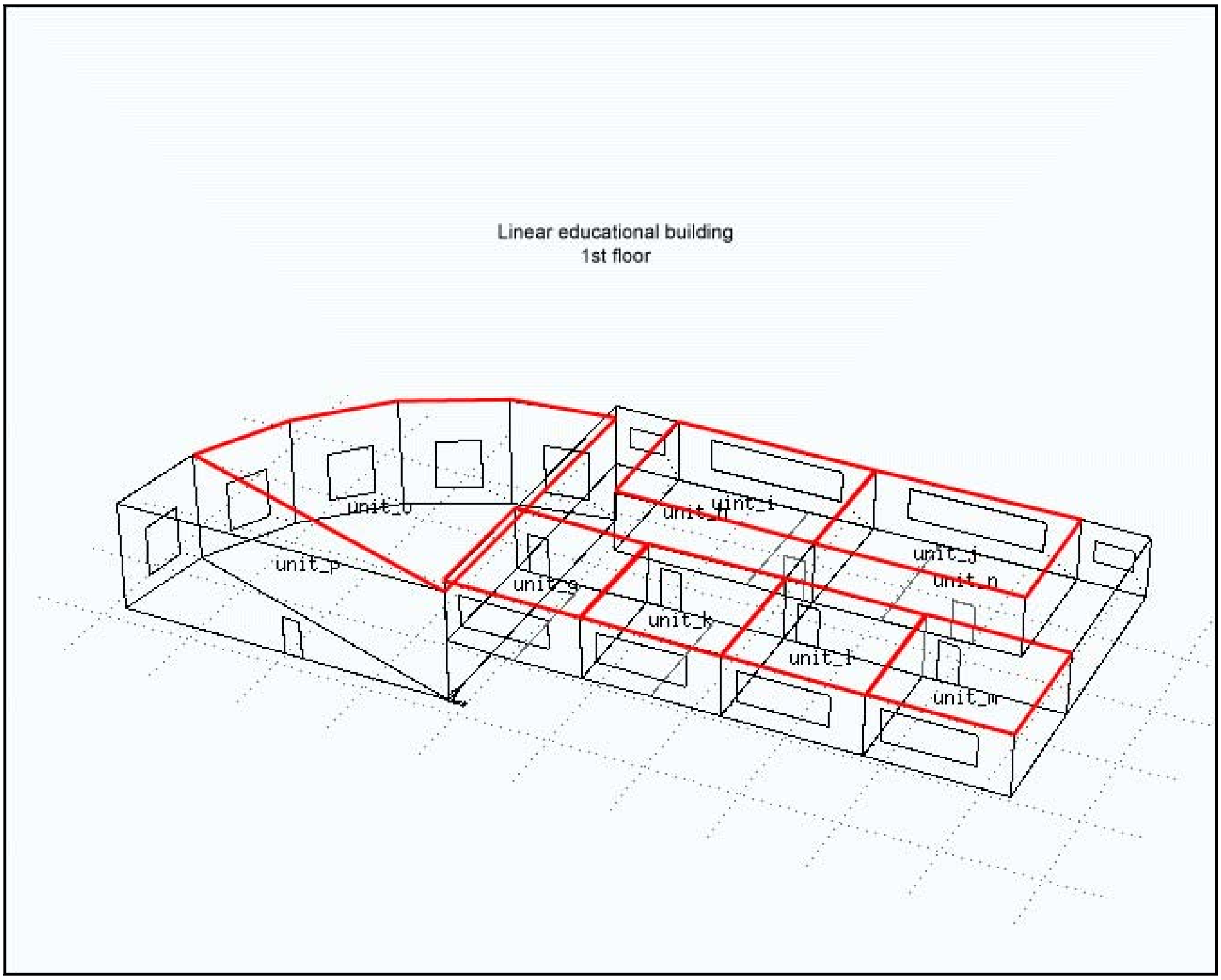
Table 7: Details of zones area and operation status of Linear educational building

As it can be seen in Model 1a below, which represents the ground level of the Linear educational building, one side of the building is controlled and this can affect the overall behaviour of the building. This is because the uncontrolled zones (consisting of toilets, storage, corridors and warehouse) the contribution from the incident solar radiation creates a buffer effect and reduces the actual energy requirements for heating/cooling of the surrounding (controlled) zones. By changing the building orientation the uncontrolled zones can generate different energy needs for the surrounding (controlled) zones.



Model 1a: Linear educational building controlled zones – ground floor

The following figure shows (Model 1b) the controlled zones for heating and cooling of the first floor of the linear educational building.



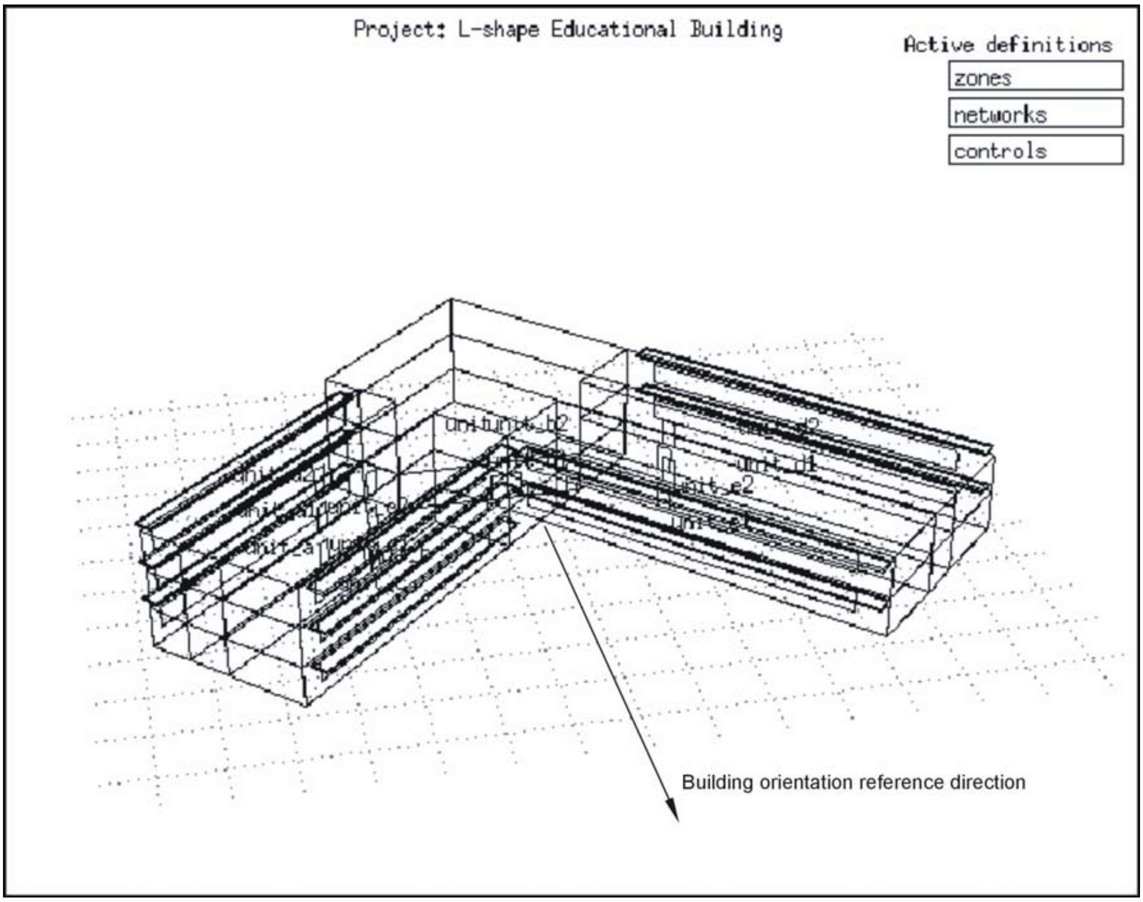
Model 1b: Linear educational building controlled zones – first floor

As it can be seen in Model 1b above, all sides of the building are controlled therefore the overall behaviour of the first level is more balanced than the ground level.

5.1.2 L-shape educational building

The following figure (Model 2) shows the L-shape educational building [11]. This building consists of 12 classrooms which are operating daily. In addition, like for the linear building a computer lab and a library exist. These again represent the controlled zones of the building. In addition to those the building consists of the following: a) toilettes, b) corridors, c) storage rooms, d) stairwell and e) boiler room. These again, represent the uncontrolled zones of the building.

The building's direction reference (represented by the arrow) is used as reference point for the simulation and analysis steps of the thesis.



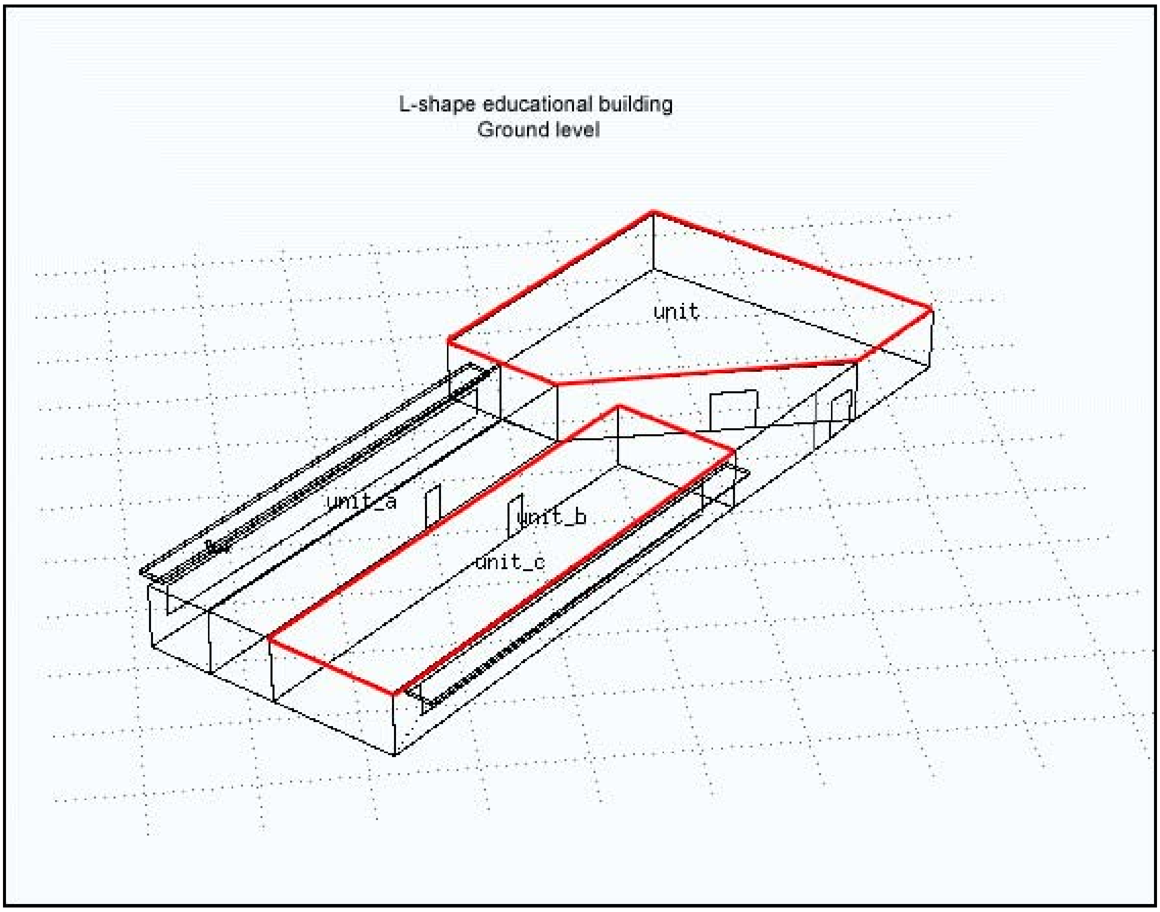
Model 2: L-shape Educational Building

For the L-shape educational building the total area of the building is 3669 m^2 out of which the 1869 m^2 represent the heated/cooling areas (controlled zones) while the remaining 1800 m^2 represent the not heated/cooling areas (uncontrolled zones). Table 8 below lists all zone details:

ZONES	OPERATION STATUS	AREA (M^2)
UNIT_A	UNCONTROLLED	99.2
UNIT_C	CONTROLLED	193
UNIT_B	UNCONTROLLED	162
UNIT_B1	UNCONTROLLED	674
UNIT	CONTROLLED	318
UNIT_A1	UNCONTROLLED	92.2
UNIT_A2	UNCONTROLLED	99.2
UNIT_C1	CONTROLLED	193
UNIT_C2	CONTROLLED	193
UNIT_B2	UNCONTROLLED	674
UNIT_E1	CONTROLLED	243
UNIT_E2	CONTROLLED	243
UNIT_D1	CONTROLLED	243
UNIT_D2	CONTROLLED	243

Table 8: Details of zones area and operation status of L-shape educational building

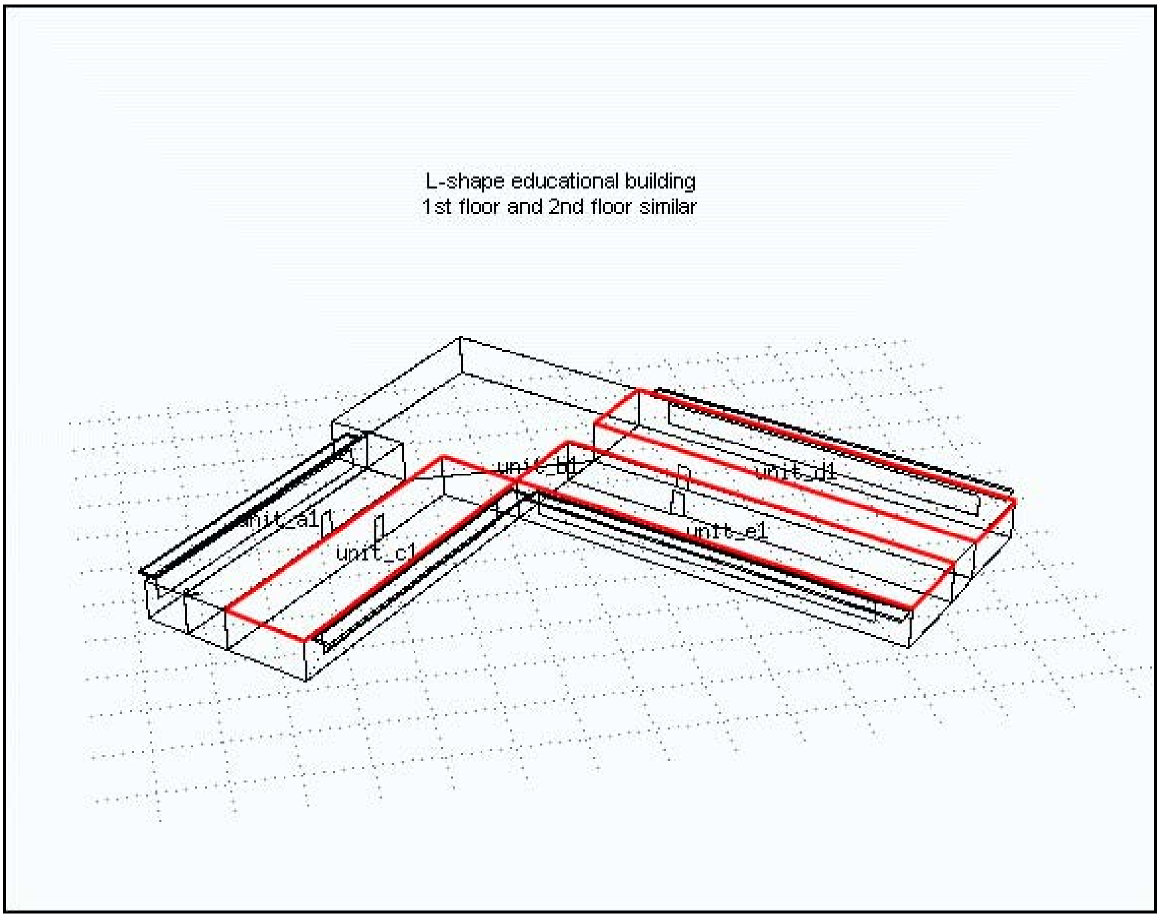
Similarly with Model 1 the controlled zones for heating and cooling (highlighted in red) are shown in the figures below (Model 2a and 2b). The remaining zones represent the uncontrolled zones.



Model 2a: L-shape educational building controlled zones – ground floor

As it can be seen in Model 2a above which represents the ground level of the L-shape educational building, again one side of the building is controlled and this can affect the overall behaviour of the building.

The following figure (Model 2b) shows the controlled zones for heating and cooling of the first and second floors of the L-shape educational building.



Model 2b: L-shape educational building controlled zones – first and second floor

As it can be seen in Model 2b above, most of the sides of the building are controlled therefore the overall behaviour of the first and second level is more balanced than the ground level.

5.2 Simulation Strategies

The test cases that were followed in order to analyze the energy performance and the occupant's comfort level for both buildings are shown in the table below (Table 9):

CLIMATIC ZONE B (ATHENS)		
Test Case	U_{wall}	$U_{opening}$
Case 1	0.6	3.8
Case 2	0.5	2.8

CLIMATIC ZONE C (THESSALONIKI)		
Test Case	U_{wall}	$U_{opening}$
Case 3	0.5	2.8
Case 4	0.4	1.4

Table 9: U-value simulation test cases [9]

For both the Linear and the L-shape buildings 8 different orientations (every 45 degrees) are being tested for every climatic zone. In addition, for each test case different U-values have been used as parameters. The U-values are according to OSK specifications for building construction elements.

5.3 Educational building daily operation

The daily operation of the schools during an academic year is shown in the table below (Table 10). The table represents the requirements according to CRES for the use of heating and cooling set points of a building along with the heat that is radiated from the lighting and electrical equipments. These data have been used as set-points for controlling the heating or cooling of a controlled zone and the casual gains from electrical equipment and lighting. Another factor that has to be mentioned is the energy radiated from the school occupants (pupils, teachers) which is 53 W/ m^2 for sensible heat and 26.5 W/ m^2 for latent heat (CRES). The value of sensible heat was obtained from taking into account the sensible heat of a student being in the classroom (90 Watt) and the area per student that is allocated according to Table 7 above (90 divided by 1.7) while the latent heat has been calculated by dividing the sensible heat by two.

EDUCATIONAL BUILDING	TIME																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Heating (°C)																								
Monday - Friday	-	-	-	-	-	-	-	19	19	19	19	19	19	19	19	19	19	-	-	-	-	-	-	-
Weekend	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cooling (°C)																								
Monday - Friday	-	-	-	-	-	-	-	26	26	26	26	26	26	26	26	26	26	-	-	-	-	-	-	-
Weekend	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lighting (W/ m^2)																								
Monday - Friday	-	-	-	-	-	-	-	16	16	16	16	16	16	16	16	16	16	-	-	-	-	-	-	-
Weekend	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Electrical Equipment (w/ m^2)																								
Monday - Friday	-	-	-	-	-	-	-	1	1	1	1	1	1	1	1	1	1	-	-	-	-	-	-	-
Weekend	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 10: Operational temperatures and sensible heating of educational building - CRES

5.4 Data collection and analysis

For every simulation the time period that has been analyzed is a full academic year which runs from 11/9 to 23/12 and from 7/1 to 21/6.

After every simulation the results collected for every model from the 8 different building orientations can be classified into the following categories:

- Energy delivered: represents the energy required for heating and cooling of the building annually.
- Heating load: represents the maximum heating load that is required in order to heat the building.
- Cooling load: represents the maximum cooling load that is required in order to cool the building.
- Percentage people dissatisfaction (PPD): represents the mean value of the occupant's comfort level annually. Furthermore, a representative mean PPD value is obtained for the 21^{st} of every month within the academic year.

The results analysis will focus on the effect of different building orientation, wall insulation and glazing type into the energy performance, heating/cooling load and PPD. The special characteristics of each building are analyzed with the same parameters as input in order to compare the results and explain why some differences occur.

6 Results Analysis

This chapter includes the analysis of the results achieved from the simulations carried out for the Linear and L-shape educational buildings taking into account the building orientations, wall insulation and glazing type. The chapter focuses on general conclusions regarding the buildings' energy performance and occupants comfort level.

6.1 Effect of building's shape and structure on energy performance

From the following figure (Figure 4) it can be seen that the energy required for heating and cooling for both the L-shape and Linear models is different although they both use the same wall insulation and glazing type in both climatic zones. In detail, the L-shape building appears to have less energy consumption (heating plus cooling) per m^2 than the Linear building. The difference is of an average 7 kWh/ m^2 for all building orientations.

One of the reasons why these differences are detected is because the L-shape building takes advantage of the incident solar radiation more than the Linear building throughout the academic year due to its shape. In addition, due to the fact that the L-shape building has a higher transparent to opaque ratio implies that it has more incident solar radiation gains than the Linear building. Finally, as it can be seen from Model 1 and Model 2 related figures above which highlight the controlled and uncontrolled zones, due to fact that the L-shape building does not contain as many separating walls within one zone as the Linear building the energy needed for both heating and cooling is less.

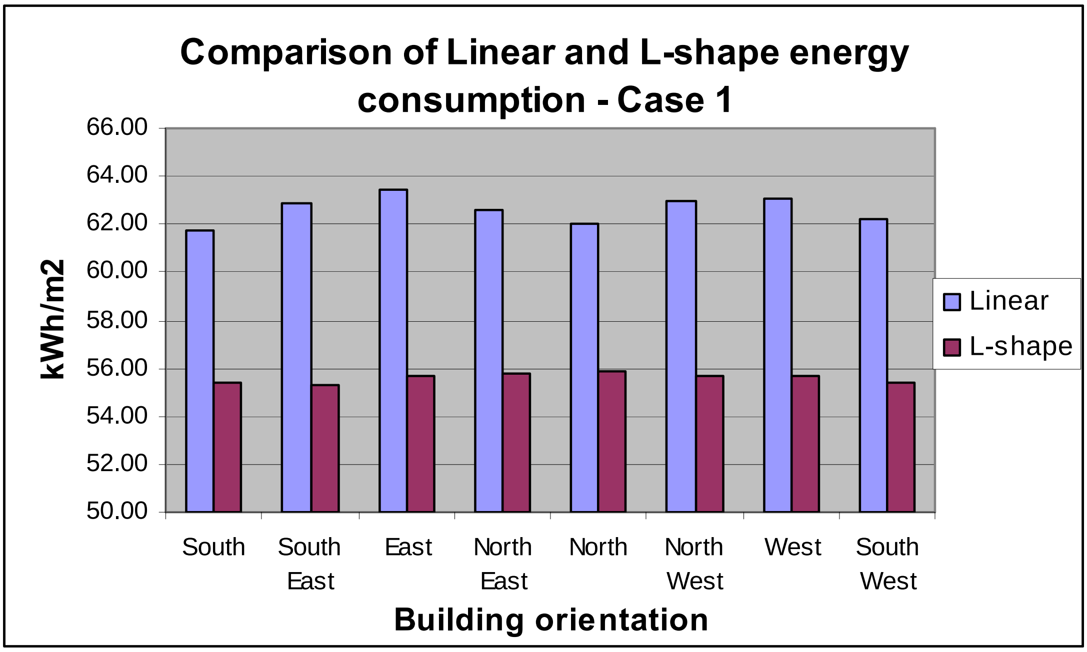


Figure 4: Energy consumption comparison – Athens – Case 1

The following figure (Figure 5) represents the outcome of the comparison of the two buildings in order to identify the differences in the heating consumption throughout the academic year. As it can be seen, the L-shape building requires less heating than the Linear building. The average difference of the above is 9.36 kWh/ m^2. Comparing the average heating consumption difference to the average energy consumption difference of both heating and cooling mentioned above it can be seen that the former is higher than the later.

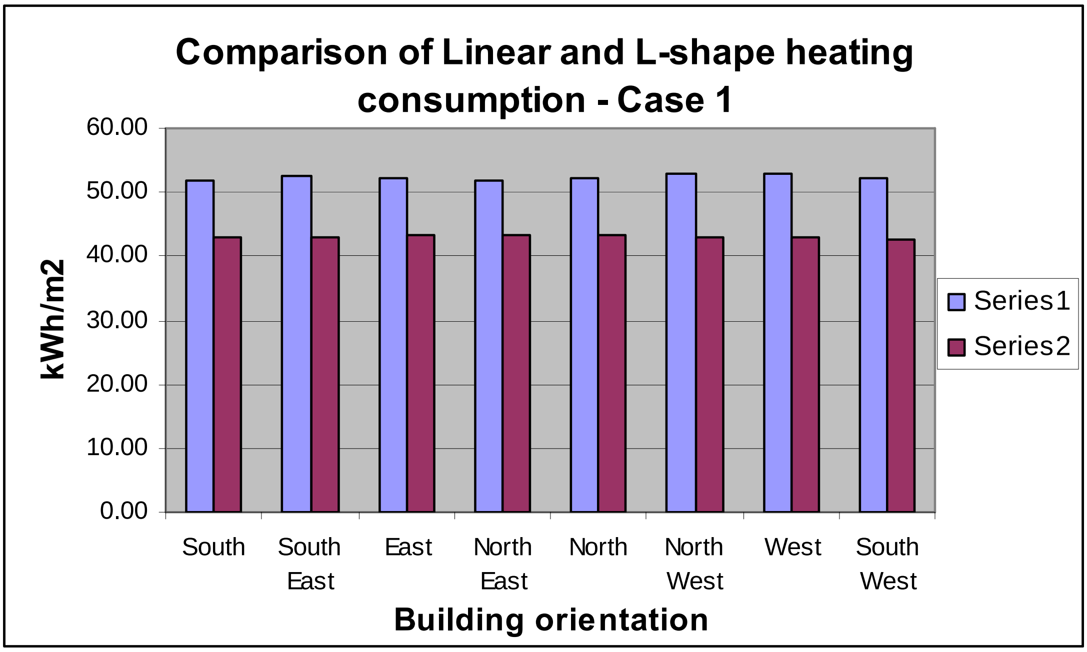


Figure 5: Heating consumption comparison – Athens – Case 1

The following figure (Figure 6) represents the outcome of the comparison of the two buildings in order to identify the differences in the cooling consumption throughout the academic year. As it can be seen, the L-shape building requires more cooling than the Linear building. The average difference is 2.36 kWh/ m^2. Comparing the average cooling consumption difference to the average energy consumption difference of both heating and cooling mentioned above it can be seen that the former is lower than the later.

Generally, considering all the abovementioned results we can conclude that although the L-shape building has less energy consumption per m^2 throughout the academic year than the Linear building it requires less heating energy and more cooling energy per m^2 compared to the Linear building. This is because the advantages of the incident solar radiation and the building's transparent to opaque ratio are greater than benefits from the shading devices (which are 1m wide). This implies that the benefits of the shading devices are minimal compared to the benefits from the incident solar radiation and the transparent to opaque ratio. However, it should be noted that if the shading devices where not in place in the L-shape building the cooling consumption results would be higher while the heating consumption results lower.

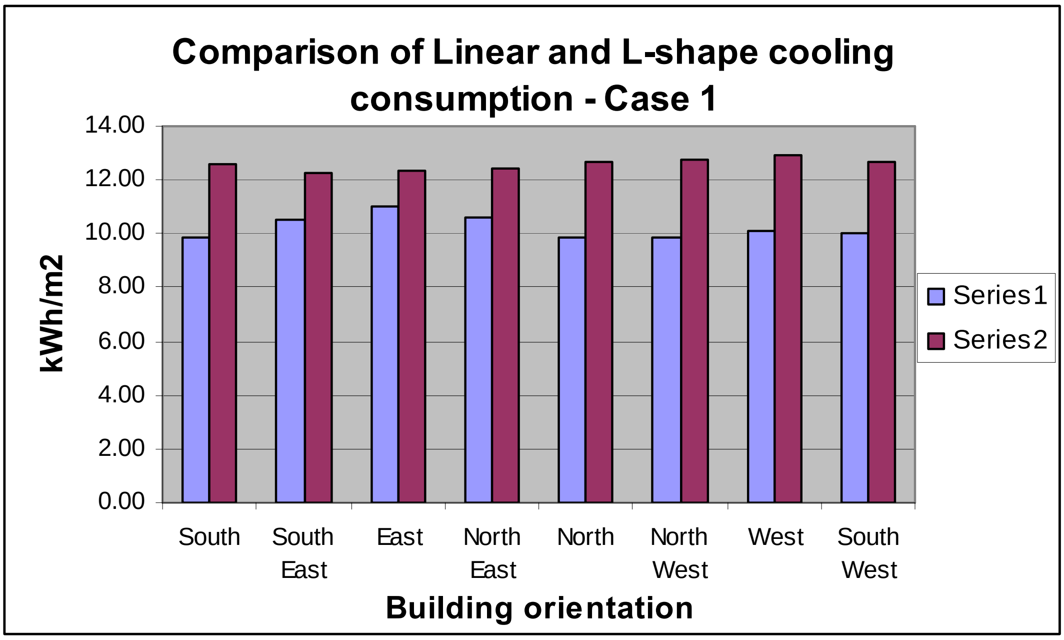


Figure 6: Cooling consumption comparison – Athens – Case 1

6.2 Educational buildings analysis

The following sections are focused in the parametric analysis of the Linear and L-shape educational buildings separately in which the building energy performance, maximum heating and cooling load required and occupant percentage people dissatisfaction factors will be evaluated modifying the following parameters:

- building' s climatic zones (Athens, Thessaloniki),
- wall insulation and glazing type (Case 1, Case 2, Case 3, Case 4)
- building orientation

6.3 Linear Educational Building -Athens

In the subsections below which represent 'Case 1' and 'Cases 2', the Linear building positioned in Athens is analyzed in order to evaluate the abovementioned factors with respect to the parameters separately.

6.3.1 Effect of building orientation, insulation and glazing type on energy performance

The figure below (Figure 7) represents the energy performance for heating and cooling of the Linear building in different orientations. As mentioned in section 5.1.1 above the reference direction of the building is shown in figure Model 1. From the figure below it can be noticed that the best energy performance of the building is in the South orientation. This means that it has the lowest energy consumption.

By rotating the building anticlockwise it can be observed that the East orientation has the worst energy performance which implies highest energy consumption. The difference between the best and worst energy performance using the same wall insulation and glazing type is 2.1 kWh/ m^2.

Naturally, it would be expected that the North orientation (which has the second best energy performance according to the figure) should have the worst energy performance. This is because as mentioned in section 5.1.1 above the uncontrolled zone contribution from the incident solar radiation of the respective zones (which face South), creates a buffer effect and reduces the actual energy requirements for heating of the surrounding (controlled) zones.

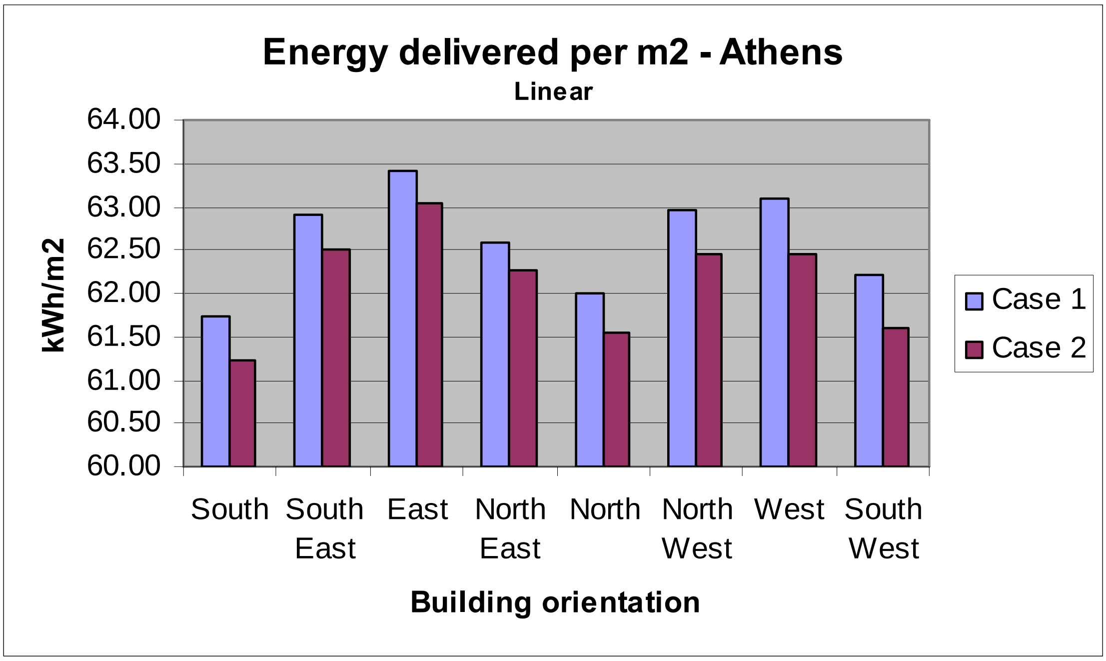


Figure 7: Annual energy delivered per m^2 - Athens

From the figure above (Figure 7) it can been seen that the better wall insulation and glazing type (Case 2) results to a better energy performance of the building in all orientations compared with the use of worse wall insulation and glazing type (Case1). In detail, the average difference of energy consumption between them is 0.5 kWh/ m^2 within the academic year.

From the figure below (Figure 8) which represents the energy performance for heating of the Linear building in different orientations it can be observed that the average difference of heating consumption is 0.66 kWh/ m^2 (between Case 1 and Case 2). Comparing this with the average difference of the energy consumption mentioned above it is higher. This implies that less energy is required for heating the building during the cold months of the academic year. In addition, it should be noted again, that Case 2 results to a better heating performance of the building.

Furthermore, it can been seen that the North West and North orientations of the building appear to have the most heating consumption compared to the rest of the orientations because the incident solar contribution is less.

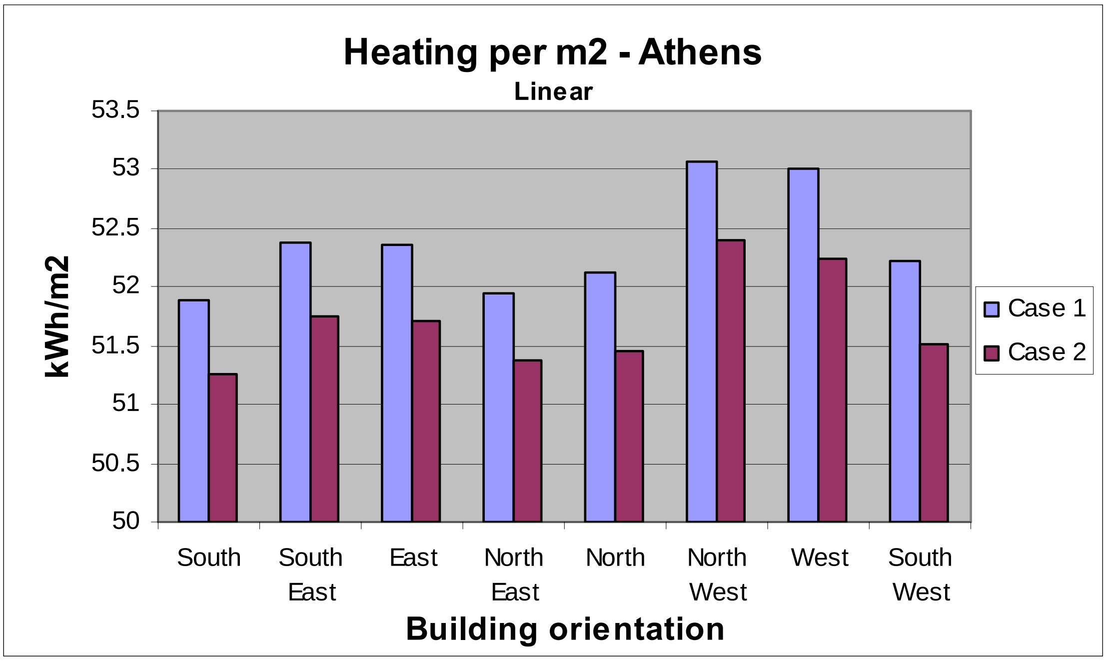


Figure 8: Annual heating energy delivered per m^2 - Athens

From the figure below (Figure 9) which represents the energy performance for cooling of the Linear building in different orientations it can be observed that the average difference of cooling consumption is -0.19 kWh/ m^2 (between Case 1 Case 2). Comparing this with the average difference of the energy consumption mentioned above it is lower. This implies that more energy is required for cooling the building during the hot months of the academic year. In addition, it should be noted again, that Case 2 results to a worse cooling performance of the building.

Furthermore, it can been seen that the South East, East and North East orientations of the building appear to have the most cooling consumption compared to the rest of the orientations because the incident solar contribution is more.

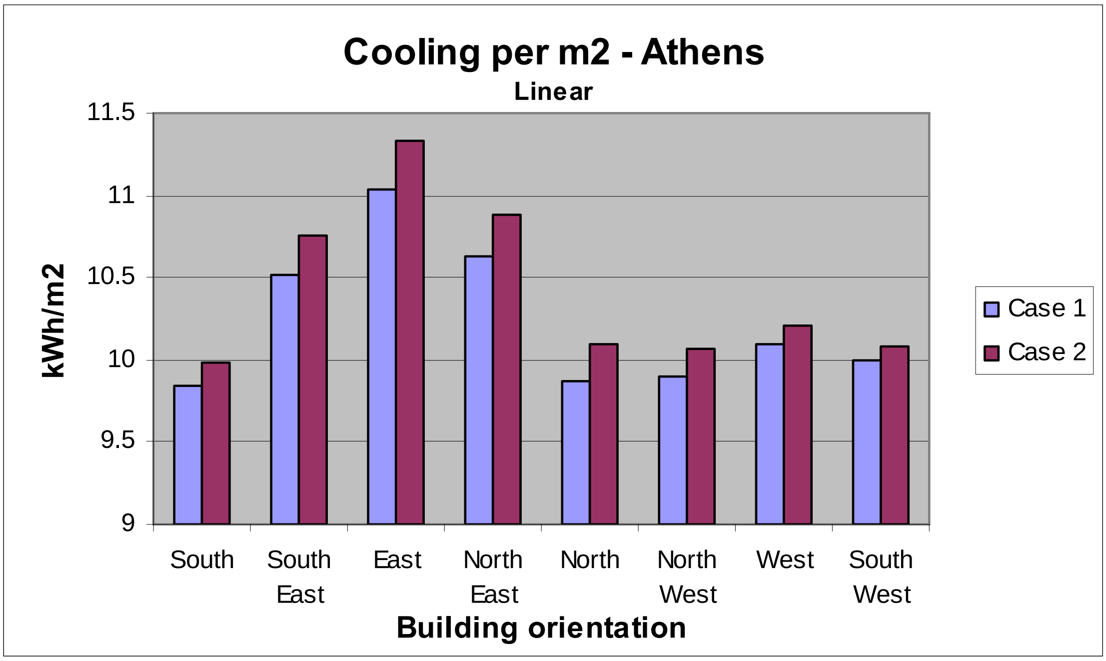


Figure 9: Annual cooling energy delivered per m^2 - Athens

Generally, from the analysis above it can be concluded that although Case 2 results to a better energy performance of the building in terms of both heating and cooling, heating performance is better in Case 2 while cooling performance is worse. This could be happening due to the fact that there is no natural ventilation throughout the day within the building and especially during the night.

6.3.2 Effect of building orientation, insulation and glazing type on heating and cooling load

The figure below (Figure 10) represents the maximum heating load per m^2 of the Linear building in different orientations. As mentioned in section 5.1.1 above the reference direction of the building is shown in figure Model 1. From the figure below it can be noticed that the best heating load performance of the building is in the North East orientation. This is because in this position, the incident solar radiation within the early hours of the day (morning) which are quite cold and the building is starting to operate the sun contribution creates the minimum heating load compared to the rest of the orientations.

In addition, the maximum heating load per m^2 is observed in the North West orientation where the benefit from the incident solar radiation contribution occurs during the later hours of the day (evening).

As observed in section 6.3.1 above for the analysis of the heating performance of the Linear building, Case 2 results to a better heating load performance than Case 1.

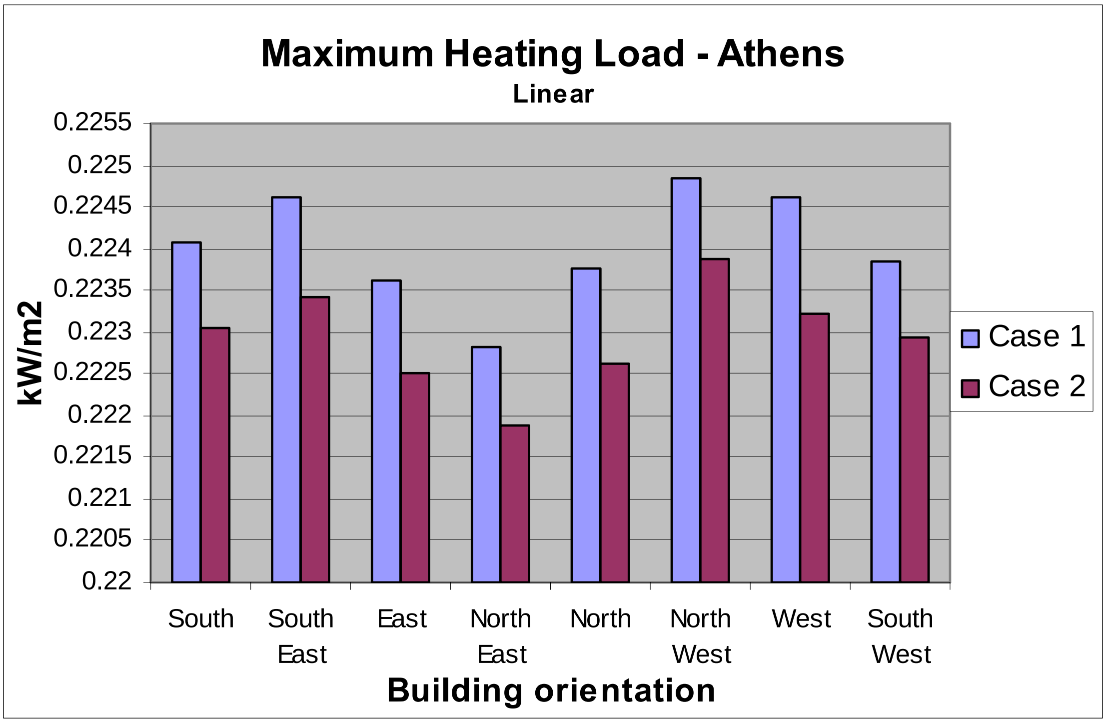


Figure 10: Maximum heating load per m^2 - Athens

The figure below (Figure 11) represents the heating load per m^2 required for each zone of the Linear building. From this it can be observed that zones that are near to entrances and/or are surrounded from uncontrolled zones appear to have increased heating loads compared with those that are surrounded from controlled zones. This is because the heating losses are higher when a controlled zone is next to the entrance instead of being surrounded from other controlled zones because higher heating load is required mainly the early hours of the day.

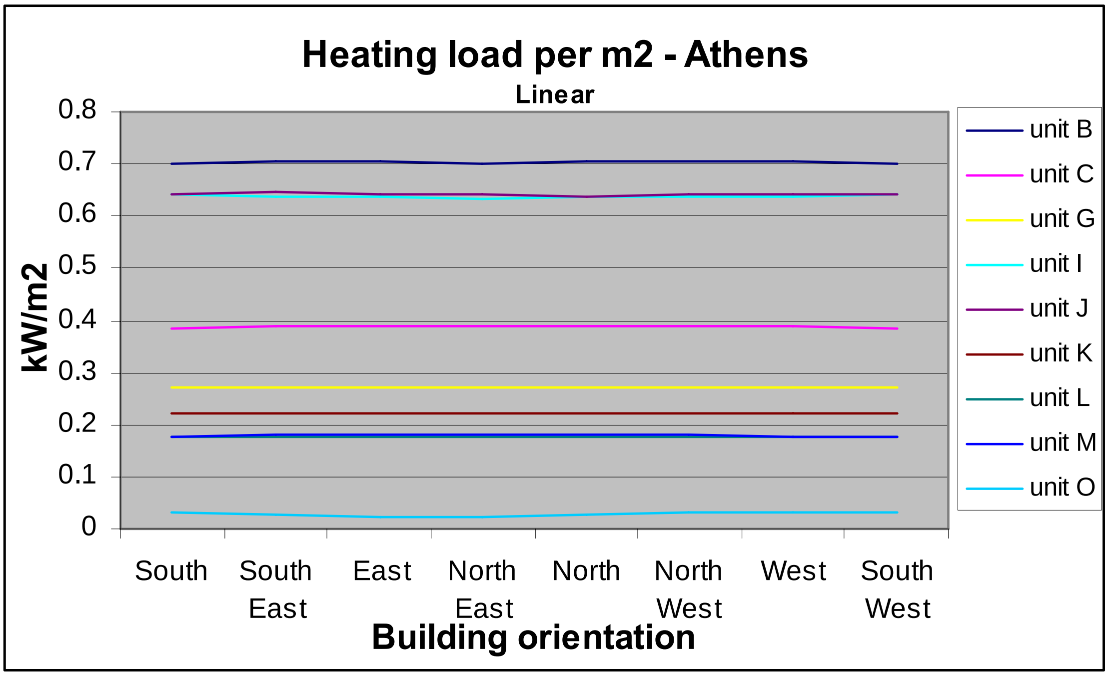


Figure 11: Maximum heating load per zone per m^2 – Athens

In the following figure (Figure 12) which represents the maximum cooling load per m^2 of the Linear building in different orientations it can be observed that the best cooling load performance of the building is in the North orientation. This is because in this position, the incident solar radiation within the hotter hours of the day (noon) is lower than in the remaining orientations. In detail, the building in the hot periods of the academic year during the hotter hours of the day reserves the heat therefore requires more cooling load. As it can be seen the maximum cooling load exists in the Eastwards and Westwards orientations (with the maximum in the West).

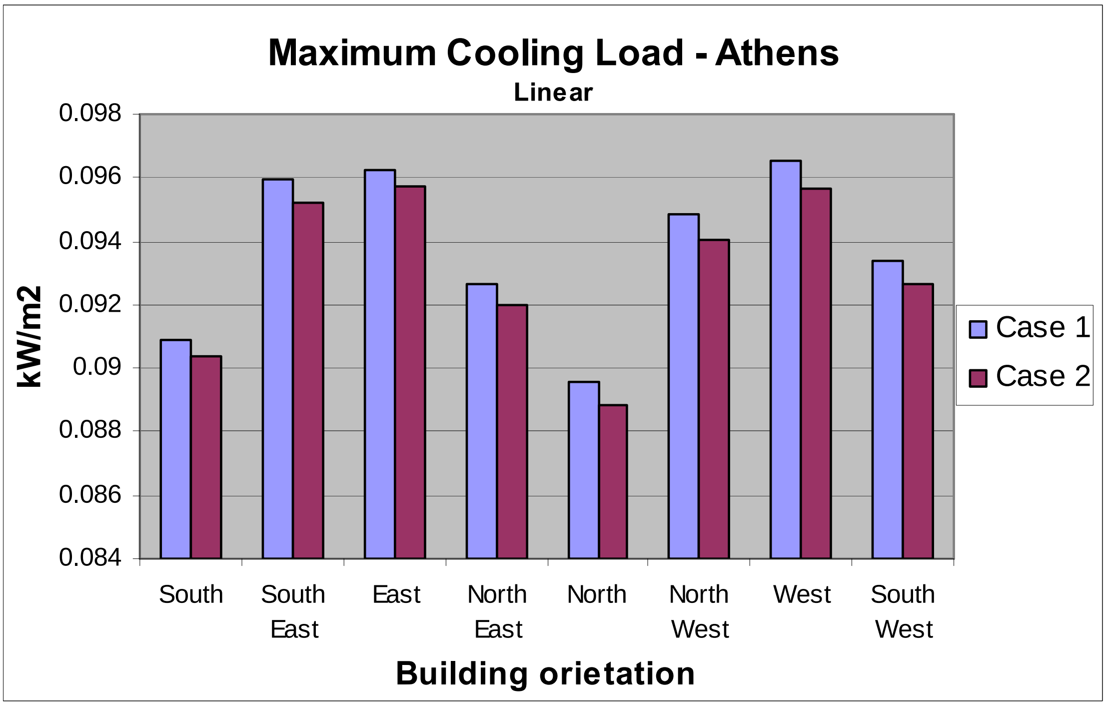


Figure 12: Maximum cooling load per m^2 - Athens

6.3.3 Effect of building orientation, insulation and glazing type on PPD

The figure below (Figure 13) which represents the percentage people dissatisfaction shows the same pattern as Figure 7 above. In detail, it can be observed that the more energy is required for the heating and cooling of the building the bigger the dissatisfaction of the occupants. The very high peaks of the resulting figure are due to the hot months of the academic year. This could be improved if natural ventilation was used for cooling the zones during the later hours of the day.

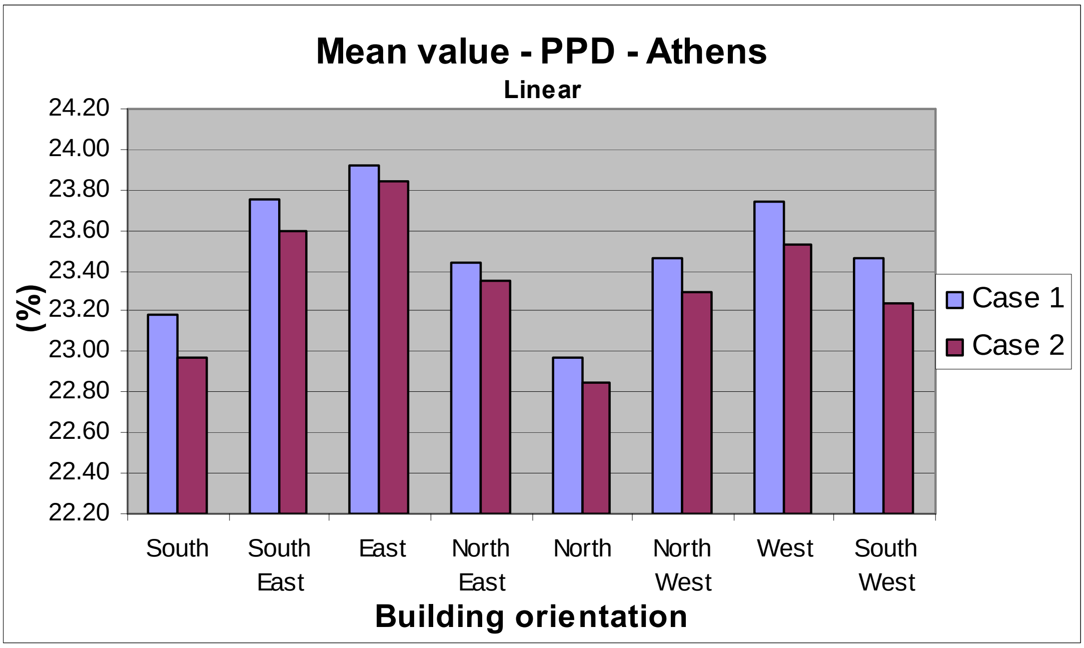


Figure 13: Annual mean PPD value - Athens

The figure below (Figure 14) represents a sample of the mean PPD value which is taken every month (specifically every 21^{st}) of the academic year. The clothing level used as an input for the simulation can be referenced in Appendix E3.

The figure shows the occupant's dissatisfaction at a representative day of every month within the year. The resulting PPD values appear to be consistent throughout the year except from certain peaks which appear in the months: May, June and September. This is due to the fact that in the aforementioned months the climate becomes hotter and the heat is trapped within the building. In addition, there is no natural cooling during the late hours of the day. Furthermore, there are no internal blinds in order to divert the incident solar radiation.

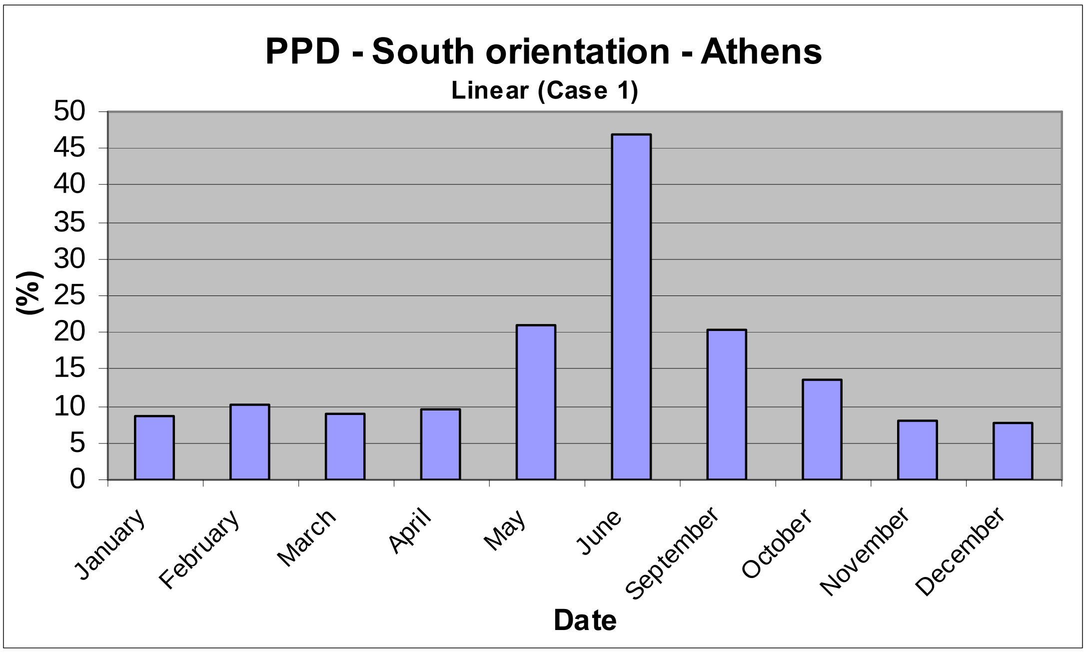


Figure 14: Monthly sample of mean PPD value (every 21st) - Athens

6.4 Linear Educational Building - Thessaloniki

In the subsections below which represent 'Case 3' and 'Cases 4', the Linear building positioned in Thessaloniki is analyzed in order to evaluate the factors with respect to the parameters (mentioned above) separately.

6.4.1 Effect of building orientation, insulation and glazing type on energy performance

The figure below (Figure 15) represents the energy performance for heating and cooling of the Linear building in different orientations. As mentioned in section 5.1.1 above the reference direction of the building is shown in figure Model 1. From the figure below it can be noticed that the best energy performance of the building is again in the South orientation which means that in this position the building has the lowest energy consumption for heating and cooling. Generally, the graph shows the same pattern as the corresponding in Athens (Figure 7 above) but since it is in a cooler climatic zone it requires more energy than in Athens which is in a hotter climatic zone. In detail, the difference of the energy consumption of the building in the two different climatic zones is about 28.5 kWh/m^2.

Regarding the energy performance of the building with the use of better wall insulation and glazing type (Case 3, Case 4) again it can be observed that the energy required is reduced at an average of 1.16 kWh/m^2 in all orientations. Compared to the results of Athens climatic zone (0.5 kWh/ m^2) the best wall insulation and glazing type is the one of Case 4 which results in a higher energy reduction although Thessaloniki is in a colder climatic zone.

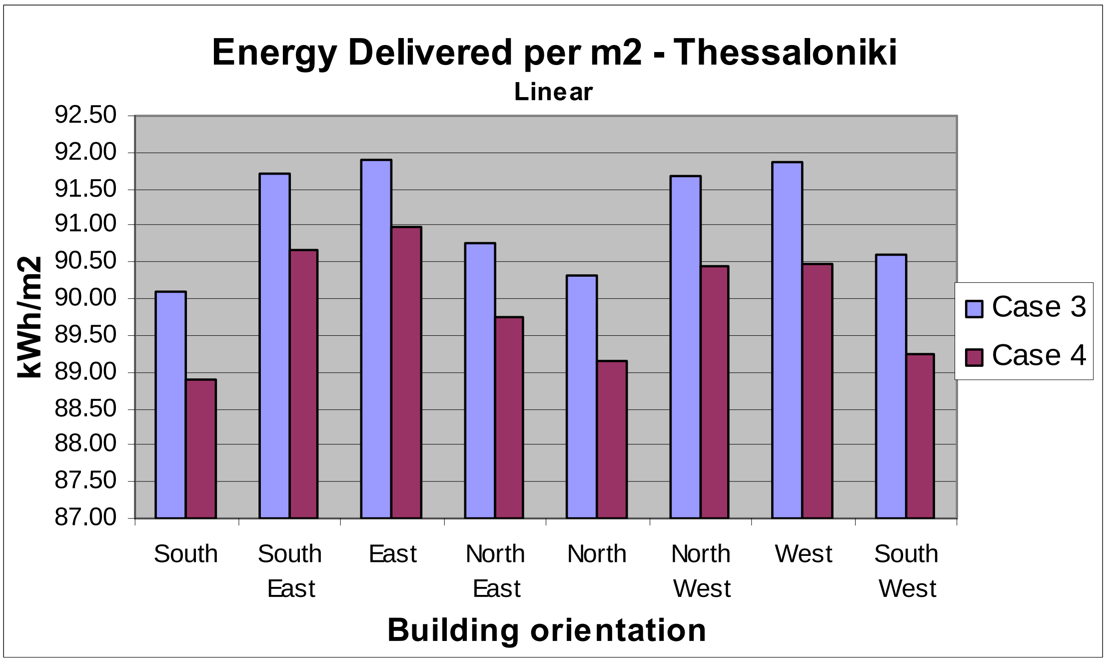


Figure 15: Annual energy delivered per m^2 - Thessaloniki

From the figure below (Figure 16) which represents the energy performance for heating of the Linear building in different orientations it can be observed that the average difference of heating consumption is 1.68 kWh/ m^2 (between Case 3 and Case 4). Comparing this with the average difference of the energy consumption mentioned above it is higher. This implies that less energy is required for heating the building during the cold months of the academic year due to better wall insulation and glazing type. In addition, it should be noted again, that Case 4 results to a better heating performance of the building.

Generally, the pattern of the figure below (Figure 16) is again similar to the one for Athens (Figure 8) with the North West and North orientations of the building having the most heating consumption compared to the rest of the orientations due to the incident solar contribution being less. In addition, the difference of heating consumption between Athens and Thessaloniki climatic zones is of an average 29.7 kWh/ m^2 which implies that more energy is required in Thessaloniki than in Athens, due to the colder climate.

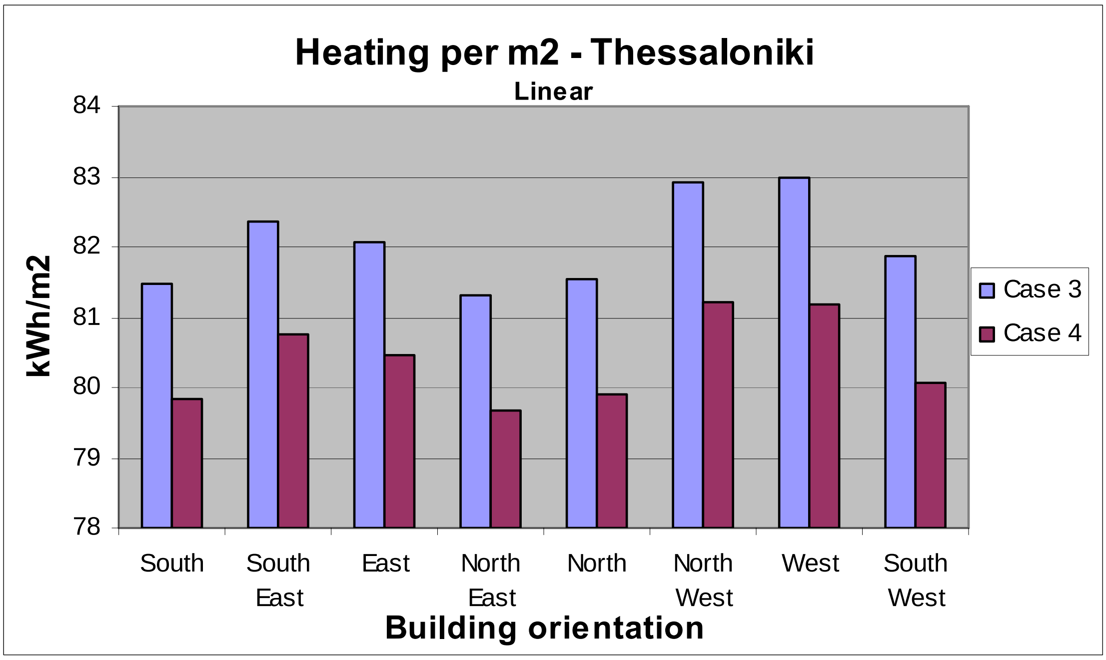


Figure 16: Annual heating energy delivered per m^2 - Thessaloniki

From the figure below (Figure 17) which represents the energy performance for cooling of the Linear building in different orientations it can be observed that the average difference of cooling consumption is -0.52 kWh/ m^2 (between Case 3 and Case 4). Comparing this with the average difference of the energy consumption mentioned above it is lower. Again this implies that more energy is required for cooling the building during the hot months of the academic year when better wall insulation and glazing type is used. In addition, it should be noted again, that Case 4 results to a worse cooling performance of the building. This is because more heat is trapped inside the building (buffer effect) due to better wall insulation and glazing type.

Furthermore, again it can been seen that the South East, East and North East orientations of the building appear to have the most cooling consumption compared to the rest of the orientations because the incident solar contribution is more.

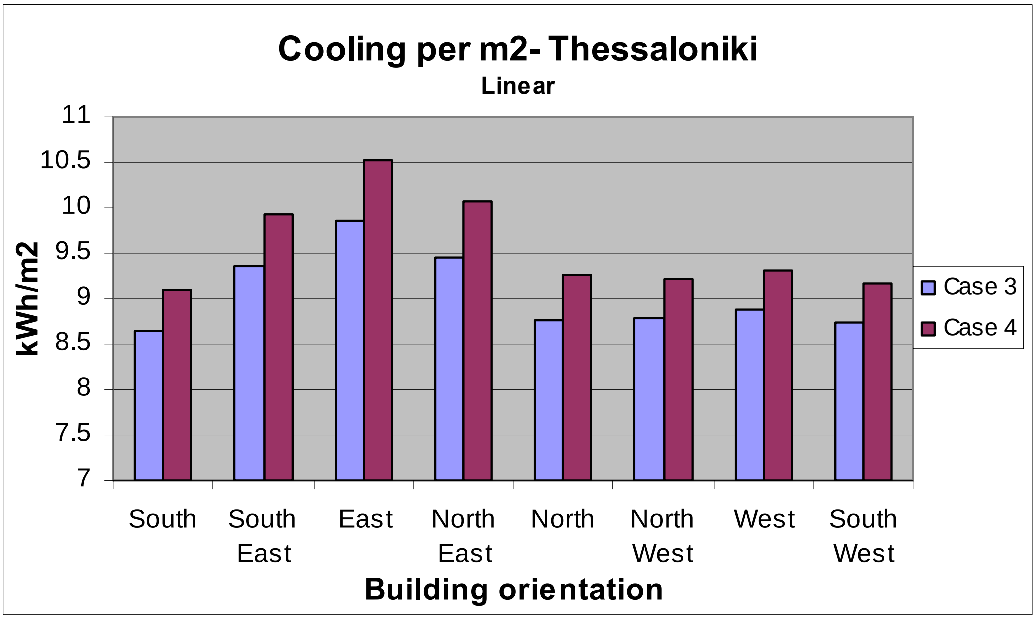


Figure 17: Annual cooling energy delivered per m^2 - Thessaloniki

In addition, the difference of cooling consumption between Athens and Thessaloniki climatic zones is of an average -1.2 kWh/ m^2, which implies that less energy is required in Thessaloniki than in Athens, due to the colder climate.

Generally, from the analysis above it can be concluded that although Case 4 results to a better energy performance of the building in terms of both heating and cooling, heating performance is better in Case 4 while cooling performance is worse. This could be happening due to the fact that there is no natural ventilation throughout the day (hotter months) within the building and especially during the night.

6.4.2 Effect of building orientation, insulation and glazing type on heating and cooling load

The figure below (Figure 18) represents the maximum heating load per m^2 of the Linear building in different orientations. As mentioned in section 5.1.1 above the reference direction of the building is shown in figure Model 1. From the figure below it can be noticed that the best heating load performance of the building is in the North East orientation and the maximum heating load per m^2 is observed in the North West orientation as it is for Athens climatic zone. Therefore, the effects that are applied to Athens zone are the same.

Furthermore, as observed in section 6.4.1 above for the analysis of the heating performance of the Linear building, Case 4 results to a better heating load performance than Case 3. In addition, it can be observed that the percentage of heating load reduction in East, North East and North orientations is greater than the reduction of the rest orientations. This is because as it can be seen in Appendix E4 the heating load reduction between Case 3 and Case 4 increases because unit b and unit c which are next to uncontrolled zones are contributed from the solar incident radiation and the heat trapped of the surrounding uncontrolled zones.

Compared to Athens the average heating load in different orientations of Thessaloniki is higher (about 37%) and this is normal because due to the cold climate the heating requirements are more during building's early operating hours.

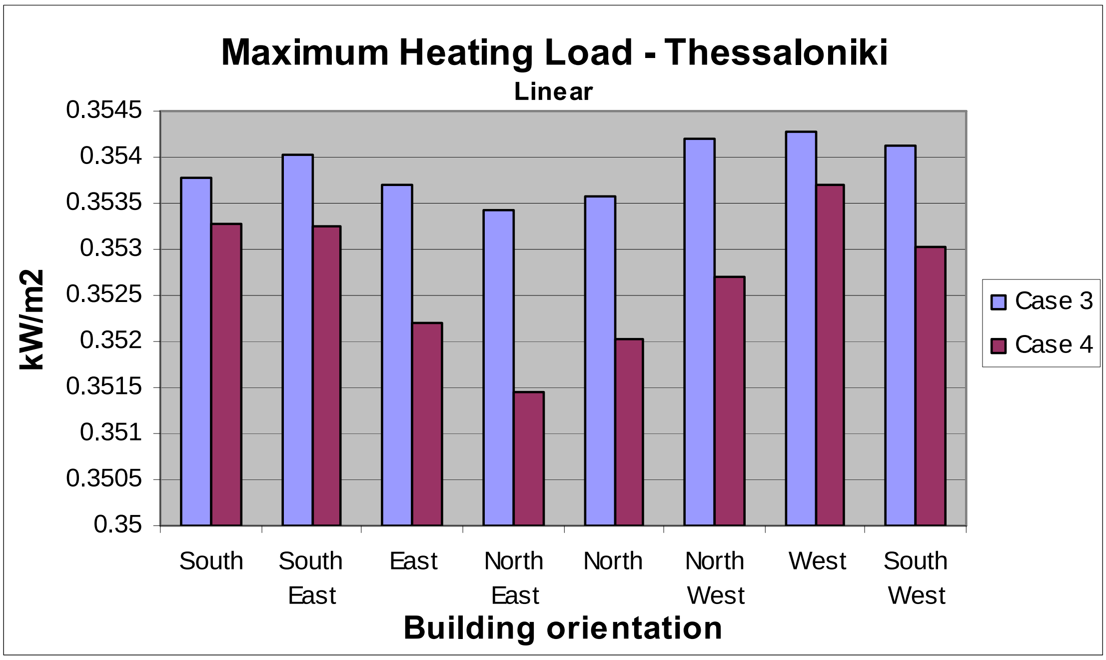


Figure 18: Maximum heating load per m^2 - Thessaloniki

In the following figure (Figure 19) which represents the maximum cooling load per m^2 of the Linear building in different orientations it can be observed that the best cooling load performance of the building is in the North orientation. This again is similar to Athens along with its interrelated effects. However, although the maximum cooling load exists in the Eastwards and Westwards orientations with the maximum being in the East while in Athens the maximum appears in the West. This could be due to the different sun path in the northern Thessaloniki than that of southern Athens.

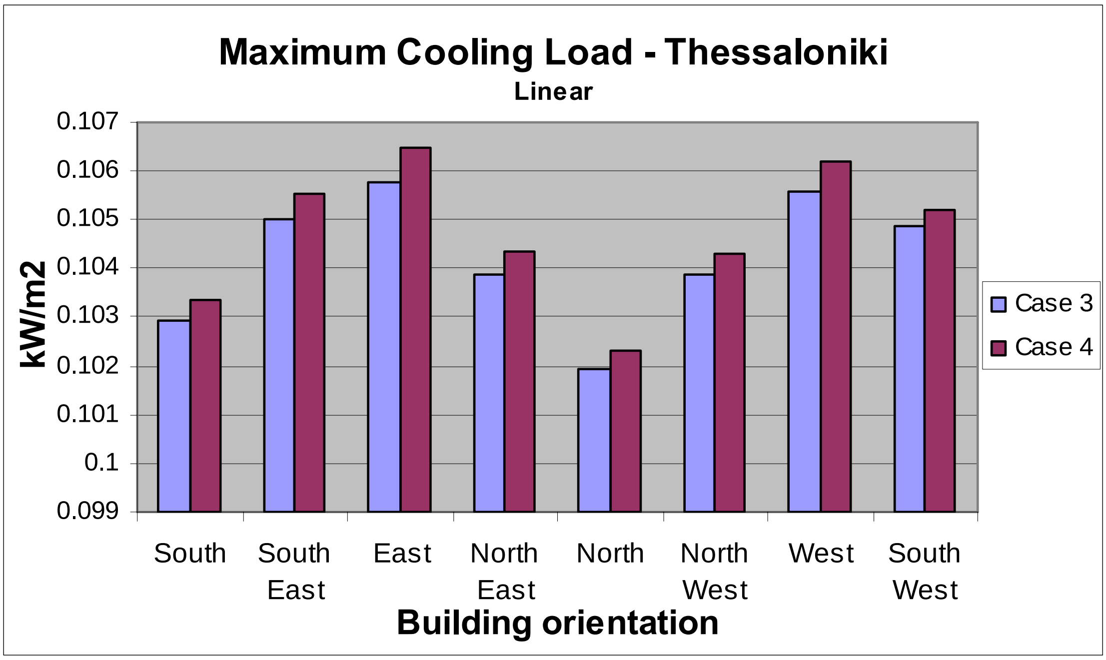


Figure 19: Maximum cooling load per m^2 - Thessaloniki

The figure below (Figure 20) represents the cooling load per m^2 required for each zone of the Linear building. From this it can be observed that zones that are near to entrances and/or are surrounded from uncontrolled zones appear to have increased cooling loads compared with those that are surrounded from controlled zones. This is because the heating gains are higher when a controlled zone is next to the entrance instead of being surrounded from other controlled zones because higher cooling load is required mainly the midday.

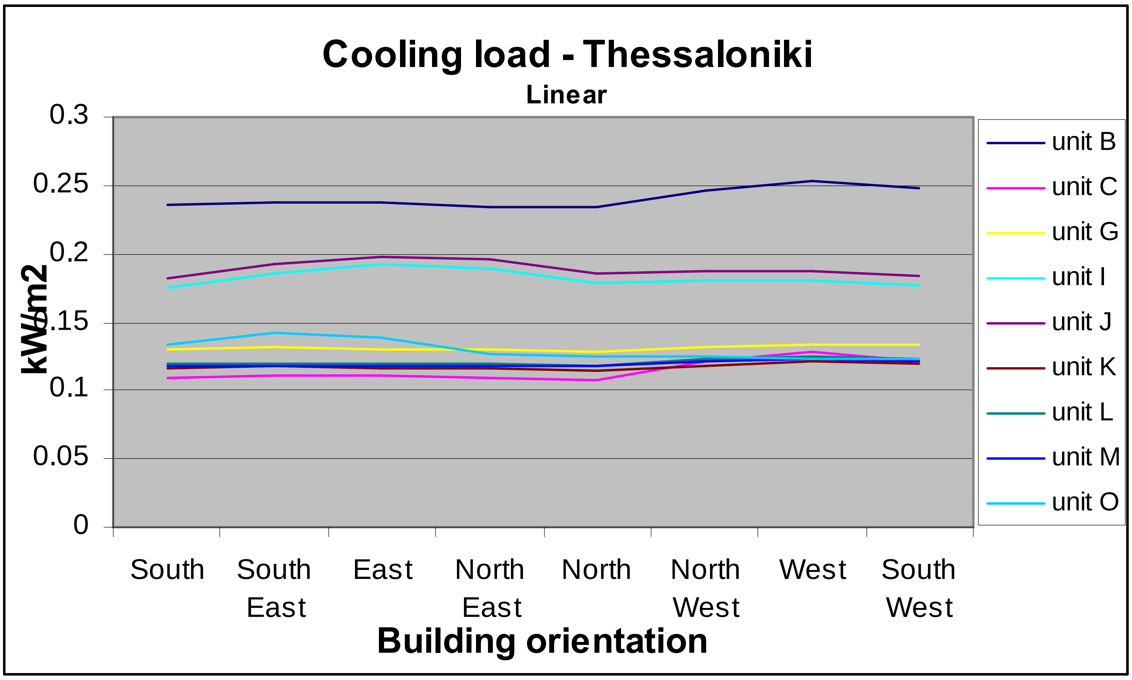


Figure 20: Maximum cooling load per zone per m^2 - Thessaloniki

6.4.3 Effect of building orientation, insulation and glazing type on PPD

From the figure below (Figure 21) which represents the percentage people dissatisfaction shows the same pattern as Figure 15 above. In detail, it can be observed that the more energy is required for the heating and cooling of the building the bigger the dissatisfaction of the occupants. The very high peaks of the resulting figure are due to the hot months of the academic year. This could be improved if natural ventilation was used for cooling the zones during the later hours of the day.

The above-mentioned effects are the same as for Athens but the average dissatisfaction of the occupants appears to be higher (mean PPD value difference is 4% higher in Thessaloniki) due to the fact the heating and cooling regime might not be the appropriate.

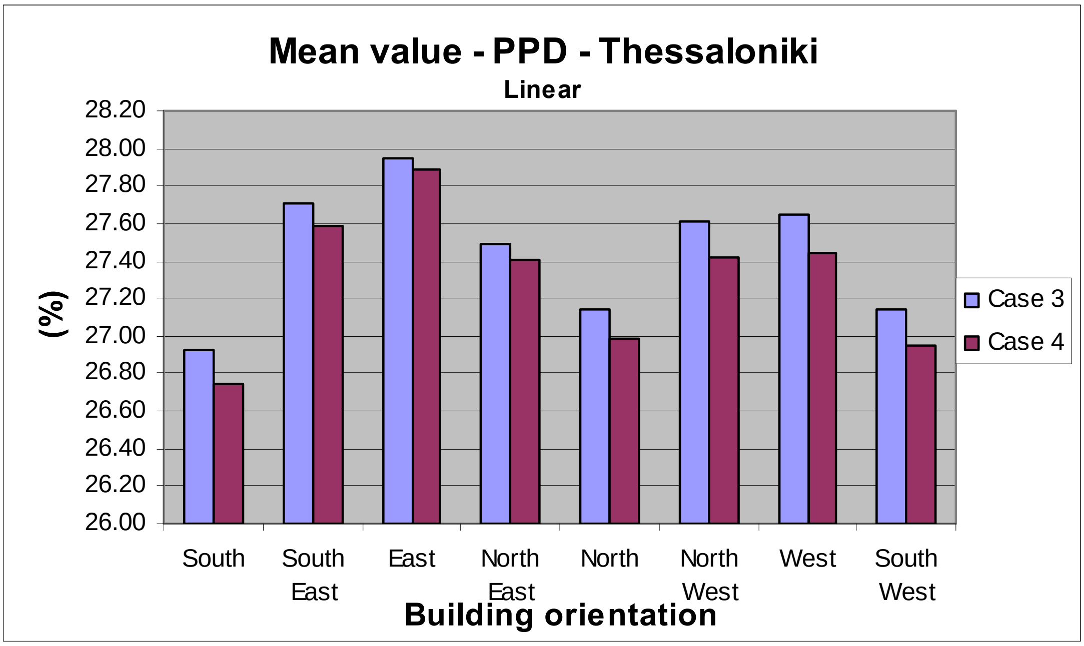


Figure 21: Annual mean PPD value - Thessaloniki

The figure below (Figure 22) represents a sample of the mean PPD value which is taken every month (specifically every 21st) of the academic year. The clothing level used as an input for the simulation can be referenced in Appendix E3.

The figure shows the occupant's dissatisfaction at a representative day of every month within the year. The resulting PPD values appear to be inconsistent compared to those of Athens. Here, the highest PPD value occurs in September instead of June in Athens.

Furthermore, the PPD value appears to be increased during the cooler months while during the hot periods it appears to be less compared to Athens. This is because Thessaloniki is in a colder climatic zone than Athens and the heating regime needs to be re-adjusted in order to reduce the PPD value. In addition, winter in Thessaloniki lasts longer than in Athens and clothing level needs to be re-adjusted to those conditions. During the hotter months similarly to Athens natural cooling in addition with internal blinds can be used. However, the humid climate of Thessaloniki justifies the high PPD values during hotter months.

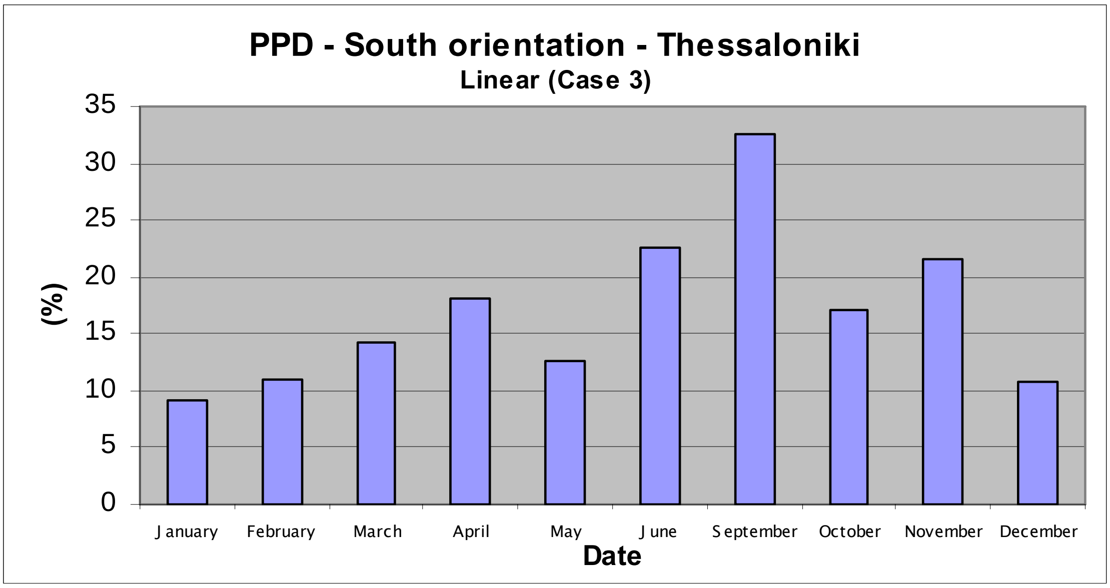


Figure 22: Annual mean PPD value - Thessaloniki

6.5 L-shape Educational Building - Athens

In the subsections below which represent 'Case 1' and 'Cases 2', the L-shape building positioned in Athens is analyzed in order to evaluate the factors with respect to the parameters (mentioned above) separately.

6.5.1 Effect of building orientation, insulation and glazing type on energy performance

The figure below (Figure 23) represents the energy performance for heating and cooling of the L-shape building in different orientations. As mentioned in section 5.1.2 above the reference direction of the building is shown in figure Model 2. From the figure below it can be noticed that the best energy performance of the building is in the South East orientation. This means that it has the lowest energy consumption.

By rotating the building anticlockwise it can be observed that the North orientation has the worst energy performance which implies highest energy consumption. The difference between the best and worst energy performance using the same wall insulation and glazing type is 0.55 kWh/ m^2.

Using a better wall insulation and glazing type (Case 2) the energy performance of the building is improved. The best energy performance can be observed in South West, South and South East orientations which complies with "Save Programme", (November 1995) analysis that best energy performances occur +/- 30degrees from South orientation.

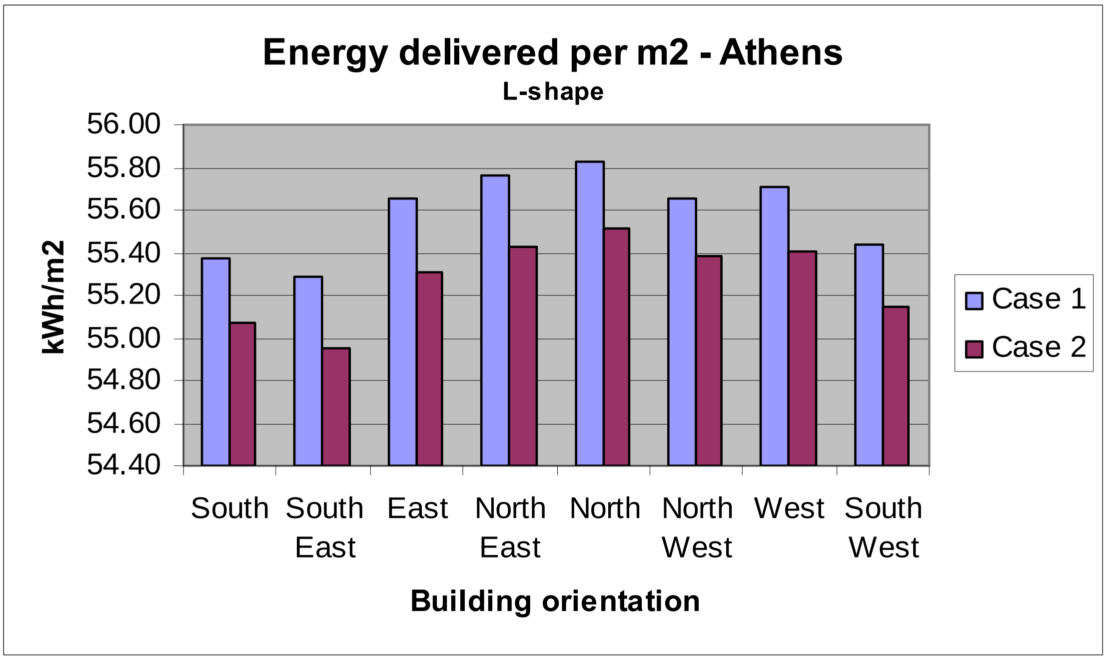


Figure 23: Annual energy delivered per m^2 - Athens

From the figure above (Figure 23) it can been seen that the better wall insulation and glazing type (Case 2) results to a better energy performance of the building in all orientations compared with the use of worse wall insulation and glazing type (Case1). In detail, the average difference of energy consumption between them is 0.31 kWh/ m^2 within the academic year.

From the figure below (Figure 24) which represents the energy performance for heating of the L-shape building in different orientations it can be observed that the average difference of heating consumption is 0.86 kWh/ m^2 (between Case 1 and

Case 2). Comparing this with the average difference of the energy consumption mentioned above it is higher. This implies that less energy is required for heating the building during the cold months of the academic year. In addition, it should be noted again, that Case 2 results to a better heating performance of the building.

Furthermore, it can been seen that the East and North East orientations of the building appear to have the most heating consumption compared to the rest of the orientations because the incident solar contribution is less.

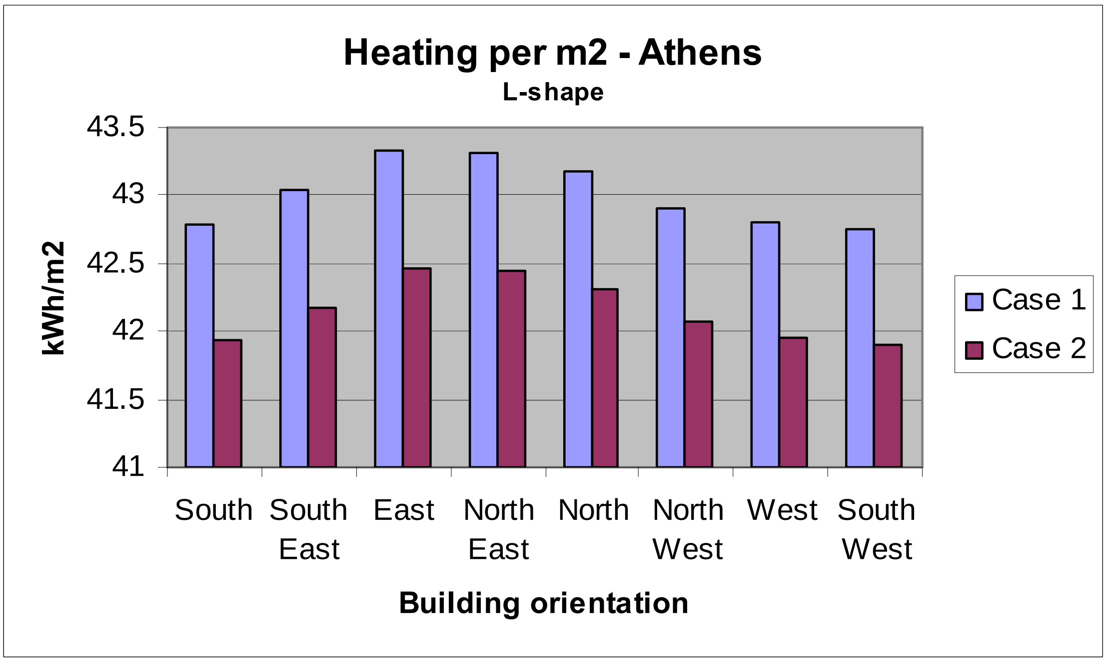


Figure 24: Annual heating energy delivered per m^2 - Athens

From the figure below (Figure 25) which represents the energy performance for cooling of the L-shape building in different orientations it can be observed that the average difference of cooling consumption is -0.54 kWh/ m^2 (between Case 1 Case 2). Comparing this with the average difference of the energy consumption mentioned above it is lower. This implies that more energy is required for cooling the building during the hot months of the academic year. In addition, it should be noted again, that Case 2 results to a worse cooling performance of the building.

Furthermore, it can been seen that the North West, West and South West orientations of the building appear to have the most cooling consumption compared to the rest of the orientations with West orientation having the highest because the incident solar contribution is more.

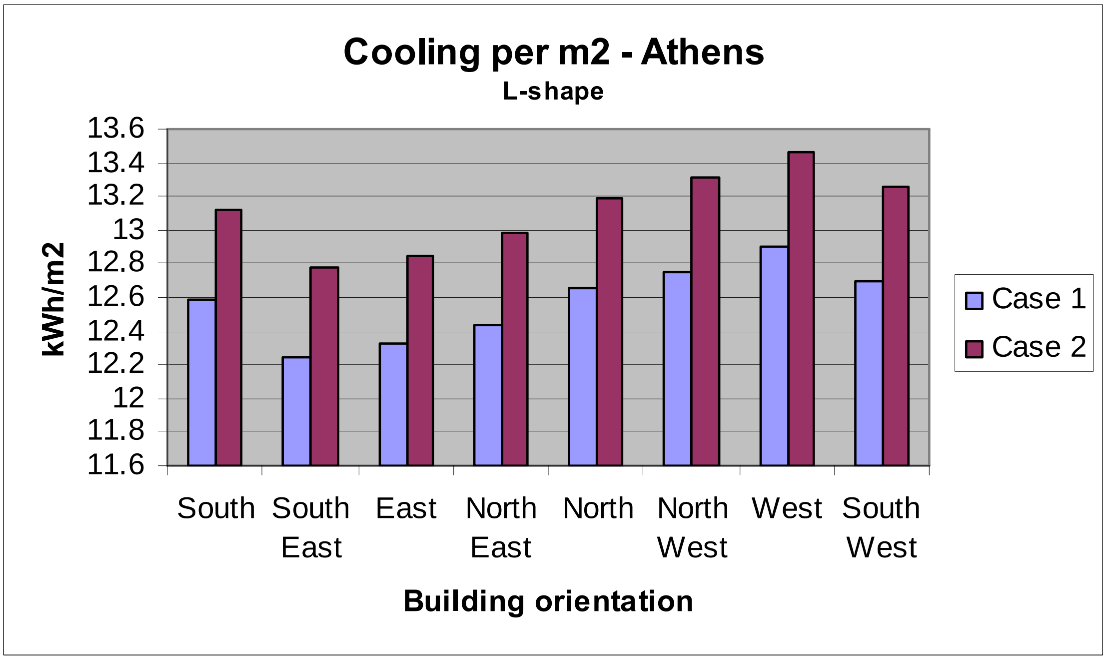


Figure 25: Annual cooling energy delivered per m^2 - Athens

Generally, from the analysis above it can be concluded that although Case 2 results to a better energy performance of the building in terms of both heating and cooling, heating performance is better in Case 2 while cooling performance is worse. This could be happening due to the fact that there is no natural ventilation throughout the day within the building and especially during the night.

6.5.2 Effect of building orientation, insulation and glazing type on heating and cooling load

The figure below (Figure 26) represents the maximum heating load per m^2 of the L-shape building in different orientations. As mentioned in section 5.1.2 above the reference direction of the building is shown in figure Model 2. From the figure below it can be noticed that the best heating load performance of the building is in the South East orientation in Case 1 and South West in Case 2. This is because in those positions, the incident solar radiation within the early hours of the day (morning) which are quite cold and the building is starting to operate the sun contribution creates the minimum heating load compared to the rest of the orientations. Furthermore, the better wall insulation and glazing type reduced the maximum loads because heat losses are reduced in combination with the incident solar radiation contribution.

In addition, the maximum heating load per m^2 is observed in the North East orientation where the least benefits from the incident solar radiation contribution occurs compared to other orientations.

As observed in section 6.5.1 above for the analysis of the heating performance of the L-shape building, Case 2 results to a better heating load performance than Case 1.

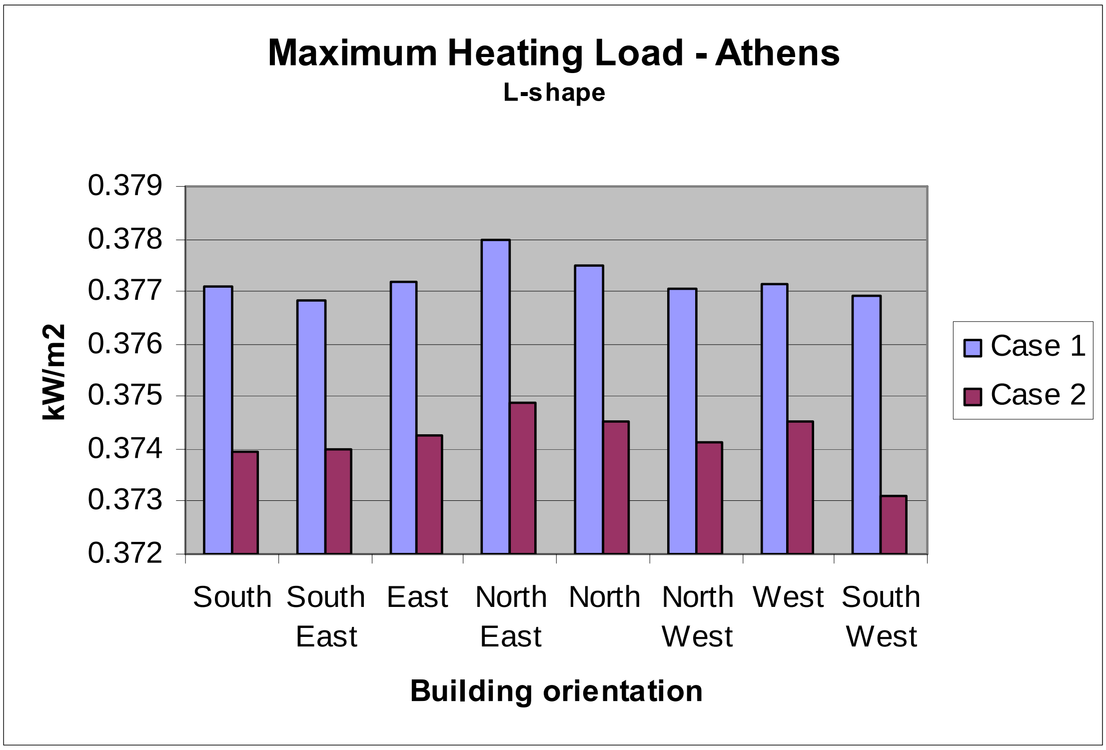


Figure 26: Maximum heating load per m^2 - Athens

The figure below (Figure 27) represents the heating load per m^2 required for each zone of the L-shape building. From this it can be observed that the heating load throughout the building's zones compared to Case 1 of Athens Linear educational building (Figure 11) is more consistent, because there are less uncontrolled heated zones. Furthermore, it can be seen that 'unit' which is the common activities area has the less heating load per m^2 required and this is due to the fact that there are no windows and therefore heat losses are minimized.

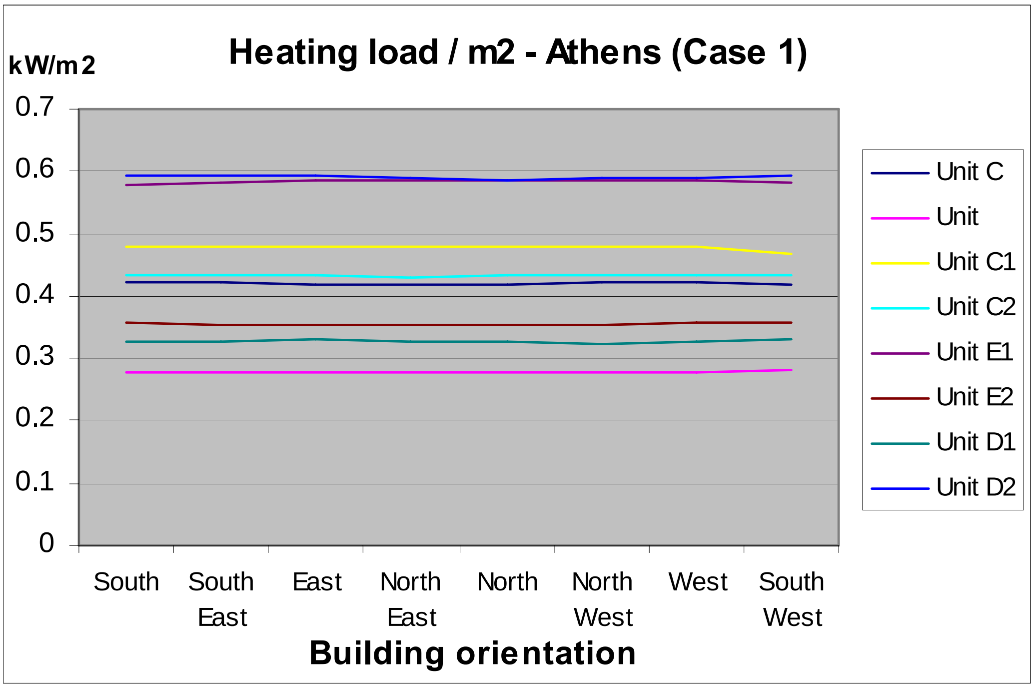


Figure 27: Maximum heating load per zone per m^2 – Athens

In the following figure (Figure 28) which represents the maximum cooling load per m^2 of the L-shape building in different orientations it can be observed that the best cooling load performance of the building is in the South East orientation. On the other hand, maximum cooling load occurs at North West orientation. By comparing these two extremes the incident solar radiation contributes less to the South East orientation (early hours) and more to the North West orientation (evening).

Furthermore, by comparing Case 1 and Case 2 the better wall insulation and glazing type increase the energy requirements for cooling because heat losses are now reduced and no natural ventilation policy is used for the natural cooling of the building.

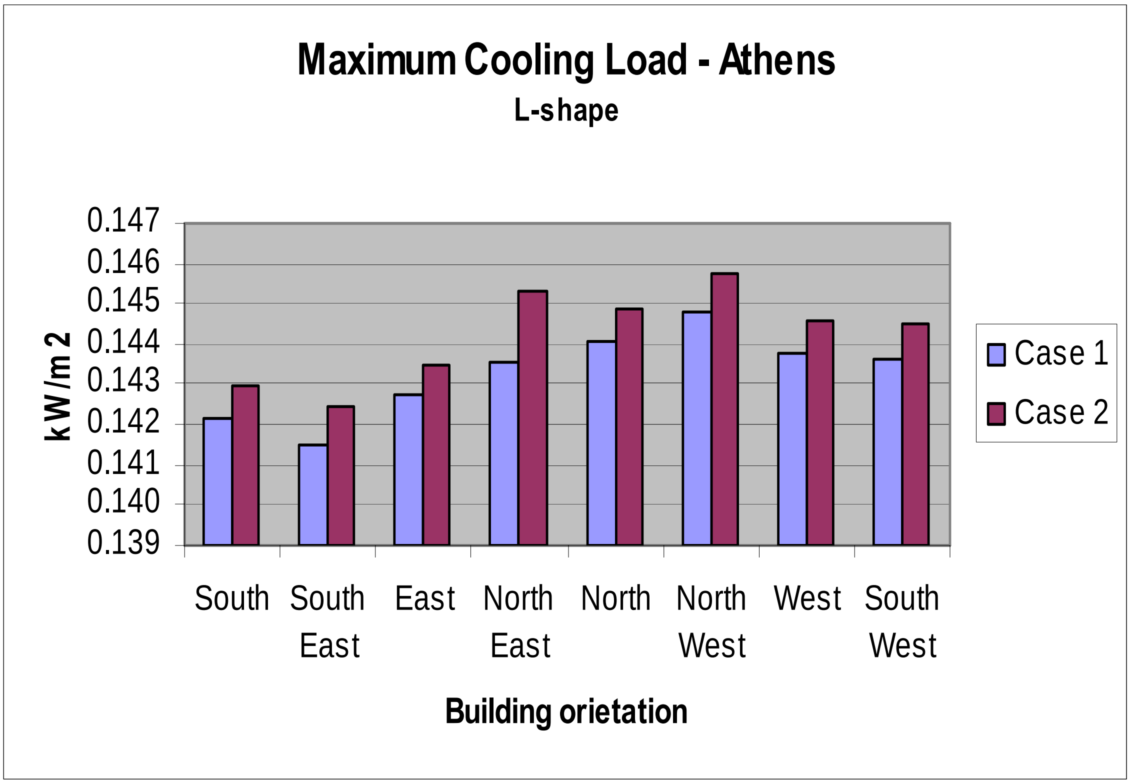


Figure 28: Maximum cooling load per m^2 - Athens

6.5.3 Effect of building orientation, insulation and glazing type on PPD

From the figure below (Figure 29) which represents the percentage people dissatisfaction does not show the same pattern as Figure 23 above. In detail, it can be observed that the less energy is required for the heating and cooling of the building the bigger the dissatisfaction of the occupants. The very high peak which is observed in the South East orientation shows an increase of about 4% compared to the rest orientation in which the PPD values are approximately the same for both cases (1&2).

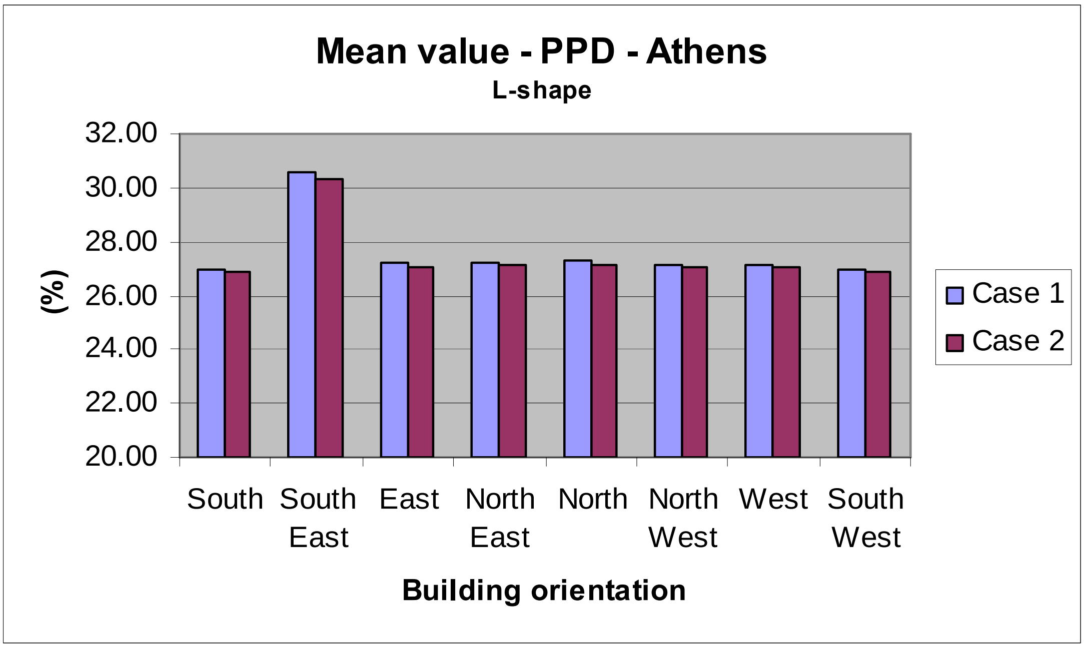


Figure 29: Annual mean PPD value - Athens

The figure below (Figure 30) represents a sample of the mean PPD value which is taken every month (specifically every 21st) of the academic year. The clothing level used as an input for the simulation can be referenced in Appendix E3.

The figure shows the occupant's dissatisfaction at a representative day of every month within the year. The resulting PPD values appear to be consistent throughout the year except from certain peaks which appear in the months: May, June and September. This is due to the fact that in the aforementioned months the climate becomes hotter and the heat is trapped within the building. In addition, there is no natural cooling during the late hours of the day. Furthermore, there are no internal blinds in order to divert the incident solar radiation.

Generally, the figure follows the same pattern as Linear educational building in Athens (Figure 14) and therefore shares the same characteristics.

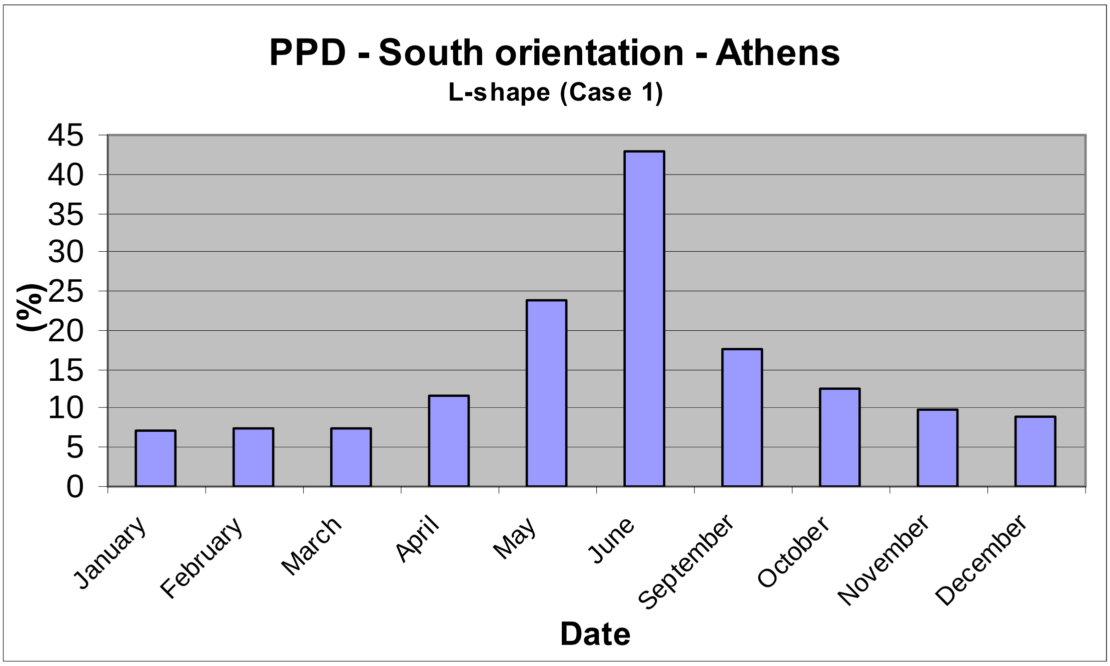


Figure 30: Annual mean PPD value - Athens

6.6 L-shape Educational Building - Thessaloniki

In the subsections below which represent 'Case 3' and 'Cases 4', the L-shape building positioned in Thessaloniki is analyzed in order to evaluate the factors with respect to the parameters (mentioned above) separately.

6.6.1 Effect of building orientation, insulation and glazing type on energy performance

The figure below (Figure 31) represents the energy performance for heating and cooling of the L-shape building in different orientations. As mentioned in section 5.1.2 above the reference direction of the building is shown in figure Model 2. From the figure below it can be noticed that the best energy performance of the building is again in the South East orientation which means that in this position the building has the lowest energy consumption for heating and cooling. Generally, the graph shows the same pattern as the corresponding in Athens (Figure 23 above) but since it is in a cooler climatic zone it requires more energy than in Athens which is in a hotter climatic zone. In detail, the difference of the energy consumption of the building in the two different climatic zones is about 21.3 kWh/ m^2.

Regarding the energy performance of the building with the use of better wall insulation and glazing type (Case 3, Case 4) again it can be observed that the energy required is reduced at an average of 1.26 kWh/ m^2 in all orientations. Compared to the results of Athens climatic zone (0.31 kWh/ m^2) the best wall insulation and glazing type is the one of Case 4 which results in a higher energy reduction although Thessaloniki is in a colder climatic zone.

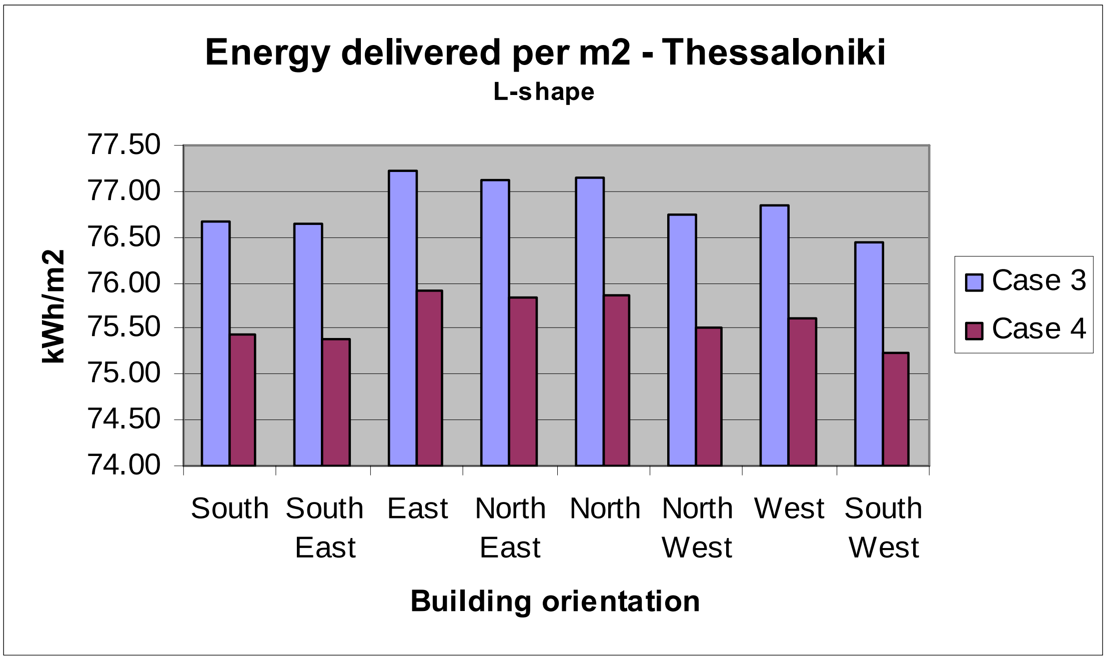


Figure 31: Annual heating energy delivered per m^2 - Thessaloniki

From the figure below (Figure 32) which represents the energy performance for heating of the L-shape building in different orientations it can be observed that the average difference of heating consumption is 1.93 kWh/ m^2 (between Case 3 and Case 4). Comparing this with the average difference of the energy consumption mentioned above it is higher. This implies that less energy is required for heating the building during the cold months of the academic year due to better wall insulation and glazing type. In addition, it should be noted again, that Case 4 results to a better heating performance of the building.

Generally, the pattern of the figure below (Figure 32) is again similar to the one for Athens (Figure 24) with the East orientation of the building having the most heating consumption compared to the rest of the orientations due to the incident solar contribution being less. In addition, the difference of heating consumption between Athens and Thessaloniki climatic zones is of an average 21.02 kWh/ m^2 which implies that more energy is required in Thessaloniki than in Athens, due to the colder climate.

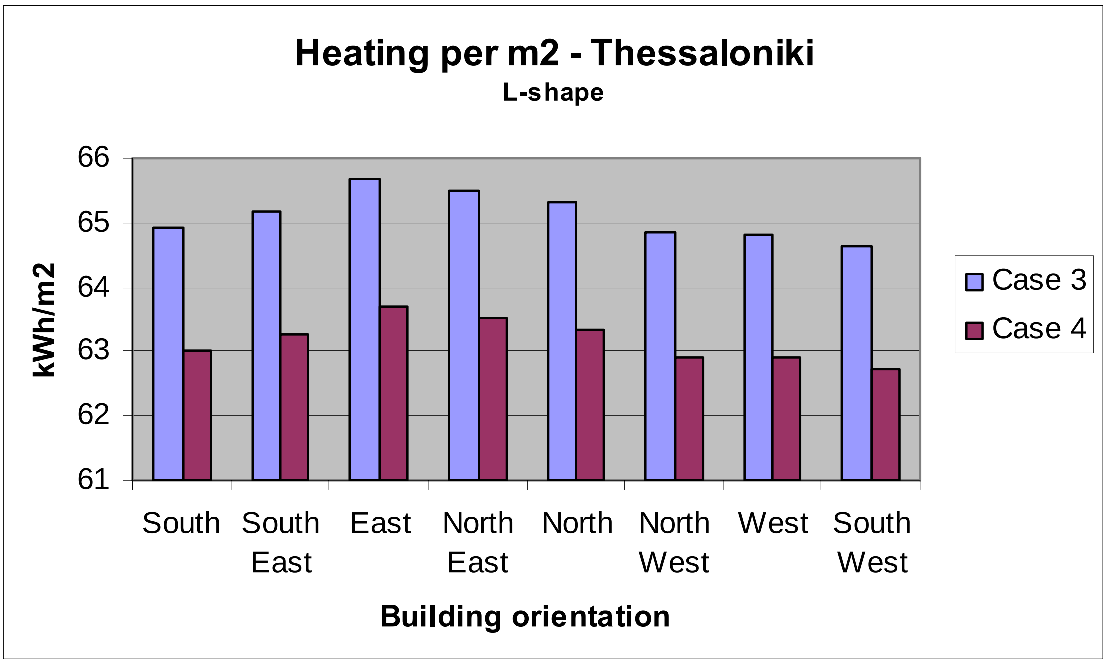


Figure 32: Annual heating energy delivered per m^2 - Thessaloniki

From the figure below (Figure 33) which represents the energy performance for cooling of the L-shape building in different orientations it can be observed that the average difference of cooling consumption is -0.68 kWh/ m^2 (between Case 3 and Case 4). Comparing this with the average difference of the energy consumption mentioned above it is lower.

Again this implies that more energy is required for cooling the building during the hot months of the academic year when better wall insulation and glazing type is used. In addition, it should be noted again, that Case 4 results to a worse cooling performance of the building. This is because more heat is trapped inside the building (buffer effect) due to better wall insulation and glazing type.

Furthermore, again it can been seen that the North, North West and West orientations of the building appear to have the most cooling consumption compared to the rest of the orientations because the incident solar contribution is more.

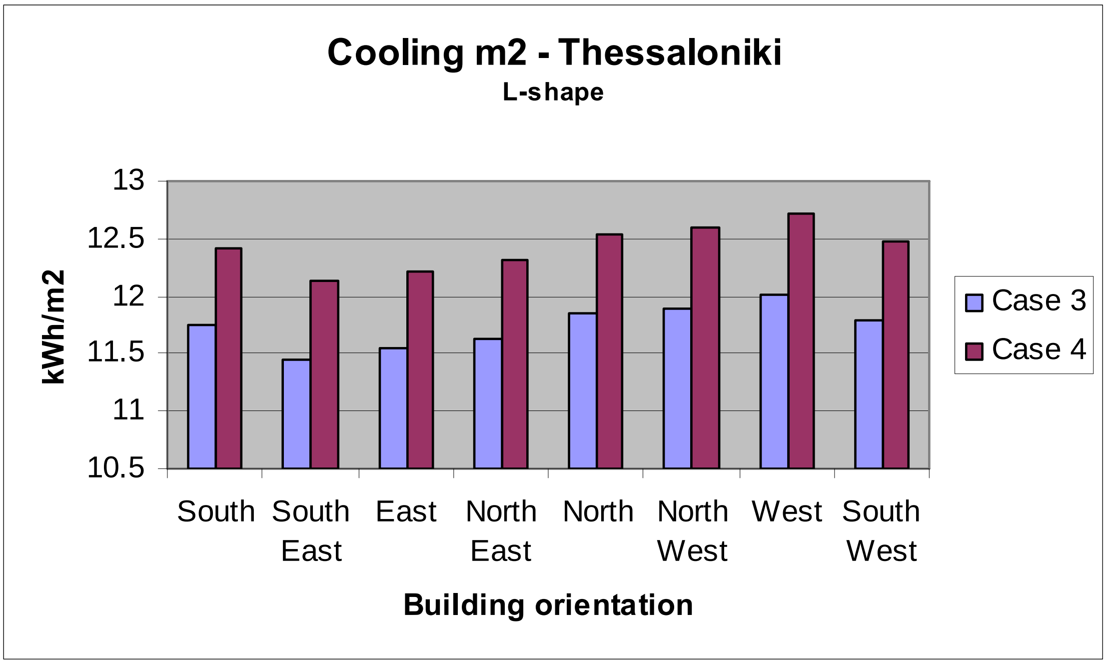


Figure 33: Annual cooling energy delivered per m^2 - Thessaloniki

In addition, the difference of cooling consumption between Athens and Thessaloniki climatic zones is of an average -0.7 kWh/ m^2, which implies that less energy is required in Thessaloniki than in Athens, due to the colder climate.

Generally, from the analysis above it can be concluded that although Case 4 results to a better energy performance of the building in terms of both heating and cooling, heating performance is better in Case 4 while cooling performance is worse. This could be happening due to the fact that there is no natural ventilation throughout the day (hotter months) within the building and especially during the night.

6.6.2 Effect of building orientation, insulation and glazing type on heating and cooling load

The figure below (Figure 34) represents the maximum heating load per m^2 of the L-shape building in different orientations. As mentioned in section 5.1.2 above the reference direction of the building is shown in figure Model 2. From the figure below it can be noticed that the best heating load performance of the building is in the South East orientation and the maximum heating load per m^2 is observed in the North East orientation as it is for Athens climatic zone. Therefore, the effects that applied to Athens zone are the same.

Furthermore, as observed in section 6.6.1 above for the analysis of the heating performance of the L-shape building, Case 4 results to a better heating load performance than Case 3.

Compared to Athens the average heating load in different orientations of Thessaloniki is higher (about 17.7%) and this is normal because due to the cold climate the heating requirements are more during building's early operating hours. Furthermore, compared to the average heating load of the Linear educational building in Athens and Thessaloniki (about 37%) this is less due to the fact that the transparent to opaque ratio of the L-shape building is greater than that of the Linear building and more incident solar radiation contribution occurs.

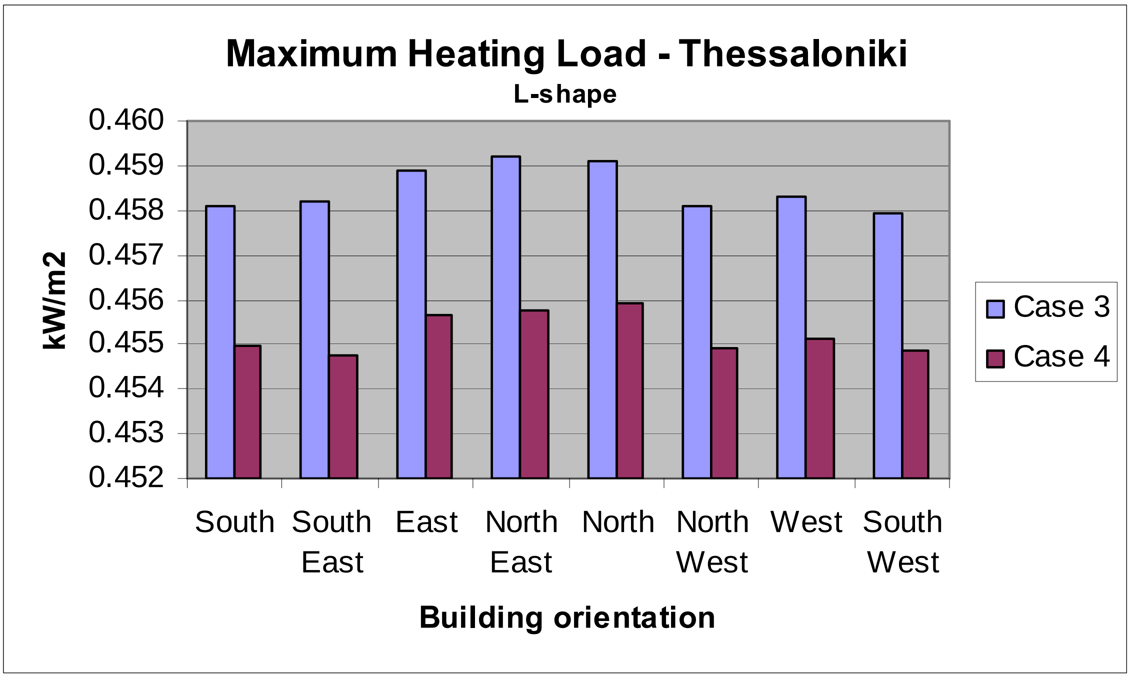


Figure 34: Maximum heating load per m^2 - Thessaloniki

In the following figure (Figure 35) which represents the maximum cooling load per m^2 of the L-shape building in different orientations it can be observed that the best cooling load performance of the building is in the South orientation. This compared to the behaviour in Athens is different (for Athens it is South East). This might be because the incident solar radiation angle is different and this might affect the heat contribution from the sun.

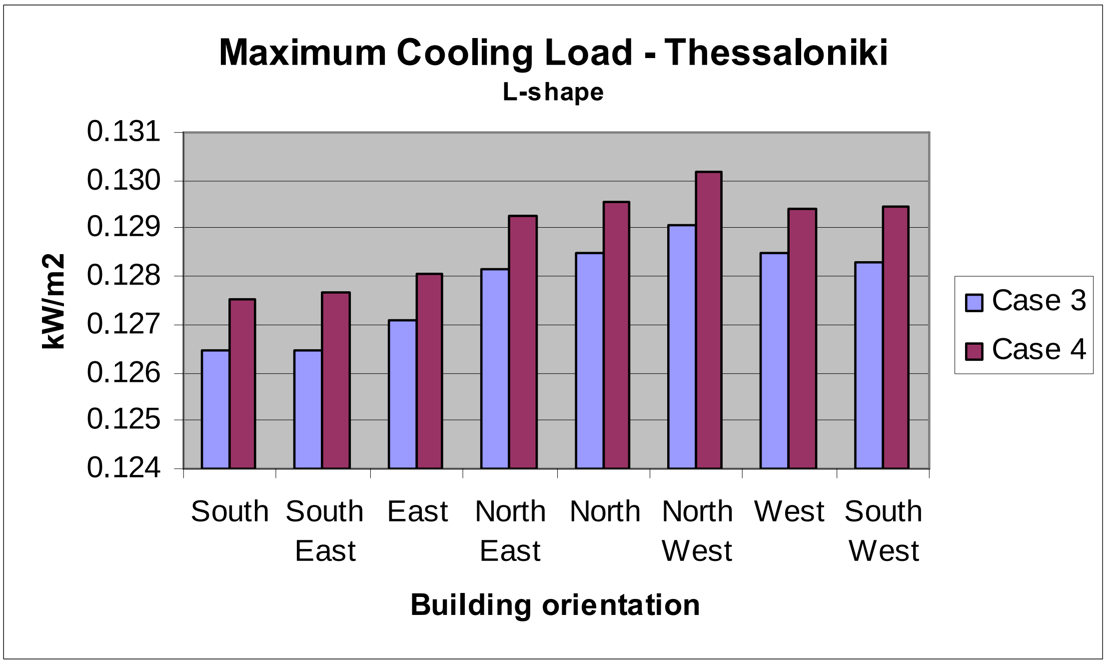


Figure 35: Maximum cooling load per m^2 - Thessaloniki

The figure below (Figure 36) represents the cooling load per m^2 required for each zone of the L-shape building. From this it can be observed that the cooling load throughout the building's zones compared to Case 1 of Thessaloniki Linear educational building (Figure 20) is more consistent, because there are less uncontrolled heated zones. Furthermore, it can be seen that according to the different building orientations the heating load per zone varies due to the change in the incident solar radiation.

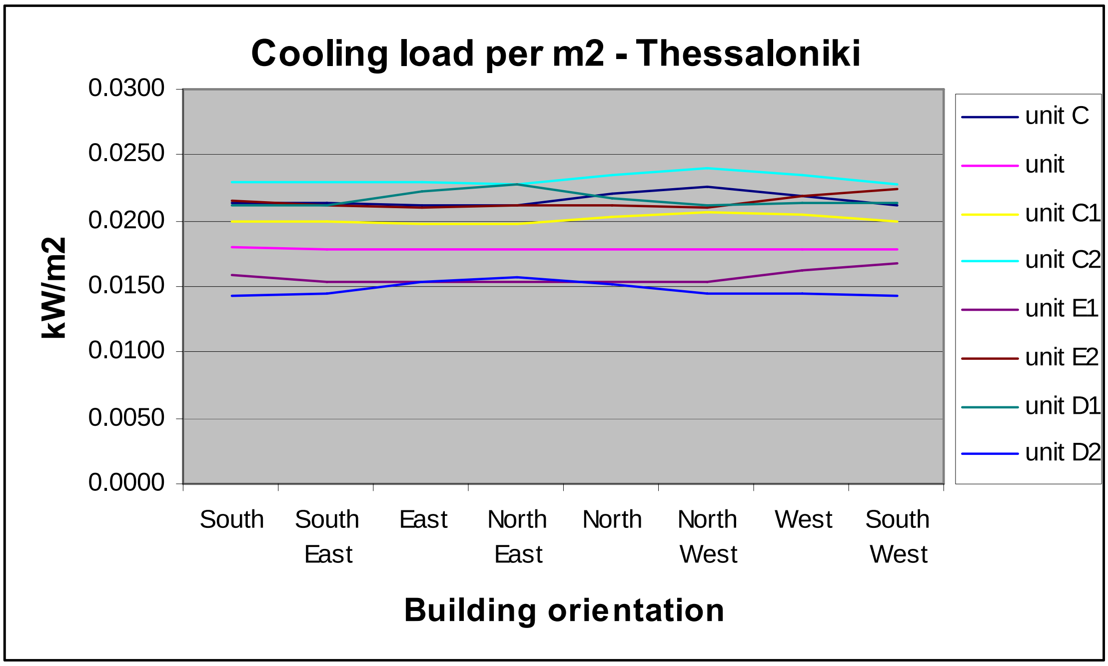


Figure 36: Maximum cooling load per zone per m^2 - Thessaloniki

6.6.3 Effect of building orientation, insulation and glazing type on PPD

The figure below (Figure 37) represents the percentage people dissatisfaction. In detail, it can be observed that the more energy is required for the cooling of the building the bigger the dissatisfaction of the occupants. The very high peaks of the resulting figure are due to the hot months of the academic year. This could be improved if natural ventilation was used for cooling the zones during the later hours of the day.

The above-mentioned effects are not the same as for Athens because as it can be seen the better wall insulation and glazing type increases the mean PPD value. As explained above, the more cooling energy required the more the PPD value increases.

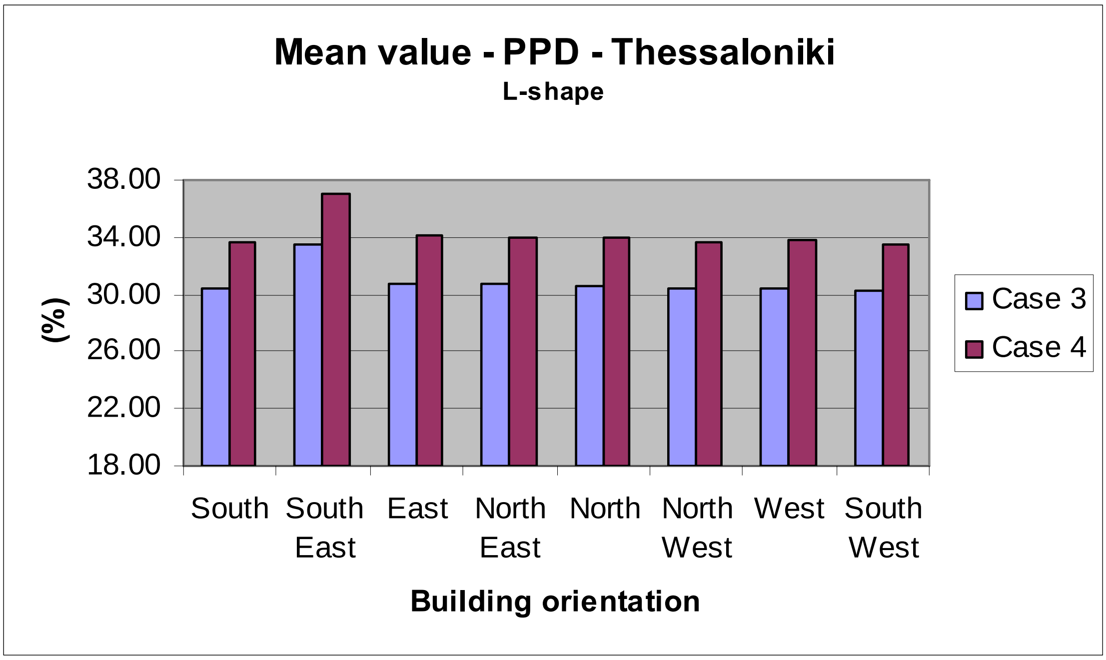


Figure 37: Annual mean PPD value - Thessaloniki

The figure below (Figure 38) represents a sample of the mean PPD value which is taken every month (specifically every 21st) of the academic year. The clothing level used as an input for the simulation can be referenced in Appendix E3.

The figure shows the occupant's dissatisfaction at a representative day of every month within the year. The resulting PPD values appear to be inconsistent compared to those of Athens. Here, the highest PPD value occurs in November instead of June in Athens.

Furthermore, the PPD value appears to be increased the cooler months while during the hot periods it appears to be less compared to Athens. This is because Thessaloniki is in a colder climatic zone than Athens and the heating regime needs to be re-adjusted in order to reduce the PPD value. In addition, winter in Thessaloniki lasts longer than in Athens and clothing level needs to be re-adjusted to those conditions. During the hotter months similarly to Athens natural cooling in addition with internal blinds can be used. However, the humid climate of Thessaloniki justifies the high PPD values during hotter months.

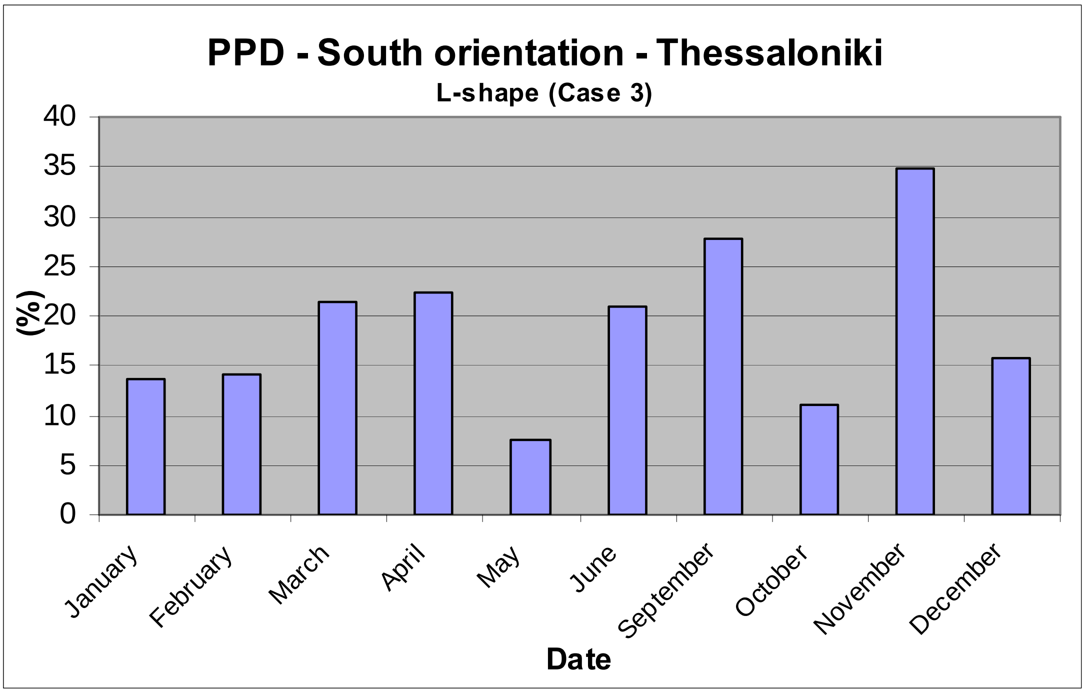


Figure 38: Annual mean PPD value - Thessaloniki

7 Conclusions and Recommendations

From the analysis performed in the two educational buildings (Linear and L-shape) in 8 different orientations considering two different climatic zones (Athens – Zone B and Thessaloniki – Zone C) and four different wall insulations and glazing types (Case 1, Case 2, Case 3, Case 4) the following general conclusions can be reached.

Initially, by comparing the two buildings (Linear and L-shape) based on their operating zones (controlled and uncontrolled) it can be concluded that although North orientation normally should have the highest energy consumption as in the case of L-shape educational building the same behaviour does not apply to the Linear building. This appears to be happening due to the buffer effect occurring in the Linear building. This deviation is worth mentioning because the advantages of the buffer effect may be used in order to improve a building's energy performance.

If the controlled and uncontrolled zones had a different layout within the building the results related to the building's energy consumption would be altered. In detail, if unit_e of Linear building was a controlled zone then the surrounding controlled zones (zones above, besides and across) energy consumption would have been less. This because the energy consumed for heating or cooling unit_e would contribute by heat transfer to the surrounding controlled and uncontrolled zones. This would result in the increase of the overall energy consumption of the building but the energy requirements for the surrounding controlled zones would have been reduced.

Generally, it was observed that the best building orientations were the South, South West and South East because they present a reduction of overall energy consumption. This reduction involves a large decrease in heating consumption though in some cases cooling consumption is increased due to a combination of the lack of adequate natural ventilation and the differences in structural properties.

In addition, it can be seen that by using better wall insulation and glazing type in both climatic zones and through all building orientations the building's energy performance can be improved. However, although the heating performance is improved, the cooling performance appears to be negatively affected. This could be improved if natural ventilation was used and therefore further energy performance improvement could have been obtained.

Furthermore, naturally the shape and size of a building affects its energy performance. Specifically, the L-shape building appears to have less energy consumption than the Linear building. However, although the heating performance of the L-shape building was better than that of the Linear building the heating load was higher. For example in Case 1, South orientation the values for heating consumption as shown in Figures 8 and 24 are 51.8 kWh/ m^2 and 42.7 kWh/ m^2 for Linear and L-shape buildings respectively. The heating loads for the same case and orientation are 0.224 kW/ m^2 and 0.377 kW/ m^2 respectively. For all other cases and climatic zones a similar pattern concerning consumption and load for heating holds true.

In addition, the cooling performance and cooling load of the L-shape building were worse than that of the Linear building. For example in Case 1, South orientation the values for cooling consumption as shown in Figures 9 and 25 are 9.75kWh/ m^2 and 12.59 kWh/ m^2 for Linear and L-shape buildings respectively. The cooling loads for the same case and orientation are 0.091 kW/ m^2 and 0.142 kW/ m^2 respectively. As for the heating this pattern between consumption and loads is similar for all orientations and climatic zones.

The above differences can be attributed to the fact that the size of the building is for Linear 1983 m^2 and for L-shape 3669 m^2 hence the size of exteriors areas (floors, walls) affect the heat losses throughout a day. Additionally, the difference in transparent surface areas of the two buildings affect the heating load required during the early hours of the day (winter) and similarly for cooling (summer). This could be improved by adjusting the transparent to opaque ratio in combination with the use of internal blinds and shading devices.

Moreover, it can be concluded that the climatic zones can affect the behaviour of the building in terms of energy consumption and therefore can result to occupant dissatisfaction. This can be proven from Figures 7 and 13 of the Linear building where it can be seen that while for Case 1 the mean annual PPD value in South orientation is 23.2% and the energy consumption is 61.75 kWh/ m^2, for East orientation where it can be observed that the building has the highest energy consumption (63.5 kWh/ m^2) the annual mean PPD value is also increased (23.9%). In addition, taking into consideration Figure 14 which explains the daily mean PPD value of every 21^{st} of a month, during the summer period the PPD has the highest values. From this it can be concluded the the energy consumption and the occupant dissatisfaction seem to be interrelated. Consequently, if natural ventilation was used during the summer periods in the later hours of the day (evening) then these affects may have been minimized (even eliminated).

Finally, the different climatic conditions should be taken into account when designing a building because the comfort level is highly affected. However, this has to be managed appropriately because although there is a real concern of reducing energy consumption of buildings the human factor should be a priority. Therefore, the level of occupant's comfort must be in balance with the need to reduce energy consumption.

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APPENDIX A – Linear Educational Building Athens results

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b	7655.86	7876.67	8039.42	8065.33	8048.60	8094.13	7952.77	7721.47
unit_c	8792.89	9176.90	9509.61	9609.13	9595.15	9610.39	9309.95	8888.49
unit_d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_g	10429.86	10598.01	10735.53	10755.09	10751.04	10793.20	10672.08	10478.31
unit_h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_i	9889.29	9744.87	9637.90	9334.25	9263.17	9539.39	9795.36	9883.68
unit_j	11180.95	11206.36	10873.80	10509.15	10422.74	10714.22	11014.65	11154.57
entry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_k	6884.95	7078.14	7247.33	7297.33	7295.29	7298.98	7122.30	6918.65
unit_l	6547.32	6727.04	6857.37	6894.10	6875.52	6852.58	6716.78	6557.61
unit_m	6694.35	6864.12	6978.27	6977.85	6965.44	6953.12	6845.22	6709.43
unit_n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_o	2240.22	1709.29	1068.72	950.99	1405.70	2039.66	2391.27	2448.44
unit_p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	70315.69	70981.40	70947.95	70393.22	70622.65	71895.67	71820.38	70760.65
kWh/m2	35.45	35.79	35.77	35.49	35.61	36.25	36.21	35.68

APPENDIX A1: Annual heating required per zone – Linear educational building – Case *1*

Annual Heating Hours								
	South	**South East**	**East**	**North East**	**North**	**North West**	**West**	**South West**
unit_a	0	0	0	0	0	0	0	0
unit_b	1335	1363	1384	1388	1386	1389	1370	1341
unit_c	1440	1461	1496	1515	1519	1519	1476	1443
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	1322	1337	1355	1356	1357	1363	1356	1328
unit_h	0	0	0	0	0	0	0	0
unit_i	1277	1343	1244	1215	1202	1236	1259	1280
unit_j	1318	1311	1291	1252	1245	1257	1298	1309
entry	0	0	0	0	0	0	0	0
unit_k	1249	1264	1301	1309	1313	1305	1278	1252
unit_l	1153	1168	1203	1219	1219	1202	1180	1155
unit_m	1187	1214	1252	1245	1244	1239	1207	1204
unit_n	0	0	0	0	0	0	0	0
unit_o	977	839	642	620	745	918	1013	1035
unit_p	0	0	0	0	0	0	0	0

APPENDIX A2: Annual heating hours required per zone – Linear educational building – Case *1*

Annual Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-835.85	-810.92	-780.29	-728.61	-701.24	-773.11	-869.61	-897.65
unit_c	-636.13	-570.27	-516.74	-445.23	-418.06	-534.75	-720	-764.94
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-1285.6	-1263.86	-1226.74	-1165.12	-1130.81	-1214.04	-1322.65	-1355.09
unit_h	0	0	0	0	0	0	0	0
unit_i	-902.04	-1052.88	-1265.73	-1317.01	-1177.23	-1137.62	-1068.32	-956.66
unit_j	-1082.99	-1216.94	-1419.64	-1481.32	-1353.07	-1310.28	-1242.74	-1134.76
entry	0	0	0	0	0	0	0	0
unit_k	-1427.1	-1395.72	-1338.08	-1256.39	-1220.21	-1330.77	-1477.36	-1513.68
unit_l	-1294.04	-1238.23	-1188.36	-1121.43	-1093.95	-1207.66	-1357.88	-1394.04
unit_m	-1247.2	-1196.61	-1159.17	-1119.22	-1099.85	-1191.75	-1314.83	-1345.46
unit_n	0	0	0	0	0	0	0	0
unit_o	-4635.23	-5510.09	-6069.22	-5762.54	-5186.79	-4711.78	-4306.25	-4181.69
unit_p	0	0	0	0	0	0	0	0
Total	-13346.2	-14255.5	-14964.0	-14396.9	-13381.2	-13411.8	-13679.6	-13544.0
kWh/m2	6.730298	7.1888654	7.546127	7.2601462	6.747963	6.7633686	6.898457	6.83004034

APPENDIX A3: Annual cooling required per zone – Linear educational building – Case *1*

Annual Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	497	476	467	448	441	458	484	509
unit_c	375	359	341	307	293	320	370	390
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	467	464	455	437	430	451	465	480
unit_h	0	0	0	0	0	0	0	0
unit_i	467	486	530	534	526	521	508	477
unit_j	415	434	468	479	460	445	441	428
entry	0	0	0	0	0	0	0	0
unit_k	584	573	563	547	540	555	573	592
unit_l	597	584	573	549	536	567	596	606
unit_m	580	573	562	546	536	551	581	596
unit_n	0	0	0	0	0	0	0	0
unit_o	727	868	944	921	852	760	645	599
unit_p	0	0	0	0	0	0	0	0

APPENDIX A4: Annual cooling hours required per zone – Linear educational building – Case *1*

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	36.21	36.42	36.49	36.38	36.41	36.52	36.42	36.22
unit_c	39.14	39.5	39.71	39.58	39.58	39.71	39.49	39.15
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	56.09	56.29	56.33	56.22	56.25	56.37	56.21	56.06
unit_h	0	0	0	0	0	0	0	0
unit_i	52.54	52.45	52.2	52.07	52.23	52.41	52.47	52.53
unit_j	52.83	53.1	52.76	52.58	52.38	52.65	52.73	52.83
entry	0	0	0	0	0	0	0	0
unit_k	46.05	46.23	46.29	46.19	46.21	46.31	46.16	46.01
unit_l	36.73	36.87	36.92	36.91	36.92	36.9	36.81	36.7
unit_m	36.87	37	37.06	37.01	37.01	37	36.94	36.84
unit_n	0	0	0	0	0	0	0	0
unit_o	6.65	5.94	4.61	4.54	5.5	6.58	6.91	6.94
unit_p	0	0	0	0	0	0	0	0
Max H-load	303.63	304.37	303	301.93	303.18	304.68	304.37	303.33

APPENDIX A5: Maximum heating load per zone – Linear educational building – Case *1*

Maximum - Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-12.43	-12.88	-12.99	-12.8	-12.46	-13.42	-13.78	-13.22
unit_c	-11.7	-12.2	-12.36	-12.11	-11.74	-13.58	-14.31	-13.17
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-13.23	-13.52	-13.6	-13.42	-13.2	-14.06	-14.39	-13.93
unit_h	0	0	0	0	0	0	0	0
unit_i	-11.99	-13.06	-13.72	-13.15	-12.14	-12.34	-12.4	-12.18
unit_j	-33.31	-34.63	-35.19	-34.48	-33.4	-33.62	-33.68	-33.46
entry	0	0	0	0	0	0	0	0
unit_k	-13.07	-13.39	-13.45	-13.27	-13.04	-14.01	-14.4	-13.85
unit_l	-12.09	-12.41	-12.53	-12.39	-12.15	-13.06	-13.44	-12.88
unit_m	-12.04	-12.31	-12.41	-12.33	-12.13	-13.05	-13.38	-12.81
unit_n	0	0	0	0	0	0	0	0
unit_o	-27.34	-29.34	-28.1	-25.38	-25.05	-25.4	-24.9	-24.76
unit_p	0	0	0	0	0	0	0	0
Max C-load	-123.17	-129.96	-130.39	-125.56	-121.38	-128.49	-130.84	-126.58

APPENDIX A6: Maximum cooling load per zone – Linear educational building – Case *1*

Mean Annual PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	31.53	31.97	31.93	31.47	31.25	31.75	31.92	31.66
unit_b	22.31	22.84	23.02	22.66	22.50	23.13	23.27	22.76
unit_c	21.81	22.36	22.59	22.20	22.00	22.78	23.01	22.43
unit_d	26.14	26.84	26.47	25.43	24.85	25.85	26.51	26.33
unit_e	31.21	31.70	31.54	30.75	30.22	30.97	31.49	31.35
unit_f	26.45	27.34	25.77	23.44	22.35	24.54	26.45	26.66
unit_g	22.67	22.72	22.64	22.28	22.01	22.71	23.26	23.23
unit_h	27.51	27.87	27.91	27.59	27.37	27.80	27.96	27.70
unit_i	22.99	23.81	24.19	23.73	23.03	23.45	23.62	23.22
unit_j	22.87	23.78	24.18	23.85	23.07	23.47	23.60	23.11
entry	21.03	22.42	23.50	23.65	23.64	24.31	23.48	21.86
unit_k	22.66	22.72	22.59	22.07	21.89	22.73	23.47	23.36
unit_l	23.56	23.39	23.02	22.42	22.21	23.17	24.31	24.30
unit_m	23.78	23.71	23.52	23.28	23.12	23.83	24.48	24.48
unit_n	28.32	28.68	28.63	28.36	28.05	28.43	28.57	28.43
unit_o	26.01	28.45	29.59	28.48	26.94	25.92	24.64	24.25
unit_p	31.58	29.35	27.85	29.77	33.68	35.97	35.26	33.77

APPENDIX A7: Annual mean PPD value per zone – Linear educational building – Case *1*

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b	7655.86	7876.67	8039.42	8065.33	8048.60	8094.13	7952.77	7721.47
unit_c	8792.89	9176.90	9509.61	9609.13	9595.15	9610.39	9309.95	8888.49
unit_d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_g	10429.86	10598.01	10735.53	10755.09	10751.04	10793.20	10672.08	10478.31
unit_h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_i	9889.29	9744.87	9637.90	9334.25	9263.17	9539.39	9795.36	9883.68
unit_j	11180.95	11206.36	10873.80	10509.15	10422.74	10714.22	11014.65	11154.57
entry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_k	6884.95	7078.14	7247.33	7297.33	7295.29	7298.98	7122.30	6918.65
unit_l	6547.32	6727.04	6857.37	6894.10	6875.52	6852.58	6716.78	6557.61
unit_m	6694.35	6864.12	6978.27	6977.85	6965.44	6953.12	6845.22	6709.43
unit_n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_o	2240.22	1709.29	1068.72	950.99	1405.70	2039.66	2391.27	2448.44
unit_p	0.00	0.00						
Total	70315.69	70981.40	70947.95	70393.22	70622.65	71895.67	71820.38	70760.65
kWh/m2	42.13	42.53	42.51	42.18	42.31	43.08	43.03	42.40

APPENDIX A8: Annual heating required per zone – Linear educational building – Case *2*

Annual Heating Hours								
	South	**South East**	**East**	**North East**	**North**	**North West**	**West**	**South West**
unit_a	0	0	0	0	0	0	0	0
unit_b	1337	1367	1383	1388	1387	1390	1371	1346
unit_c	1434	1460	1485	1505	1514	1512	1461	1439
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	1316	1328	1350	1351	1347	1356	1339	1322
unit_h	0	0	0	0	0	0	0	0
unit_i	1273	1273	1236	1199	1194	1229	1256	1272
unit_j	1318	1309	1288	1157	1248	1268	1295	1307
entry	0	0	0	0	0	0	0	0
unit_k	1239	1259	1293	1307	1304	1298	1268	1244
unit_l	1147	1165	1194	1203	1199	1199	1170	1149
unit_m	1207	1238	1256	1262	1262	1256	1229	1212
unit_n	0	0	0	0	0	0	0	0
unit_o	905	733	549	515	649	812	935	956
unit_p	0	0	0	0	0	0	0	0

APPENDIX A9: Annual heating hours per zone – Linear educational building – Case *2*

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-809.8	-786.91	-759.21	-708.73	-682.56	-751.86	-846.57	-870.02
unit_c	-604.17	-549.22	-500.59	-428.64	-401.56	-508.91	-680.85	-718.22
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-1301.07	-1277.2	-1239.49	-1174.56	-1139.97	-1226.5	-1343.42	-1373.38
unit_h	0	0	0	0	0	0	0	0
unit_i	-904.56	-1055.15	-1274.77	-1322.77	-1179.26	-1139.8	-1074.01	-960.34
unit_j	-1078.46	-1214.88	-1424.22	-1481.95	-1353.18	-1311.94	-1237.2	-1130.56
entry	0	0	0	0	0	0	0	0
unit_k	-1445.96	-1411.86	-1354.83	-1270.35	-1233.36	-1346.56	-1500.8	-1537.96
unit_l	-1306.53	-1253.38	-1200.74	-1129.86	-1106.12	-1218.86	-1374.95	-1409.48
unit_m	-1175.39	-1143.42	-1112.61	-1078.51	-1058.31	-1139.35	-1239.8	-1259.49
unit_n	0	0	0	0	0	0	0	0
unit_o	-4901.06	-5890.3	-6494.83	-6156.13	-5516.91	-4989.67	-4532.36	-4396.92
unit_p	0	0	0	0	0	0	0	0
Total	-13527	-14582.3	-15361.3	-14751.5	-13671.2	-13633.45	-13829.9	-13656.37
kWh/m2	8.10	8.74	9.20	8.84	8.19	8.19	8.29	8.18

APPENDIX A10: Annual cooling required per zone – Linear educational building – Case *2*

Annual Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	495	478	465	445	439	451	486	501
unit_c	358	450	339	306	291	322	361	376
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	471	471	461	445	435	454	470	487
unit_h	0	0	0	0	0	0	0	0
unit_i	470	494	537	539	533	525	514	485
unit_j	414	437	471	484	466	454	444	432
entry	0	0	0	0	0	0	0	0
unit_k	587	585	565	552	546	565	583	598
unit_l	601	588	572	552	546	571	610	617
unit_m	562	557	540	533	529	541	553	577
unit_n	0	0	0	0	0	0	0	0
unit_o	775	946	1039	1018	927	837	699	655
unit_p	0	0	0	0	0	0	0	0

APPENDIX A11: Annual cooling hours required per zone – Linear educational building – Case *2*

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	35.89	36.1	36.16	36	36.43	36.19	36.08	35.9
unit_c	38.85	39.14	39.3	39.17	39.46	39.32	39.16	38.86
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	55.98	56.17	56.19	56.11	56.13	56.23	56.1	55.96
unit_h	0	0	0	0	0	0	0	0
unit_i	52.46	52.39	52.14	52	52.14	52.33	52.4	52.45
unit_j	52.52	52.59	52.56	52.37	52.04	52.16	52.51	52.62
entry	0	0	0	0	0	0	0	0
unit_k	45.97	46.13	46.17	46.1	46.1	46.18	46.06	45.94
unit_l	36.68	36.81	36.86	36.88	36.88	36.86	36.75	36.66
unit_m	36.95	37.06	37.1	37.1	37.09	37.08	37	37.04
unit_n	0	0	0	0	0	0	0	0
unit_o	6.07	5.26	4.01	3.96	4.81	5.95	6.29	6.31
unit_p	0	0	0	0	0	0	0	0
Max H-load	302.25	302.73	301.49	300.65	301.64	303.36	302.46	302.06

APPENDIX A12: Maximum heating load per zone – Linear educational building – Case *2*

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-12.15	-12.57	-12.7	-12.49	-12.13	-13.06	-13.44	-12.86
unit_c	-11.42	-11.9	-12.08	-11.79	-11.39	-13.06	-13.79	-12.76
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-13.19	-13.46	-13.46	-13.37	-13.15	-14.01	-14.39	-13.92
unit_h	0	0	0	0	0	0	0	0
unit_i	-11.95	-13.01	-13.69	-13.14	-12.11	-12.3	-12.37	-12.14
unit_j	-33.26	-34.57	-35.19	-34.46	-33.35	-33.57	-33.63	-33.41
entry	0	0	0	0	0	0	0	0
unit_k	-13.03	-13.29	-13.4	-13.19	-12.96	-13.91	-14.35	-13.84
unit_l	-12.04	-12.32	-12.43	-12.29	-12.09	-13	-13.41	-12.85
unit_m	-11.88	-12.13	-12.24	-12.15	-11.95	-12.75	-13.09	-12.59
unit_n	0	0	0	0	0	0	0	0
unit_o	-27.67	-29.78	-28.48	-25.68	-25.34	-25.66	-25.16	-25.05
unit_p	0	0	0	0	0	0	0	0
Max C-load	122.43	129.03	129.7	124.63	120.4	120.4	129.66	125.56

APPENDIX A13: Maximum cooling load per zone – Linear educational building – Case *2*

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	30.87	31.33	31.285	30.83	30.615	31.11	31.285	31.005
unit_b	21.575	22.155	22.37	22.02	21.85	22.505	22.64	22.075
unit_c	21.04	21.66	21.95	21.56	21.36	22.17	22.38	21.725
unit_d	25.455	26.08	25.815	24.82	24.245	25.215	25.84	25.65
unit_e	30.79	31.3	31.125	30.315	29.78	30.54	31.075	30.94
unit_f	25.445	26.22	24.785	22.5	21.43	23.555	25.455	25.665
unit_g	22.62	22.675	22.55	22.185	21.91	22.62	23.25	23.205
unit_h	27.24	27.63	27.69	27.33	27.105	27.555	27.71	27.445
unit_i	22.8	23.62	24.02	23.6	22.91	23.29	23.435	23.04
unit_j	22.65	23.565	24	23.735	22.965	23.285	23.345	22.9
entry	20.19	21.59	22.67	22.79	22.745	23.39	22.585	20.995
unit_k	22.685	22.69	22.595	21.995	21.83	22.715	23.5	23.41
unit_l	23.63	23.395	23.055	22.395	22.235	23.27	24.33	24.43
unit_m	22.985	23.01	22.905	22.71	22.525	23.12	23.63	23.585
unit_n	28.075	28.49	28.385	28.125	27.845	28.165	28.31	28.205
unit_o	26.775	29.62	31.09	29.915	28.04	26.7	25.235	24.795
unit_p	31.495	28.88	26.6	29.285	33.55	36.015	35.34	33.885

APPENDIX A14: Annual mean PPD value per zone – Linear educational building – Case *2*

APPENDIX B – Linear Educational Building Thessaloniki results

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	12808.5	13121.09	13337.82	13351.62	13329.09	13381.88	13200.76	12876.42
unit_c	14187.46	14721.62	15115.42	15195.63	15173.88	15201.51	14837.73	14288.71
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	13479.19	13722.6	13880.49	13879.03	13884.07	13943.38	13800.64	13541.18
unit_h	0	0	0	0	0	0	0	0
unit_i	16993.43	16961.68	16552.35	16051.01	15961.38	16435.24	16854.03	17001.53
unit_j	17931.28	17955.93	17524.67	17001.85	16892.26	17325.41	17748.66	17900.47
entry	0	0	0	0	0	0	0	0
unit_k	8563.89	8825.79	9008.81	9075.67	9073.12	9061.84	8871.84	8606.02
unit_l	11532.1	11794.61	11985.19	11990.99	11960.74	11962.05	11776.03	11534.29
unit_m	11966.2	12223.7	12359.65	12373.53	12345.75	12300.69	12191.73	11986.54
unit_n	0	0	0	0	0	0	0	0
unit_o	2941.12	2273.86	1428.69	1243.59	1872.74	2739.81	3172.38	3206.27
unit_p	0	0	0	0	0	0	0	0
total kWh	110403.17	111600.88	111193.09	110162.92	110493.03	112351.81	112453.80	110941.43
kWh/m2	66.15	66.87	66.62	66.01	66.20	67.32	67.38	66.47

APPENDIX B1: Annual heating required per zone – Linear educational building – Case 3

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	1655	1669	1681	1692	1690	1690	1673	1654
unit_c	1724	1743	1764	1790	1797	1779	1744	1721
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	1570	1583	1593	1593	1598	1596	1582	1568
unit_h	0	0	0	0	0	0	0	0
unit_i	1690	1679	1661	1651	1643	1669	1676	1686
unit_j	1673	1658	1637	1604	1613	1643	1654	1671
entry	0	0	0	0	0	0	0	0
unit_k	1464	1490	1508	1521	1522	1511	1477	1455
unit_l	1458	1476	1493	1499	1494	1491	1457	1448
unit_m	1523	1534	1550	1543	1539	1534	1535	1526
unit_n	0	0	0	0	0	0	0	0
unit_o	1073	956	768	724	912	1060	1124	1129
unit_p	0	0	0	0	0	0	0	0

APPENDIX B2: Annual heating hours required per zone – Linear educational building – Case 3

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-654.1	-651.61	-642.4	-607.12	-586.35	-648.24	-715.2	-715.94
unit_c	-432.13	-413.94	-402.29	-365.93	-349.24	-434.17	-544.22	-546.43
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-1155.14	-1153.79	-1142.68	-1101.41	-1073.33	-1149.28	-1231.05	-1232.81
unit_h	0	0	0	0	0	0	0	0
unit_i	-678.52	-783.75	-915.94	-926.44	-810.97	-792.34	-759.78	-703.79
unit_j	-961.56	-1071.81	-1217.21	-1234.16	-1117.81	-1099.44	-1060.57	-992.7
entry	0	0	0	0	0	0	0	0
unit_k	-1262.59	-1240.6	-1206.5	-1148.41	-1124.94	-1226.4	-1345.65	-1360.28
unit_l	-1139.36	-1122.63	-1101.41	-1057.09	-1034.93	-1134.16	-1241.23	-1241.94
unit_m	-1057.74	-1050.81	-1042.17	-1012.79	-994.25	-1069.21	-1144.36	-1137.09
unit_n	0	0	0	0	0	0	0	0
unit_o	-4354.28	-5181.5	-5677.89	-5352.62	-4790.65	-4336.76	-3981.94	-3911.32
unit_p	0	0	0	0	0	0	0	0
mean C-load	-11695.42	-12670.44	-13348.49	-12805.97	-11882.47	-11890	-12024	-11842.3
mean C-load/m2	7.007442	7.5916357	7.997897	7.67284	7.119515	7.1240264	7.204314	7.09544638

APPENDIX B3: Annual cooling required per zone – Linear educational building – Case 3

				Cooling Hours				
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	353	345	339	326	313	341	373	374
unit_c	268	240	228	212	200	225	272	292
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	395	394	387	378	371	386	404	409
unit_h	0	0	0	0	0	0	0	0
unit_i	319	335	368	379	365	354	342	326
unit_j	342	361	380	381	368	368	361	351
entry	0	0	0	0	0	0	0	0
unit_k	499	480	452	448	445	460	499	516
unit_l	443	431	423	417	418	432	452	455
unit_m	417	415	403	409	402	419	429	436
unit_n	0	0	0	0	0	0	0	0
unit_o	671	817	911	864	753	671	598	586
unit_p	0	0	0	0	0	0	0	0

APPENDIX B4: Annual cooling hours required per zone – Linear educational building – Case 3

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	54.92	55.66	56.16	56.35	56.29	56.36	56.33	56.04
unit_c	58.32	59.17	60.02	60.43	60.36	60.43	60.31	59.78
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	47.74	47.79	47.83	47.83	47.82	47.87	47.82	47.75
unit_h	0	0	0	0	0	0	0	0
unit_i	83.43	83.46	83.3	82.51	81.64	82.05	83.09	83.46
unit_j	90.03	90.03	89.97	89.85	89.83	89.93	90.01	90.04
entry	0	0	0	0	0	0	0	0
unit_k	38.2	38.29	38.34	38.33	38.33	38.35	38.29	38.21
unit_l	87.67	87.98	87.94	87.8	87.76	87.9	87.94	87.88
unit_m	88.15	88.23	88.18	88.03	88	88.13	88.19	88.15
unit_n	0	0	0	0	0	0	0	0
unit_o	8.76	7.74	6.61	6.56	7.47	8.15	8.92	9.08
unit_p	0	0	0	0	0	0	0	0
Max H-load	479.35	479.69	479.25	478.89	479.08	479.94	480.05	479.83

APPENDIX B5: Maximum heating load per zone – Linear educational building – Case 3

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-12.22	-12.28	-12.33	-12.15	-12.11	-12.8	-13.11	-12.82
unit_c	-11.15	-11.26	-11.33	-11.09	-11.04	-12.38	-13.1	-12.39
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-26.9	-27.14	-26.93	-26.81	-26.74	-27.32	-27.68	-27.5
unit_h	0	0	0	0	0	0	0	0
unit_i	-14.42	-15.28	-15.8	-15.53	-14.67	-14.78	-14.76	-14.54
unit_j	-14.96	-15.77	-16.24	-16.05	-15.23	-15.41	-15.35	-15.13
entry	0	0	0	0	0	0	0	0
unit_k	-24	-24.29	-24.02	-23.89	-23.83	-24.5	-24.96	-24.67
unit_l	-24.73	-24.77	-24.74	-24.61	-24.55	-25.33	-25.74	-25.42
unit_m	-24.51	-24.53	-24.53	-24.45	-24.39	-25.06	-25.38	-25.12
unit_n	0	0	0	0	0	0	0	0
unit_o	-27.8	-29.82	-28.82	-26.4	-26.01	-26.1	-25.62	-25.56
unit_p	0	0	0	0	0	0	0	0
Max C-load	139.47	242.28	143.33	140.75	138.11	140.75	143.09	142.1

APPENDIX B6: Maximum cooling load per zone – Linear educational building – Case 3

Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	43.55	43.95	43.79	43.36	43.28	43.75	43.825	43.58
unit_b	27.755	28.73	29.275	29.165	29.07	29.445	29.05	28.09
unit_c	26.805	28.05	28.7	28.56	28.445	28.935	28.51	27.275
unit_d	37.025	37.385	36.665	35.42	35.085	36.395	37.155	37.105
unit_e	41.11	41.4	40.86	39.78	39.38	40.475	41.17	41.18
unit_f	36.73	36.975	34.7	31.425	30.475	33.84	36.355	36.915
unit_g	26.105	26.505	26.71	26.535	26.38	26.925	27.155	26.685
unit_h	37.89	38.25	38.135	37.7	37.555	38.095	38.235	38.005
unit_i	29.73	30.155	30.14	29.415	28.91	29.55	29.94	29.82
unit_j	28.06	28.615	28.64	27.82	27.175	27.895	28.32	28.2
entry	28.855	31.03	32.605	33.115	33.195	33.47	32.055	29.725
unit_k	25.935	26.37	26.35	26.09	25.965	26.73	27.16	26.67
unit_l	25.535	25.925	26.01	25.725	25.595	26.335	26.705	26.24
unit_m	26.555	27.02	27.14	26.935	26.83	27.345	27.52	27.04
unit_n	36.025	36.46	36.345	35.82	35.595	35.94	36.115	36.035
unit_o	25.85	27.96	28.53	27.185	25.945	25.335	24.45	24.24
unit_p	41.265	38.01	36.195	40.225	44.765	46.875	46.155	44.65
	26.93	27.70	27.94	27.49	27.15	27.61	27.65	27.14

APPENDIX B7: Annual mean PPD value per zone – Linear educational building – Case 3

Heating KWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	12634.13	12965.98	13162	13152.41	13141.14	13195.16	13012.32	12697.7
unit_c	13953.52	14491.51	14861.48	14923	14917.22	14943.03	14577.47	14036.95
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	13257.51	13512.43	13665.89	13648.37	13653.37	13712.94	13566.36	13306.72
unit_h	0	0	0	0	0	0	0	0
unit_i	16768.93	16735.27	16317.46	15827.96	15751.2	16218.18	16635.25	16763.51
unit_j	17713.91	17710.51	17279.96	16762.3	16662.96	17116.13	17505.1	17660.09
entry	0	0	0	0	0	0	0	0
unit_k	8413.14	8689.5	8874.33	8920.99	8920.95	8900.67	8711.84	8438.06
unit_l	11383.01	11665.22	11812.47	11819.61	11814.58	11794.52	11609.15	11375.57
unit_m	11840.25	12064.34	12210.22	12197.95	12154.15	12183.51	11998.85	11824.15
unit_n	0	0	0	0	0	0	0	0
unit_o	2196.17	1565.3	851.86	713.29	1235.36	2001.11	2373.84	2405.41
unit_p	0	0	0	0	0	0	0	0
total kWh	108160.57	109400.06	109035.67	107965.88	108250.93	110065.25	109990.18	108508.16
kWh/m2	64.81	65.55	65.33	64.69	64.86	65.95	65.90	65.01

APPENDIX B8: Annual heating required per zone – Linear educational building – Case 4

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	1645	1663	1669	1681	1682	1677	1662	1647
unit_c	1710	1738	1757	1771	1779	1767	1734	1709
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	1549	1567	1575	1578	1582	1581	1567	1551
unit_h	0	0	0	0	0	0	0	0
unit_i	1685	1672	1651	1632	1634	1660	1670	1681
unit_j	1659	1645	1616	1597	1602	1625	1638	1653
entry	0	0	0	0	0	0	0	0
unit_k	1450	1469	1495	1502	1503	1499	1462	1444
unit_l	1438	1460	1477	1476	1481	1469	1445	1420
unit_m	1512	1523	1522	1522	1531	1534	1521	1514
unit_n	0	0	0	0	0	0	0	0
unit_o	946	788	548	508	739	913	999	1001
unit_p	0	0	0	0	0	0	0	0

APPENDIX B9: Annual heating hours per zone – Linear educational building – Case 4

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b	-666.38	-662.14	-653.96	-618.89	-597.15	-659.42	-732.34	-731.88
unit_c	-444.53	-422.28	-410.69	-373.98	-355.36	-442.58	-563.13	-566.28
unit_d	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_f	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_g	-1189.40	-1185.75	-1174.94	-1133.46	-1103.42	-1183.07	-1271.71	-1272.32
unit_h	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_i	-696.41	-804.61	-946.81	-958.50	-836.25	-813.08	-781.55	-723.65
unit_j	-981.80	-1095.76	-1250.92	-1267.45	-1143.33	-1123.72	-1085.70	-1016.44
entry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_k	-1302.71	-1276.09	-1240.97	-1183.54	-1157.93	-1262.52	-1391.33	-1405.71
unit_l	-1172.02	-1151.83	-1130.97	-1086.62	-1060.94	-1164.00	-1281.23	-1280.58
unit_m	-1083.38	-1074.59	-1067.60	-1038.44	-1017.37	-1093.72	-1174.06	-1168.06
unit_n	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_o	-4774.57	-5784.56	-6374.98	-5985.49	-5280.45	-4748.76	-4342.11	-4262.35
unit_p	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mean C-load	-12311.2	-13457.6	-14251.8	-13646.4	-12552.2	-12490.9	-12623.2	-12427.3
mean C-load/m2	7.38	8.06	8.54	8.18	7.52	7.48	7.56	7.45

APPENDIX B10: Annual cooling required per zone – Linear educational building – Case 4

Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	364	352	346	336	322	347	384	386
unit_c	273	246	232	220	207	234	285	300
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	412	403	393	385	380	395	416	422
unit_h	0	0	0	0	0	0	0	0
unit_i	327	352	382	387	375	363	357	337
unit_j	350	363	383	388	373	372	373	359
entry	0	0	0	0	0	0	0	0
unit_k	513	495	466	458	456	473	508	535
unit_l	449	440	433	430	419	443	456	463
unit_m	427	422	416	414	409	426	444	451
unit_n	0	0	0	0	0	0	0	0
unit_o	757	956	1063	1027	872	771	656	639
unit_p	0	0	0	0	0	0	0	0

APPENDIX B11: Annual cooling hours required per zone – Linear educational building – Case 4

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	54.92	55.66	56.16	56.35	56.29	56.36	56.33	56.04
unit_c	58.32	59.17	60.02	60.43	60.36	60.43	60.31	59.78
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	47.74	47.79	47.83	47.83	47.82	47.87	47.82	47.75
unit_h	0	0	0	0	0	0	0	0
unit_i	83.43	83.46	83.3	82.51	81.64	82.05	83.09	83.46
unit_j	90.03	90.03	89.97	89.85	89.83	89.93	90.01	90.04
entry	0	0	0	0	0	0	0	0
unit_k	38.2	38.29	38.34	38.33	38.33	38.35	38.29	38.21
unit_l	87.67	87.98	87.94	87.8	87.76	87.9	87.94	87.88
unit_m	88.15	88.23	88.18	88.03	88	88.13	88.19	88.15
unit_n	0	0	0	0	0	0	0	0
unit_o	8.76	7.74	6.61	6.56	7.47	8.15	8.92	9.08
unit_p	0	0	0	0	0	0	0	0
Max H-load	478.7	478.67	477.24	476.21	476.98	477.9	479.27	478.36

APPENDIX B12: Maximum heating load per zone – Linear educational building – Case 4

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_b	-12.23	-12.29	-12.32	-12.21	-12.12	-12.8	-13.44	-12.85
unit_c	-11.2	-11.26	-11.35	-11.2	-11.06	-12.37	-13.79	-12.44
unit_d	0	0	0	0	0	0	0	0
unit_e	0	0	0	0	0	0	0	0
unit_f	0	0	0	0	0	0	0	0
unit_g	-26.96	-27.21	-27	-26.87	-26.8	-27.38	-14.39	-27.59
unit_h	0	0	0	0	0	0	0	0
unit_i	-14.47	-15.33	-15.91	-15.58	-14.72	-14.84	-12.37	-14.59
unit_j	-15.01	-15.78	-16.39	-16.13	-15.3	-15.45	-33.63	-15.15
entry	0	0	0	0	0	0	0	0
unit_k	-24.05	-24.33	-24.07	-23.94	-23.88	-24.5	-14.35	-24.74
unit_l	-24.78	-24.81	-24.79	-24.65	-24.6	-25.36	-13.41	-25.49
unit_m	-24.54	-24.57	-24.57	-24.49	-24.42	-25.09	-13.09	-25.17
unit_n	0	0	0	0	0	0	0	0
unit_o	-28.24	-30.52	-29.4	-26.7	-26.28	-26.37	-25.16	-25.85
unit_p	0	0	0	0	0	0	0	0
Max C-load	140.02	142.98	144.25	141.4	138.65	141.31	143.88	142.57

APPENDIX B13: Maximum cooling load per zone – Linear educational building – Case 4

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	43.22	43.63	43.45	43.01	42.935	43.435	43.5	43.235
unit_b	27.225	28.21	28.725	28.605	28.52	28.935	28.505	27.59
unit_c	26.195	27.465	28.08	27.9	27.805	28.335	27.96	26.7
unit_d	36.465	36.84	36.12	34.875	34.55	35.86	36.6	36.52
unit_e	40.685	40.995	40.455	39.38	38.97	40.07	40.755	40.73
unit_f	35.63	35.895	33.595	30.3	29.36	32.73	35.26	35.73
unit_g	25.915	26.26	26.46	26.28	26.12	26.71	26.95	26.505
unit_h	37.555	37.925	37.805	37.375	37.225	37.76	37.9	37.64
unit_i	29.375	29.825	29.835	29.12	28.595	29.225	29.585	29.465
unit_j	27.695	28.27	28.315	27.53	26.875	27.58	27.93	27.805
entry	27.775	30.01	31.575	31.995	32.035	32.365	30.945	28.615
unit_k	25.85	26.26	26.255	25.915	25.81	26.58	27.09	26.58
unit_l	25.365	25.775	25.845	25.55	25.425	26.175	26.66	26.275
unit_m	26.44	26.81	26.92	26.71	26.57	27.16	27.34	26.95
unit_n	35.795	36.22	35.975	35.505	35.27	35.715	35.81	35.725
unit_o	26.64	29.375	30.55	29.095	27.19	26.085	24.94	24.705
unit_p	40.315	36.34	34.075	38.735	43.985	46.335	45.6	44.1

APPENDIX B14: Annual mean PPD value per zone – Linear educational building – Case 4

APPENDIX C – L-shape Educational Building Athens Results

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c	6648.45	6803.90	6744.72	6718.33	6797.05	6603.43	6342.65	6401.41
unit_b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit	7060.18	7062.59	7115.91	7162.14	7167.11	7145.00	7122.66	7093.08
unit_a1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_a2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c1	11821.76	12087.37	12170.22	12169.95	12133.19	11791.12	11434.15	11489.05
unit_c2	7560.98	7653.40	7580.10	7551.37	7634.00	7524.68	7345.82	7368.04
unit_b2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e1	14737.68	14780.76	15262.66	15679.42	15813.05	15808.42	15746.88	15244.94
unit_e2	9010.35	8970.29	9152.78	9414.27	9605.68	9692.32	9687.29	9359.25
unit_d1	6916.05	6905.65	6851.24	6450.12	6037.75	6083.80	6464.13	6804.00
unit_d2	16211.03	16176.83	16113.97	15811.88	15505.46	15547.04	15849.88	16129.03
	79966.48	80440.79	80991.60	80957.48	80693.29	80195.81	79993.46	79888.80
	42.77	43.03	43.32	43.30	43.16	42.89	42.79	42.73

APPENDIX C1: Annual heating required per zone – L-shape educational building – Case *1*

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	657	675	679	681	678	662	646	647
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	747	745	754	756	759	759	756	749
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	799	817	825	822	823	790	770	768
unit_c2	719	734	727	726	732	718	704	707
unit_b2	0	0	0	0	0	0	0	0
unit_e1	798	811	833	861	873	877	863	827
unit_e2	791	787	801	818	830	834	829	808
unit_d1	796	798	785	752	714	727	760	788
unit_d2	816	812	799	775	757	770	782	809

APPENDIX C2: Annual heating hours required per zone – L-shape educational building – Case *1*

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-2981.24	-2958.39	-2854.79	-2773.88	-2981.5	-3354	-3338.54	-3016.05
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-1499.04	-1498.06	-1492.4	-1470.13	-1473.16	-1468.95	-1474.77	-1477.3
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-2666.06	-2620.23	-2530.96	-2494.65	-2670.75	-2936.76	-2936.18	-2690.28
unit_c2	-3549.77	-3570.61	-3473.16	-3395.63	-3600.08	-3871.46	-3811.66	-3525.46
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-3161.63	-2864.98	-2842.94	-2765.67	-2664.92	-2624.41	-2861.82	-3175.31
unit_e2	-3365.29	-3119.75	-3137.23	-3067.43	-2955.98	-2891.81	-3089.64	-3380.3
unit_d1	-2619.59	-2568.05	-2793.79	-3090.69	-3095.02	-2807.24	-2799.49	-2728.41
unit_d2	-3681.44	-3680.21	-3907.96	-4194.45	-4207.45	-3876.3	-3805.41	-3731.28
	-23524.06	-22880.28	-23033.23	-23252.53	-23648.86	-23830.93	-24117.51	-23724.39
	12.5824	12.238062	12.31987	12.437168	12.64915	12.746539	12.89982	12.6895539

APPENDIX C3: **Annual cooling required per zone – L-shape educational building – Case *1***

Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	597	581	572	569	579	618	627	611
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	323	322	315	315	319	321	321	321
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	471	463	451	453	467	496	514	501
unit_c2	603	596	587	581	584	609	612	609
unit_b2	0	0	0	0	0	0	0	0
unit_e1	555	533	516	498	483	479	504	532
unit_e2	477	472	467	453	440	432	439	462
unit_d1	509	505	521	541	560	554	539	519
unit_d2	544	540	554	571	586	575	556	551

APPENDIX C4: **Annual cooling hours required per zone – L-shape educational building – Case *1***

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	81.27	81.43	81.1	80.53	81.04	81.18	81.19	80.93
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	87.72	88.06	88.32	88.64	88.9	88.47	87.93	89.81
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	92.24	92.78	92.84	92.76	92.83	92.6	92.26	90.5
unit_c2	83.87	83.85	83.47	82.93	83.4	83.63	83.72	83.55
unit_b2	0	0	0	0	0	0	0	0
unit_e1	140.86	141.19	142.01	142.5	142.3	142.29	142.44	141.2
unit_e2	86.58	85.94	85.72	85.67	86.12	86.41	86.83	86.66
unit_d1	79.8	79.79	80.14	79.94	79.59	79.04	79.27	80.8
unit_d2	143.8	143.81	143.93	143.24	142.77	143.03	143.63	143.93
Max H-load	704.82	704.26	704.94	706.42	705.51	704.73	704.89	704.42

APPENDIX C5: Maximum heating load per zone – L-shape educational building – Case *1*

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-30.15	-30.44	-29.93	-29.61	-30.78	-31.98	-30.3	-29.55
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-17.55	-17.5	-17.48	-17.43	-17.45	-17.41	-17.51	-17.54
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-66.22	-66.38	-66.09	-65.97	-67.59	-68.56	-66.75	-66.04
unit_c2	-34.31	-34.45	-33.96	-33.61	-34.68	-35.54	-34.2	-33.59
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-25.56	-24.67	-24.88	-25.03	-24.79	-24.6	-26.57	-27.6
unit_e2	-39.19	-38.51	-38.34	-38.35	-38.2	-38.06	-39.99	-41.05
unit_d1	-20.44	-20.31	-22.12	-22.94	-21.1	-20.23	-20.34	-20.59
unit_d2	-49.23	-49.35	-50.77	-51.64	-49.71	-49.04	-48.93	-48.79
Max C-load	265.65	264.52	266.73	268.25	269.19	270.62	268.74	268.38

APPENDIX C6: Maximum cooling load per zone – L-shape educational building – Case *1*

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	31.925	35.72	31.22	29.855	30.65	31.29	30.93	30.82
unit_c	24.355	28.84	24.455	24.305	25.18	25.235	24.275	23.48
unit_b	27.055	30.76	26.49	26.105	26.66	26.865	26.725	26.62
unit_b1	29.885	34.81	29.825	29.725	29.86	29.85	29.92	29.835
unit	23.455	27.54	23.645	23.655	23.68	23.59	23.605	23.47
unit_a1	34.135	35.9	35.225	33.35	33.225	33.23	32.57	32.345
unit_a2	34.605	38.82	33.845	32.785	33.5	34.045	33.815	33.74
unit_c1	26.065	30.46	26.33	26.255	26.985	26.93	25.89	25.145
unit_c2	28.165	32.34	28.15	28.02	28.865	29.075	28.3	27.52
unit_b2	28.43	32.92	28.615	28.605	28.625	28.53	28.575	28.465
unit_e1	27.895	30.03	28.335	29	28.945	28.865	29.48	29.21
unit_e2	28.135	30.09	28.02	28.33	28.205	28.155	28.865	28.94
unit_d1	26.695	30.38	27.175	26.97	25.895	25.19	26.27	26.805
unit_d2	30.79	34.97	31.29	31.195	30.4	29.775	30.48	30.905

APPENDIX C7: Annual mean PPD value per zone – L-shape educational building – Case *1*

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c	6448.09	6579.91	6534.42	6516.24	6580.11	6386.30	6141.07	6213.80
unit_b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit	6933.04	6935.93	6992.17	7042.27	7044.23	7018.87	6995.60	6967.47
unit_a1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_a2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c1	11643.03	11892.22	11978.47	11981.69	11931.13	11588.17	11254.03	11325.84
unit_c2	7368.00	7442.14	7382.78	7359.95	7430.79	7320.50	7150.77	7187.76
unit_b2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e1	14531.71	14583.66	15039.02	15437.23	15567.60	15578.96	15508.60	15011.17
unit_e2	8764.24	8734.22	8918.66	9164.65	9361.40	9459.06	9432.80	9104.02
unit_d1	6661.51	6655.48	6591.30	6204.01	5824.96	5874.61	6227.49	6550.21
unit_d2	16038.79	16008.18	15929.06	15627.03	15347.54	15394.15	15690.01	15944.15
Total	78388.41	78831.74	79365.88	79333.07	79087.76	78620.62	78400.37	78304.42
kWh/m2	41.93	42.17	42.45	42.43	42.30	42.05	41.93	41.88

APPENDIX C8: Annual heating required per zone – L-shape educational building – Case *2*

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	657	675	679	681	678	662	646	647
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	747	745	754	756	759	759	756	749
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	799	817	825	822	823	790	770	768
unit_c2	719	734	727	726	732	718	704	707
unit_b2	0	0	0	0	0	0	0	0
unit_e1	798	811	833	861	873	877	863	827
unit_e2	791	787	801	818	830	834	829	808
unit_d1	796	798	785	752	714	727	760	788
unit_d2	816	812	799	775	757	770	782	809

APPENDIX C9: Annual heating hours per zone – L-shape educational building – Case *2*

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c	-3130.70	-3111.20	-2998.85	-2910.18	-3128.87	-3530.87	-3510.32	-3172.87
unit_b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit	-1523.46	-1524.13	-1516.71	-1494.87	-1497.45	-1494.67	-1501.55	-1502.59
unit_a1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_a2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c1	-2750.66	-2702.88	-2608.41	-2571.65	-2759.66	-3047.77	-3043.61	-2783.06
unit_c2	-3715.19	-3739.52	-3632.84	-3548.03	-3765.26	-4062.99	-3994.80	-3693.67
unit_b2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e1	-3316.81	-3004.82	-2972.62	-2892.33	-2781.82	-2742.63	-2993.98	-3337.10
unit_e2	-3504.55	-3251.20	-3260.85	-3187.48	-3069.06	-3002.10	-3206.54	-3518.83
unit_d1	-2743.26	-2695.33	-2930.40	-3260.15	-3256.33	-2949.95	-2933.83	-2859.19
unit_d2	-3845.06	-3852.23	-4087.64	-4400.32	-4404.17	-4060.73	-3977.25	-3902.19
Total	-24529.7	-23881.3	-24008.3	-24265.0	-24662.6	-24891.7	-25161.9	-24769.5
kWh/m2	13.12	12.77	12.84	12.98	13.19	13.31	13.46	13.25

APPENDIX C10: Annual cooling required per zone – L-shape educational building – Case 2

Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	597	581	572	569	579	618	627	611
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	323	322	315	315	319	321	321	321
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	471	463	451	453	467	496	514	501
unit_c2	603	596	587	581	584	609	612	609
unit_b2	0	0	0	0	0	0	0	0
unit_e1	555	533	516	498	483	479	504	532
unit_e2	477	472	467	453	440	432	439	462
unit_d1	509	505	521	541	560	554	539	519
unit_d2	544	540	554	571	586	575	556	551

APPENDIX C11: Annual cooling hours required per zone – L-shape educational building – Case *2*

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	80.53	80.54	80.26	79.76	80.18	80.39	80.45	80.22
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	86.69	87.07	87.65	90.79	88.14	87.75	87.21	86.84
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	91.86	92.27	92.36	91.02	92.43	92.19	91.9	91.65
unit_c2	82.99	82.91	82.56	82.09	82.51	82.73	82.89	82.78
unit_b2	0	0	0	0	0	0	0	0
unit_e1	140.51	140.8	141.59	141.57	141.84	141.84	141.91	141.09
unit_e2	85.67	85.06	84.22	84.72	85.19	85.52	85.88	85.77
unit_d1	78.67	78.74	79.16	80.44	78.79	78.29	78.44	78.56
unit_d2	143.47	143.43	143.53	142.96	142.55	142.8	143.35	143.52
Max H-load	698.91	698.97	699.53	705.63	699.98	699.22	699.96	697.3

APPENDIX C12: Maximum heating load per zone – L-shape educational building – Case *2*

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-30.34	-30.69	-30.07	-29.79	-30.96	-32.23	-30.51	-29.74
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-17.57	-17.53	-17.51	-17.46	-17.47	-17.44	-17.54	-17.57
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-66.3	-66.48	-66.2	-66.07	-67.69	-68.73	-66.88	-66.12
unit_c2	-34.45	-34.79	-34.2	-33.91	-34.96	-35.89	-34.52	-33.88
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-25.84	-24.91	-25.09	-25.26	-25	-24.83	-26.79	-27.93
unit_e2	-39.54	-38.82	-38.62	-38.61	-38.46	-38.37	-40.26	-41.43
unit_d1	-20.61	-20.5	-22.31	-23.27	-21.33	-20.43	-20.53	-20.79
unit_d2	-49.61	-49.82	-51.13	-52.1	-50.12	-49.12	-49.27	-49.17
Max C-load	267.17	266.22	268.21	271.65	270.75	272.4	270.26	270.05

APPENDIX C13: Maximum cooling load per zone – L-shape educational building – Case *2*

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	31.925	35.67	31.51	30.075	30.71	31.25	30.845	30.755
unit_c	24.1	28.39	24.14	23.98	24.87	25.055	24.125	23.265
unit_b	26.94	30.52	26.41	26.005	26.545	26.755	26.61	26.505
unit_b1	29.74	34.57	29.68	29.575	29.71	29.7	29.775	29.69
unit	23.255	27.25	23.45	23.46	23.49	23.395	23.415	23.275
unit_a1	34.865	36.63	36.475	34.505	34.105	33.92	33.195	32.985
unit_a2	34.695	38.86	34.11	33.01	33.63	34.105	33.85	33.8
unit_c1	25.955	30.16	26.185	26.105	26.855	26.905	25.9	25.105
unit_c2	28.125	32.19	28.065	27.935	28.795	29.09	28.325	27.5
unit_b2	28.275	32.69	28.455	28.445	28.465	28.375	28.42	28.305
unit_e1	27.89	29.78	28.25	28.9	28.835	28.76	29.4	29.19
unit_e2	28.17	29.93	27.975	28.265	28.125	28.07	28.815	28.965
unit_d1	26.56	30.1	27.07	26.955	25.9	25.15	26.165	26.68
unit_d2	30.755	34.88	31.28	31.245	30.45	29.805	30.475	30.885

APPENDIX C14: Annual mean PPD value per zone – L-shape educational building – Case *2*

APPENDIX D – L-shape Educational Building Thessaloniki results

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	12045.8	12346.64	12286.61	12212.26	12332.87	12014.78	11532.48	11479.98
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	9880.65	9870.35	9942.08	9973.69	9983.81	9976.94	9997.01	9940.95
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	26772.47	27177.98	27309.13	27297.01	27215.49	26707.35	26178.7	26186.91
unit_c2	13671.87	13839.21	13757.07	13681.26	13795.96	13618.01	13312.53	13286.31
unit_b2	0	0	0	0	0	0	0	0
unit_e1	12825.34	12752.36	13640.36	14282.94	14488.69	14484.96	14359.83	13629.1
unit_e2	17297.98	17117.33	17432.97	17753.92	18104.89	18254.18	18210.88	17772.04
unit_d1	11673.25	11650.05	11533.47	10879.24	10174.13	10125.41	10948.98	11502.56
unit_d2	17158.98	17076.17	16848.26	16339.52	15955.7	16039.93	16621.93	17028.37
total kWh	121326.34	121830.09	122749.95	122419.84	122051.54	121221.56	121162.34	120826.22
kWh/m2	33.06	33.20	33.45	33.36	33.26	33.03	33.02	32.93

APPENDIX D1: **Annual heating required per zone – L-shape educational building – Case 3**

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	899	918	910	915	916	889	854	865
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	939	937	941	943	941	942	947	945
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	1047	1066	1079	1081	1067	1034	1019	1029
unit_c2	978	979	981	980	979	970	948	952
unit_b2	0	0	0	0	0	0	0	0
unit_e1	948	967	1000	1024	1034	1032	1020	983
unit_e2	1002	1003	1018	1037	1059	1060	1056	1017
unit_d1	991	991	974	949	917	926	967	976
unit_d2	1060	1059	1044	1010	998	1012	1036	1048

APPENDIX D2: **Annual heating hours required per zone – L-shape educational building – Case 3**

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

unit_c	-2732.97	-2738.05	-2644.62	-2567.12	-2779.41	-3084.32	-3060.65	-2731.56
unit_b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_b1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit	-1679.79	-1671.71	-1672.47	-1658.22	-1665.70	-1661.31	-1671.94	-1664.65
unit_a1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_a2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_c1	-2401.39	-2382.34	-2314.95	-2294.52	-2466.18	-2659.17	-2611.65	-2388.70
unit_c2	-3187.56	-3204.92	-3118.61	-3048.31	-3244.49	-3467.64	-3405.71	-3144.12
unit_b2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
unit_e1	-2706.59	-2400.19	-2401.03	-2359.06	-2278.97	-2258.97	-2493.53	-2751.54
unit_e2	-3731.65	-3484.13	-3472.07	-3390.43	-3314.96	-3283.18	-3465.29	-3714.84
unit_d1	-2436.77	-2411.57	-2620.69	-2864.33	-2865.53	-2591.62	-2590.89	-2529.50
unit_d2	-3077.74	-3117.79	-3339.97	-3552.85	-3533.94	-3220.80	-3160.78	-3104.46
Total	-21954.5	-21410.7	-21584.4	-21734.8	-22149.2	-22227.0	-22460.4	-22029.4
kWh/m2	11.75	11.46	11.55	11.63	11.85	11.89	12.02	11.79

APPENDIX D3: Annual cooling required per zone – L-shape educational building – Case 3

Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	457	444	442	437	447	486	497	484
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	315	315	312	312	313	317	317	314
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	343	340	337	336	350	362	376	355
unit_c2	450	447	447	437	448	476	480	460
unit_b2	0	0	0	0	0	0	0	0
unit_e1	437	418	399	397	390	394	409	436
unit_e2	433	428	418	410	406	404	411	424
unit_d1	411	413	421	449	457	437	425	418
unit_d2	413	422	439	463	467	439	431	421

APPENDIX D4: Annual cooling hours required per zone – L-shape educational building – Case 3

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	109.65	110.85	110.79	110.48	110.88	110.8	110.32	109.08
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	108.6	108.5	108.74	108.61	108.72	108.66	108.58	108.6
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	193.4	193.53	193.58	193.56	193.56	193.47	193.27	193.22
unit_c2	114.89	115.55	115.42	115.16	115.51	115.64	115.49	114.65
unit_b2	0	0	0	0	0	0	0	0
unit_e1	141.79	140.41	141.59	143.5	143.89	143.79	143.78	143.3
unit_e2	139.92	138.86	138.39	138.99	139.85	140.14	140.39	140.23
unit_d1	102.36	102.38	103.01	102.73	102.03	101.06	101.35	102.16
unit_d2	147.87	147.67	148.38	148.17	147.54	146.09	146.83	148.14
Max H-load	856.16	856.37	857.67	858.24	858.02	856.18	856.6	855.83

APPENDIX D5: Maximum heating load per zone – L-shape educational building – Case 3

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-39.76	-39.87	-39.61	-39.46	-41.11	-42.15	-40.9	-39.48
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-33.53	-33.47	-33.42	-33.35	-33.35	-33.33	-33.4	-33.38
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-37.31	-37.33	-37.01	-36.95	-37.87	-38.63	-38.14	-37.22
unit_c2	-42.92	-43.01	-42.73	-42.57	-43.95	-44.78	-43.84	-42.65
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-29.69	-28.66	-28.71	-28.81	-28.64	-28.57	-30.37	-31.27
unit_e2	-40.29	-39.54	-39.35	-39.57	-39.46	-39.38	-40.93	-41.93
unit_d1	-39.69	-39.66	-41.43	-42.48	-40.64	-39.72	-39.81	-39.84
unit_d2	-26.88	-27.09	-28.79	-29.35	-28.33	-27.15	-26.95	-26.87
Max C-load	-236.38	-236.38	-237.5	-239.54	-240.19	-241.19	-240.16	-239.81

APPENDIX D6: Maximum cooling load per zone – L-shape educational building – Case 3

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	40.67	42.82	38.23	36.765	38.835	39.99	39.86	39.8
unit_c	33.105	37.24	33.425	33.34	33.855	33.42	32.295	31.76
unit_b	36.405	39.64	35.415	35.065	35.85	36.105	35.965	35.925
unit_b1	40.135	45.22	40.01	39.92	40.09	40.1	40.205	40.1
unit	31.18	34.7	31.34	31.29	31.295	31.23	31.335	31.21
unit_a1	38.075	40.56	36.685	34.43	36.16	37.04	36.665	36.53
unit_a2	43.52	46.44	41.58	40.51	42.12	42.94	42.835	42.805
unit_c1	32.64	36.37	33.185	33.145	33.63	33.115	31.86	31.155
unit_c2	36.045	40.19	36.19	36.11	36.66	36.49	35.6	35.04
unit_b2	38.155	42.7	38.29	38.225	38.2	38.14	38.28	38.165
unit_e1	33.49	36.01	34.735	35.71	35.845	35.815	36.1	35.25
unit_e2	34.49	36.68	34.605	35.06	35.125	35.12	35.58	35.39
unit_d1	35.39	39.54	35.565	34.755	33.255	32.765	34.59	35.335
unit_d2	37.275	40.83	37.64	37.21	36.165	35.635	36.805	37.315

APPENDIX D7: Annual mean PPD value per zone – L-shape educational building – Case 3

Heating kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	11600.69	11866.01	11786.05	11727.63	11853.41	11525.78	11056.28	11034.04
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	9629.83	9617.19	9692.15	9728.03	9738.07	9729.72	9752.92	9690.81
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	26376.17	26775.94	26883.93	26868.64	26807.24	26282.19	25762.48	25800.27
unit_c2	13273.14	13410.94	13311.63	13252.12	13371.13	13177.86	12883.71	12885.16
unit_b2	0	0	0	0	0	0	0	0
unit_e1	12316.21	12251.86	13115.02	13751.22	13931.63	13944.24	13830.57	13077.1
unit_e2	16717.96	16545.41	16854.24	17164.06	17506.92	17663.33	17621.99	17181.22
unit_d1	11156.36	11146.43	11034.88	10361.39	9687.94	9659.57	10476.03	11008.66
unit_d2	16696.03	16614.38	16386.2	15863.4	15498.23	15602.72	16195.34	16580.97
total kWh	117766.39	118228.16	119064.10	118716.49	118394.57	117585.41	117579.32	117258.23
kWh/m2	63.01	63.26	63.70	63.52	63.35	62.91	62.91	62.74

APPENDIX D8: Annual heating required per zone – L-shape educational building – Case 4

Heating Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	899	918	910	915	916	889	854	865
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	939	937	941	943	941	942	947	945
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	1047	1066	1079	1081	1067	1034	1019	1029
unit_c2	978	979	981	980	979	970	948	952
unit_b2	0	0	0	0	0	0	0	0
unit_e1	948	967	1000	1024	1034	1032	1020	983
unit_e2	1002	1003	1018	1037	1059	1060	1056	1017
unit_d1	991	991	974	949	917	926	967	976
unit_d2	1060	1059	1044	1010	998	1012	1036	1048

APPENDIX D9: Annual heating hours per zone – L-shape educational building – Case 4

Cooling kWh								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-2895.26	-2908.95	-2814.95	-2727.8	-2945.189	-3290.68	-3261.5	-2910.4
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-1721.98	-1717.01	-1715.1	-1700.78	-1708.38	-1706.28	-1715.25	-1705.99
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-2494.87	-2477.42	-2407.85	-2385.11	-2566.54	-2785.93	-2732.42	-2489.92
unit_c2	-3359.65	-3386.35	-3299.02	-3218.89	-3421.65	-3678.86	-3608.66	-3327.2
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-2909.29	-2575.21	-2559.66	-2516.53	-2435.99	-2414.48	-2664.29	-2961.55
unit_e2	-3969.66	-3709.71	-3680.92	-3592.36	-3513.11	-3481.17	-3671.61	-3960.38
unit_d1	-2587.25	-2561.6	-2779.29	-3061.94	-3053.92	-2752.27	-2737.91	-2678.31
unit_d2	-3276.16	-3326.68	-3558.29	-3799.29	-3769.57	-3433.26	-3359.46	-3298.77
Total	-23214.1	-22662.93	-22815.1	-23002.7	-23414.3	-23542.93	-23751.1	-23332.52
kWh/m2	12.42061	12.125698	12.20711	12.307491	12.52774	12.596538	12.70792	12.4839593

APPENDIX D10: Annual cooling required per zone – L-shape educational building – Case 4

Cooling Hours								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	457	444	442	437	447	486	497	484
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	315	315	312	312	313	317	317	314
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	343	340	337	336	350	362	376	355
unit_c2	450	447	447	437	448	476	480	460
unit_b2	0	0	0	0	0	0	0	0
unit_e1	437	418	399	397	390	394	409	436
unit_e2	433	428	418	410	406	404	411	424
unit_d1	411	413	421	449	457	437	425	418
unit_d2	413	422	439	463	467	439	431	421

APPENDIX D11: Annual cooling hours required per zone – L-shape educational building – Case 4

Maximum Heating load (kW)								
	South	South East	East	North East	North	North West	West	South West

unit_a	0	0	0	0	0	0	0	0
unit_c	108.5	109.53	109.41	109.14	109.55	109.39	109.02	108.01
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	108.49	108.43	108.51	108.55	108.54	108.5	108.33	108.41
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	193.19	193.29	193.31	193.31	193.32	193.2	193.01	192.98
unit_c2	113.86	114.39	114.21	113.98	114.35	114.42	114.35	113.7
unit_b2	0	0	0	0	0	0	0	0
unit_e1	141.4	139.74	140.11	142.65	142.97	143	142.89	142.35
unit_e2	138.79	137.74	137.28	137.84	138.71	139.01	139.26	139.11
unit_d1	101.08	101.13	101.73	101.44	100.74	99.85	100.16	100.88
unit_d2	147.75	147.74	146.66	147.47	146.94	145.66	146.3	147.55
Max H-load	850.3	849.93	851.66	851.86	852.13	850.21	850.64	850.11

APPENDIX D12: **Maximum heating load per zone – L-shape educational building – Case 4**

Maximum Cooling load (kW)								
	South	South East	East	North East	North	North West	West	South West
unit_a	0	0	0	0	0	0	0	0
unit_c	-39.96	-40.12	-39.84	-39.67	-41.32	-42.46	-41.13	-39.69
unit_b	0	0	0	0	0	0	0	0
unit_b1	0	0	0	0	0	0	0	0
unit	-33.62	-33.56	-33.5	-33.43	-33.42	-33.41	-33.48	-33.47
unit_a1	0	0	0	0	0	0	0	0
unit_a2	0	0	0	0	0	0	0	0
unit_c1	-37.47	-37.51	-37.22	-37.14	-38.07	-38.92	-38.36	-37.42
unit_c2	-43.22	-43.36	-43.07	-42.89	-44.26	-45.19	-44.18	-42.96
unit_b2	0	0	0	0	0	0	0	0
unit_e1	-30.16	-29.09	-29.15	-29.24	-29.06	-28.98	-30.79	-31.9
unit_e2	-40.66	-39.88	-39.89	-40.01	-39.77	-39.68	-41.26	-42.48
unit_d1	-39.88	-39.86	-41.61	-42.78	-40.86	-39.92	-39.99	-40.04
unit_d2	-27.52	-39.86	-29.3	-29.99	-28.64	-27.67	-27.46	-27.4
Max C-load	-238.31	-238.62	-239.32	-241.63	-242.16	-243.35	-241.84	-241.96

APPENDIX D13: **Maximum cooling load per zone – L-shape educational building – Case 4**

Annual Mean PPD								
	South	South East	East	North East	North	North West	West	South West
unit_a	40.1	41.79	37.85	36.18	38.19	39.31	39.11	39.07
unit_c	32.35	36.39	32.645	32.55	33.15	32.76	31.6	30.98
unit_b	35.875	38.91	34.89	34.495	35.305	35.555	35.4	35.36
unit_b1	39.67	44.65	39.53	39.43	39.615	39.625	39.73	39.63
unit	30.715	34.13	30.885	30.835	30.845	30.77	30.88	30.745
unit_a1	38.13	40.44	37.415	34.95	36.285	36.99	36.535	36.42
unit_a2	43.15	45.74	41.275	40.075	41.69	42.505	42.365	42.365
unit_c1	32.02	35.55	32.565	32.495	33.055	32.595	31.34	30.535
unit_c2	35.61	39.74	35.745	35.655	36.26	36.12	35.195	34.565
unit_b2	37.695	42.18	37.835	37.755	37.74	37.67	37.825	37.705
unit_e1	32.88	34.94	34.075	35.11	35.26	35.25	35.57	34.715
unit_e2	34.1	36	34.16	34.615	34.665	34.66	35.185	35.025
unit_d1	34.815	38.92	35.035	34.215	32.675	32.07	33.975	34.77
unit_d2	36.895	40.43	37.325	36.905	35.815	35.225	36.43	36.955

APPENDIX D14: Annual mean PPD value per zone – L-shape educational building – Case 4

APPENDIX E – Climate Data of Athens and Thessaloniki

Athens (Elliniko)	Mean Average Temp (C)	Absolute Max Temp (C)	Absolute Min Temp (C)	Humiditi (%)	Rain (mm)	Wind Direction	Wind Speed (m/s)	Raining Days	Total Vertical Radiation kWh/m2	Total Horizontal Radiation kWh/m2	Diffuse Horizontal Radiation kWh/m2
January	10.3	13.6	7	68.8	48.3	N	7.6	13.2	98	63	28
February	10.6	14.1	7.1	68	40.9	N	7.7	11.8	119	93	31
March	12.3	15.7	8.4	65.9	39.7	N	7.3	11.9	104	116	48
April	15.9	19.4	11.4	62.6	26	S	6.4	9.7	99	163	49
May	20.7	24.1	15.8	59	15.2	S	6	6.8	93	204	66
June	25.2	28.7	20.1	52.8	5.6	S	6.4	3.7	89	229	58
July	28	31.8	22.8	47	5.2	N	7.6	1.6	96	230	73
August	27.8	31.7	22.8	47.1	7	N	7.8	1.8	114	206	48
September	24.2	28.2	19.6	53.4	9.6	N	7	3.9	120	147	47
October	19.5	23.2	15.6	62.1	47.8	N	7.1	8.9	131	116	43
November	15.4	18.8	12	68.7	55.4	N	6.7	11.3	79	59	31
December	12	15.2	8.8	70.2	64.1	N	7.4	13.7	101	60	25

APPENDIX E1: Athens Climate Data

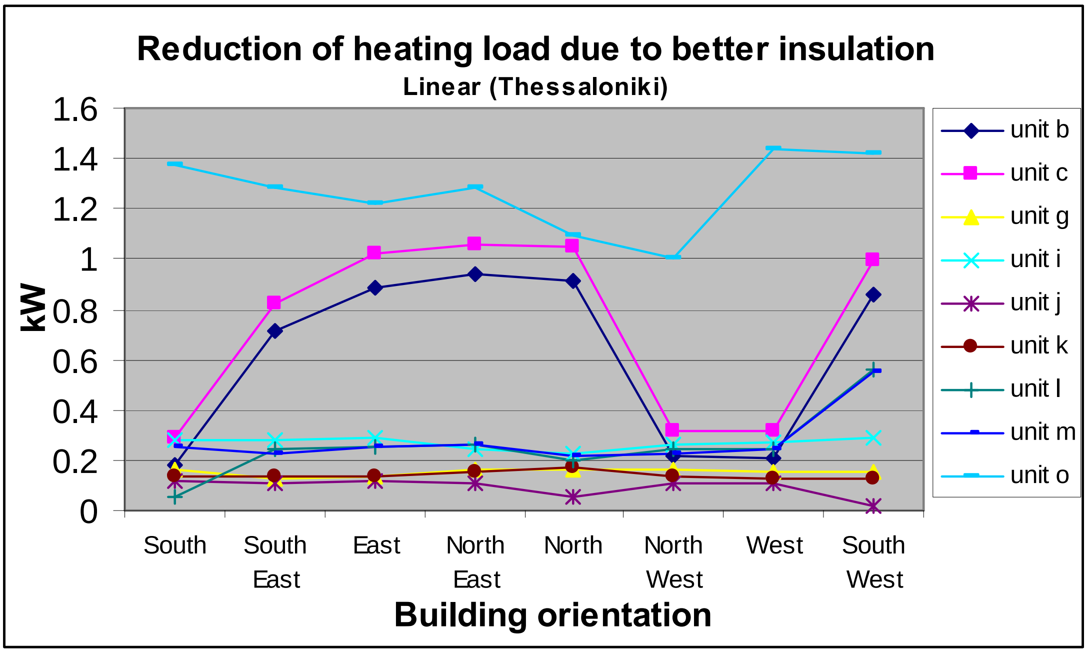
Salonika	Mean Average Temp (C)	Absolute Max Temp (C)	Absolute Min Temp (C)	Humidity (%)	Rain (mm)	Wind Direction	Wind Speed (m/s)	Raining Days
January	5.2	9.3	1.3	76.1	36.8	NW	5.8	11.8
February	6.7	10.9	2.2	73	38	NW	5.9	11.3
March	9.7	14.2	4.5	72.4	40.6	NW	5.5	12.4
April	14.2	19	7.5	67.8	37.5	NW	5.4	11.2
May	19.6	24.5	12.1	63.8	44.4	NW	5.1	10.7
June	24.4	29.2	16.3	55.9	29.6	NW	6	7.5
July	26.6	31.5	18.6	53.2	23.9	NW	6.5	5.9
August	26	31.1	18.3	55.3	20.4	S	5.7	4.7
September	21.8	27.2	14.9	62	27.4	NW	5.4	5.9
October	16.2	21.2	10.8	70.2	40.8	NW	4.9	8.7
November	11	15.4	6.8	76.8	54.4	NW	5	11.5
December	6.9	11	3	78	54.9	NW	5.4	12.5

APPENDIX E2: Thessaloniki Climate Data

The data below have been derived from McMullan's and McCollugh tables for clothingt level [12] and [16].

DATE	21/1	21/2	21/3	21/4	21/5	21/6	21/9	21/10	21/11	21/12
CLOTHING LEVEL	1.2	1.4	1.2	0.7	0.5	0.4	0.5	0.7	0.9	1.2

APPENDIX E3: Clothing level for different months of the academic year [12], [16].



APPENDIX E4: Reduction of heating load due to better insulation

APPENDIX F – Linear educational building esp-r files.

1)*.cfg

```
* CONFIGURATION3.0
# ESRU system configuration defined by file
# six_seat.cfg
*date Tue Sep 20 11:47:17 2005  # latest file modification
*root six_seat
*zonpth ../zones                # path to zones
*netpth ../nets                 # path to networks
*ctlpth ../ctl                  # path to controls
*radpth ../rad                  # path to radiance files
*imgpth ../images               # path to project images
*tmppth ../temp                 # path to project scratch folder
*docpth ../doc                  # path to project documents
*dbspth ../dbs                  # path to local databases
*indx    1 # Building only
 37.900    6.300   # Latitude & Longitude (diff from meridian)
      1   0.200   # Site exposure & ground reflectivity
* DATABASES
*prm  ../dbs/six_seat.materialdb
*mlc  ../dbs/b3a.constrdb
*opt  /usr/esru/esp-r/databases/optics.db2
*prs  /usr/esru/esp-r/databases/pressc.db1
*evn  /usr/esru/esp-r/databases/profiles.db1
*clm  /home/george/Greek_climate/GRC_Athens_IWEC/GRC_Athens_IWEC
*pdb  /usr/esru/esp-r/databases/plantc.db1
*ctl  ../ctl/six_seat.ctl
*calename standard weekday Sat & Sun
*calentag weekdays,weekdays (all year),259
*calentag saturday,Saturdays (all year), 53
*calentag sunday,Sundays (all year), 53
*list

2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,
1,1,1,

1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,
3,1,1,

1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,
1,2,3,

1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,
1,1,1,

2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,
1,1,1,
```

```
1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,
2,3,1,

1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,
1,1,2,
 3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3
*end_list
*year  2005 # assessment year
# sim setup: no. sets startup zone_ts plant_ts save_lv
*sps     1    7    1   10    4
   7   1  21    6  annual   # period & name
*sblr 1stb1first.res
*sflr 1stb1first.mfr
*end_set
*end_sps
* PROJ LOG
six_seat.log
* Building
Linear Educational Building
     17  # no of zones
*zon   1   # reference for unit_a
*opr ../zones/unit_a.opr  # schedules
*geo ../zones/unit_a.geo  # geometry
*con ../zones/unit_a.con  # construction
*tmc ../zones/unit_a.tmc  # transparent constr
*cgc ../zones/unit_a.cgc # casual gn control
*zend
*zon   2   # reference for unit_b
*opr ../zones/unit_b.opr  # schedules
*geo ../zones/unit_b.geo  # geometry
*con ../zones/unit_b.con  # construction
*tmc ../zones/unit_b.tmc  # transparent constr
*cgc ../zones/unit_b.cgc # casual gn control
*zend
*zon   3   # reference for unit_c
*opr ../zones/unit_c.opr  # schedules
*geo ../zones/unit_c.geo  # geometry
*con ../zones/unit_c.con  # construction
*tmc ../zones/unit_c.tmc  # transparent constr
*cgc ../zones/unit_c.cgc # casual gn control
*zend
*zon   4   # reference for unit_d
*opr ../zones/unit_d.opr  # schedules
*geo ../zones/unit_d.geo  # geometry
*con ../zones/unit_d.con  # construction
*tmc ../zones/unit_d.tmc  # transparent constr
*cgc ../zones/unit_d.cgc # casual gn control
*zend
*zon   5   # reference for unit_e
```

```
*opr ../zones/unit_e.opr  # schedules
*geo ../zones/unit_e.geo  # geometry
*con ../zones/unit_e.con  # construction
*tmc ../zones/unit_e.tmc  # transparent constr
*cgc ../zones/unit_e.cgc # casual gn control
*zend
*zon   6   # reference for unit_f
*opr ../zones/unit_f.opr  # schedules
*geo ../zones/unit_f.geo  # geometry
*con ../zones/unit_f.con  # construction
*tmc ../zones/unit_f.tmc  # transparent constr
*cgc ../zones/unit_f.cgc # casual gn control
*zend
*zon   7   # reference for unit_g
*opr ../zones/unit_g.opr  # schedules
*geo ../zones/unit_g.geo  # geometry
*con ../zones/unit_g.con  # construction
*tmc ../zones/unit_g.tmc  # transparent constr
*cgc ../zones/unit_g.cgc # casual gn control
*zend
*zon   8   # reference for unit_h
*opr ../zones/unit_h.opr  # schedules
*geo ../zones/unit_h.geo  # geometry
*con ../zones/unit_h.con  # construction
*tmc ../zones/unit_h.tmc  # transparent constr
*cgc ../zones/unit_h.cgc # casual gn control
*zend
*zon   9   # reference for uint_i
*opr ../zones/uint_i.opr  # schedules
*geo ../zones/uint_i.geo  # geometry
*con ../zones/uint_i.con  # construction
*tmc ../zones/uint_i.tmc  # transparent constr
*cgc ../zones/uint_i.cgc # casual gn control
*zend
*zon  10   # reference for unit_j
*opr ../zones/unit_j.opr  # schedules
*geo ../zones/unit_j.geo  # geometry
*con ../zones/unit_j.con  # construction
*tmc ../zones/unit_j.tmc  # transparent constr
*cgc ../zones/unit_j.cgc # casual gn control
*zend
*zon  11   # reference for entry
*opr ../zones/entry.opr  # schedules
*geo ../zones/entry.geo  # geometry
*con ../zones/entry.con  # construction
*tmc ../zones/entry.tmc  # transparent constr
*cgc ../zones/entry.cgc # casual gn control
*zend
*zon  12   # reference for unit_k
*opr ../zones/unit_k.opr  # schedules
```

```
*geo ../zones/unit_k.geo  # geometry
*con ../zones/unit_k.con  # construction
*tmc ../zones/unit_k.tmc  # transparent constr
*cgc ../zones/unit_k.cgc # casual gn control
*zend
*zon  13   # reference for unit_l
*opr ../zones/unit_l.opr  # schedules
*geo ../zones/unit_l.geo  # geometry
*con ../zones/unit_l.con  # construction
*tmc ../zones/unit_l.tmc  # transparent constr
*cgc ../zones/unit_l.cgc # casual gn control
*zend
*zon  14   # reference for unit_m
*opr ../zones/unit_m.opr  # schedules
*geo ../zones/unit_m.geo  # geometry
*con ../zones/unit_m.con  # construction
*tmc ../zones/unit_m.tmc  # transparent constr
*cgc ../zones/unit_m.cgc # casual gn control
*zend
*zon  15   # reference for unit_n
*opr ../zones/unit_n.opr  # schedules
*geo ../zones/unit_n.geo  # geometry
*con ../zones/unit_n.con  # construction
*tmc ../zones/unit_n.tmc  # transparent constr
*cgc ../zones/unit_n.cgc # casual gn control
*zend
*zon  16   # reference for unit_o
*opr ../zones/unit_o.opr  # schedules
*geo ../zones/unit_o.geo  # geometry
*con ../zones/unit_o.con  # construction
*tmc ../zones/unit_o.tmc  # transparent constr
*cgc ../zones/unit_o.cgc # casual gn control
*zend
*zon  17   # reference for unit_p
*opr ../zones/unit_p.opr  # schedules
*geo ../zones/unit_p.geo  # geometry
*con ../zones/unit_p.con  # construction
*tmc ../zones/unit_p.tmc  # transparent constr
*cgc ../zones/unit_p.cgc # casual gn control
*zend
*cnn  six_seat.cnn  # connections
     1   # fluid flow network:
../nets/six_seat.afn    # leakage description
 4,1,21,22,5,23,17,14,10,12,7,31,33,35,30,37,38
```

2) *.cnn

```
*connections  for six_seat
*Date Tue Sep 20 11:47:17 2005
   177   # number of connections
   1   1   3  11   6  #   1  a1 in unit_a >|< a1 in entry
   1   2   3   2   5  #   2  a3 in unit_a >|< a3 in unit_b
   1   3   0   0   0  #   3  a5 in unit_a is External
   1   4   0   0   0  #   4  a6 in unit_a is External
   1   5   3   6   8  #   5  a7 in unit_a >|< a7 in unit_f
   1   6   3   6   6  #   6  a8 in unit_a >|< a8 in unit_f
   1   7   3   5   7  #   7  a9 in unit_a >|< a9 in unit_e
   1   8   3   4   9  #   8  a10 in unit_a >|< a10 in unit_d
   1   9   3   4   3  #   9  a11 in unit_a >|< d4 in unit_d
   1  10   0   0   0  #  10  a12 in unit_a is External
   1  11   0   0   0  #  11  a13 in unit_a is External
   1  12   2  14   0  #  12  afloor in unit_a >|< Constant @ 14 dC &   0 W rad
   1  13   0   0   0  #  13  a6_wn1 in unit_a is External
   1  14   0   0   0  #  14  a12_wn1 in unit_a is External
   1  15   3   2   9  #  15  a3_dr in unit_a >|< a3_dr in unit_b
   1  16   3   5   9  #  16  ae_dr in unit_a >|< ae_dr in unit_e
   1  17   3   3   5  #  17  c4 in unit_a >|< a4 in unit_c
   1  18   0   0   0  #  18  a4 in unit_a is External
   1  19   3   3   2  #  19  c2 in unit_a >|< c2 in unit_c
   1  20   0   0   0  #  20  a4_dr in unit_a is External
   1  21   3   6   9  #  21  a8_fict in unit_a >|< a8_fict in unit_f
   1  22   3   8  13  #  22  h_floor in unit_a >|< h_floor in unit_h
   1  23   3  15  13  #  23  n_floor in unit_a >|< n_floor in unit_n
   1  24   3  14   8  #  24  m_floor in unit_a >|< m_floor in unit_m
   1  25   3   3  11  #  25  c_dr1 in unit_a >|< c_dr1 in unit_c
   2   1   0   0   0  #  26  b1 in unit_b is External
   2   2   3   3   6  #  27  b2 in unit_b >|< b2 in unit_c
   2   3   1   0   0  #  28  bceil in unit_b >|< Identical environment
   2   4   2  14   0  #  29  bfloor in unit_b >|< Constant @ 14 dC &   0 W rad
   2   5   3   1   2  #  30  a3 in unit_b >|< a3 in unit_a
   2   6   3  11   5  #  31  en2 in unit_b >|< en2 in entry
   2   7   0   0   0  #  32  b1_wn1 in unit_b is External
   2   8   0   0   0  #  33  b1_wn2 in unit_b is External
   2   9   3   1  15  #  34  a3_dr in unit_b >|< a3_dr in unit_a
   3   1   0   0   0  #  35  c1 in unit_c is External
   3   2   3   1  19  #  36  c2 in unit_c >|< c2 in unit_a
   3   3   3  12   8  #  37  cceil in unit_c >|< cceil in unit_k
   3   4   2  14   0  #  38  cfloor in unit_c >|< Constant @ 14 dC &   0 W rad
   3   5   3   1  17  #  39  a4 in unit_c >|< c4 in unit_a
   3   6   3   2   2  #  40  b2 in unit_c >|< b2 in unit_b
   3   7   0   0   0  #  41  c1_wn1 in unit_c is External
   3   8   0   0   0  #  42  c1_wn2 in unit_c is External
   3   9   0   0   0  #  43  c1_wn3 in unit_c is External
   3  10   3  13   7  #  44  cceil_1 in unit_c >|< cceil in unit_l
```

```
 3  11   3   1  25  #  45  c_dr1 in unit_c >|< c_dr1 in unit_a
 4   1   3   5   8  #  46  d2 in unit_d >|< d2 in unit_e
 4   2   0   0   0  #  47  d3 in unit_d is External
 4   3   3   1   9  #  48  d4 in unit_d >|< a11 in unit_a
 4   4   3   9   5  #  49  dceil in unit_d >|< dceil in uint_i
 4   5   2  14   0  #  50  dfloor in unit_d >|< Constant @ 14 dC &   0 W rad
 4   6   0   0   0  #  51  d3_wn1 in unit_d is External
 4   7   0   0   0  #  52  d3_wn2 in unit_d is External
 4   8   0   0   0  #  53  d3_wn3 in unit_d is External
 4   9   3   1   8  #  54  a10 in unit_d >|< a10 in unit_a
 5   1   3   6   7  #  55  e2 in unit_e >|< e2 in unit_f
 5   2   0   0   0  #  56  e3 in unit_e is External
 5   3   3   9   6  #  57  eceil in unit_e >|< eceil in uint_i
 5   4   2  14   0  #  58  efloor in unit_e >|< Constant @ 14 dC &   0 W rad
 5   5   0   0   0  #  59  e3_wn1 in unit_e is External
 5   6   0   0   0  #  60  e3_wn2 in unit_e is External
 5   7   3   1   7  #  61  a9 in unit_e >|< a9 in unit_a
 5   8   3   4   1  #  62  d2 in unit_e >|< d2 in unit_d
 5   9   3   1  16  #  63  ae_dr in unit_e >|< ae_dr in unit_a
 5  10   3  10   9  #  64  eceil2 in unit_e >|< eceil2 in unit_j
 6   1   0   0   0  #  65  f3 in unit_f is External
 6   2   3  10   5  #  66  fceil in unit_f >|< fceil in unit_j
 6   3   2  14   0  #  67  fflor in unit_f >|< Constant @ 14 dC &   0 W rad
 6   4   0   0   0  #  68  f3_wn1 in unit_f is External
 6   5   0   0   0  #  69  f3_dr in unit_f is External
 6   6   3   1   6  #  70  a8 in unit_f >|< a8 in unit_a
 6   7   3   5   1  #  71  e2 in unit_f >|< e2 in unit_e
 6   8   3   1   5  #  72  a7 in unit_f >|< a7 in unit_a
 6   9   3   1  21  #  73  a8_fict in unit_f >|< a8_fict in unit_a
 7   1   0   0   0  #  74  g1 in unit_g is External
 7   2   0   0   0  #  75  g4 in unit_g is External
 7   3   0   0   0  #  76  gceil in unit_g is External
 7   4   0   0   0  #  77  g1_wn1 in unit_g is External
 7   5   3   8   8  #  78  h1 in unit_g >|< h1 in unit_h
 7   6   3   8  10  #  79  g_dr4 in unit_g >|< g_dr4 in unit_h
 7   7   3  11   3  #  80  enceil in unit_g >|< enceil in entry
 7   8   1   0   0  #  81  bceil in unit_g >|< Identical environment
 7   9   3  12   2  #  82  g4_k in unit_g >|< k4 in unit_k
 8   1   3   9   7  #  83  h6 in unit_h >|< h6 in uint_i
 8   2   3   9   3  #  84  h7 in unit_h >|< i4 in uint_i
 8   3   0   0   0  #  85  h8 in unit_h is External
 8   4   0   0   0  #  86  h9 in unit_h is External
 8   5   0   0   0  #  87  hceil in unit_h is External
 8   6   0   0   0  #  88  a12_wn1 in unit_h is External
 8   7   3   9   9  #  89  i_dr in unit_h >|< i_dr in uint_i
 8   8   3   7   5  #  90  h1 in unit_h >|< h1 in unit_g
 8   9   3  12   5  #  91  k_h in unit_h >|< k_h in unit_k
 8  10   3   7   6  #  92  g_dr4 in unit_h >|< g_dr4 in unit_g
 8  11   3  12   6  #  93  k_dr in unit_h >|< k_dr in unit_k
 8  12   3  15   5  #  94  h_n in unit_h >|< h_n in unit_n
```

```
  8  13   3   1  22  #  95  h_floor in unit_h >|< h_floor in unit_a
  9   1   3  10   3  #  96  i2 in uint_i >|< i4 in unit_j
  9   2   0   0   0  #  97  i3 in uint_i is External
  9   3   3   8   2  #  98  i4 in uint_i >|< h7 in unit_h
  9   4   0   0   0  #  99  iceil in uint_i is External
  9   5   3   4   4  # 100  dceil in uint_i >|< dceil in unit_d
  9   6   3   5   3  # 101  eceil in uint_i >|< eceil in unit_e
  9   7   3   8   1  # 102  h6 in uint_i >|< h6 in unit_h
  9   8   0   0   0  # 103  i3_wn1 in uint_i is External
  9   9   3   8   7  # 104  i_dr in uint_i >|< i_dr in unit_h
 10   1   3  15  12  # 105  i2 in unit_j >|< i2 in unit_n
 10   2   0   0   0  # 106  i3 in unit_j is External
 10   3   3   9   1  # 107  i4 in unit_j >|< i2 in uint_i
 10   4   0   0   0  # 108  iceil in unit_j is External
 10   5   3   6   2  # 109  fceil in unit_j >|< fceil in unit_f
 10   6   3  15  11  # 110  h5 in unit_j >|< h5 in unit_n
 10   7   0   0   0  # 111  i3_wn1 in unit_j is External
 10   8   3  15  10  # 112  j_dr in unit_j >|< j_dr in unit_n
 10   9   3   5  10  # 113  eceil2 in unit_j >|< eceil2 in unit_e
 11   1   0   0   0  # 114  en1 in entry is External
 11   2   0   0   0  # 115  en4 in entry is External
 11   3   3   7   7  # 116  enceil in entry >|< enceil in unit_g
 11   4   2  14   0  # 117  enfloor in entry >|< Constant @ 14 dC &   0 W rad
 11   5   3   2   6  # 118  en2 in entry >|< en2 in unit_b
 11   6   3   1   1  # 119  a1 in entry >|< a1 in unit_a
 11   7   0   0   0  # 120  en1_dr in entry is External
 12   1   0   0   0  # 121  k1 in unit_k is External
 12   2   3   7   9  # 122  k4 in unit_k >|< g4_k in unit_g
 12   3   0   0   0  # 123  kceil in unit_k is External
 12   4   0   0   0  # 124  k1_wn1 in unit_k is External
 12   5   3   8   9  # 125  k_h in unit_k >|< k_h in unit_h
 12   6   3   8  11  # 126  k_dr in unit_k >|< k_dr in unit_h
 12   7   1   0   0  # 127  bceil in unit_k >|< Identical environment
 12   8   3   3   3  # 128  cceil in unit_k >|< cceil in unit_c
 12   9   3  13   2  # 129  g4 in unit_k >|< l4 in unit_l
 13   1   0   0   0  # 130  l1 in unit_l is External
 13   2   3  12   9  # 131  l4 in unit_l >|< g4 in unit_k
 13   3   0   0   0  # 132  lceil in unit_l is External
 13   4   0   0   0  # 133  l1_wn1 in unit_l is External
 13   5   3  15   8  # 134  l1_h in unit_l >|< l1_h in unit_n
 13   6   3  15   9  # 135  l_dr in unit_l >|< l_dr in unit_n
 13   7   3   3  10  # 136  cceil in unit_l >|< cceil_1 in unit_c
 13   8   3  14   2  # 137  m4 in unit_l >|< m4 in unit_m
 14   1   0   0   0  # 138  m1 in unit_m is External
 14   2   3  13   8  # 139  m4 in unit_m >|< m4 in unit_l
 14   3   0   0   0  # 140  mceil in unit_m is External
 14   4   0   0   0  # 141  m1_wn1 in unit_m is External
 14   5   3  15   6  # 142  m_h in unit_m >|< m_h in unit_n
 14   6   3  15   7  # 143  m_dr in unit_m >|< m_dr in unit_n
 14   7   0   0   0  # 144  m5 in unit_m is External
```

```
14   8   3   1  24  # 145  m_floor in unit_m >|< m_floor in unit_a
15   1   0   0   0  # 146  h2 in unit_n is External
15   2   0   0   0  # 147  h3 in unit_n is External
15   3   0   0   0  # 148  hceil in unit_n is External
15   4   0   0   0  # 149  a6_wn1 in unit_n is External
15   5   3   8  12  # 150  h_n in unit_n >|< h_n in unit_h
15   6   3  14   5  # 151  m_h in unit_n >|< m_h in unit_m
15   7   3  14   6  # 152  m_dr in unit_n >|< m_dr in unit_m
15   8   3  13   5  # 153  l1_h in unit_n >|< l1_h in unit_l
15   9   3  13   6  # 154  l_dr in unit_n >|< l_dr in unit_l
15  10   3  10   8  # 155  j_dr in unit_n >|< j_dr in unit_j
15  11   3  10   6  # 156  h5 in unit_n >|< h5 in unit_j
15  12   3  10   1  # 157  i2 in unit_n >|< i2 in unit_j
15  13   3   1  23  # 158  n_floor in unit_n >|< n_floor in unit_a
16   1   2  18   0  # 159  o1 in unit_o >|< Constant @ 18 dC &   0 W rad
16   2   0   0   0  # 160  o2 in unit_o is External
16   3   0   0   0  # 161  o3 in unit_o is External
16   4   0   0   0  # 162  o4 in unit_o is External
16   5   0   0   0  # 163  o5 in unit_o is External
16   6   3  17   5  # 164  o6 in unit_o >|< o6 in unit_p
16   7   0   0   0  # 165  oroof in unit_o is External
16   8   4   4   0  # 166  ofloor in unit_o >|< ground profile 4
16   9   0   0   0  # 167  o2_win in unit_o is External
16  10   0   0   0  # 168  o3_win in unit_o is External
16  11   0   0   0  # 169  o4_win in unit_o is External
16  12   0   0   0  # 170  o5_win in unit_o is External
17   1   0   0   0  # 171  p2 in unit_p is External
17   2   0   0   0  # 172  p3 in unit_p is External
17   3   0   0   0  # 173  proof in unit_p is External
17   4   4   4   0  # 174  pfloor in unit_p >|< ground profile 4
17   5   3  16   6  # 175  o6 in unit_p >|< o6 in unit_o
17   6   0   0   0  # 176  odr in unit_p is External
17   7   0   0   0  # 177  p2_win in unit_p is External
```

3) *.ctl

```
no overall control description supplied
* Building
no zone control description supplied
   2  # No. of functions
* Control function
# senses the temperature of the current zone.
    0    0    0    0  # sensor data
# actuates air point of the current zone
    0    0    0  # actuator data
    1 # No. day types
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     3  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
    0    1   8.000  # ctl type, law (basic control), start @
      7.  # No. of data items
  200000.000 0.000 200000.000 0.000 19.000 26.000 0.000
    0    2  17.000  # ctl type, law (free floating), start @
      0.  # No. of data items
* Control function
# senses the temperature of the current zone.
    0    0    0    0  # sensor data
# actuates air point of the current zone
    0    0    0  # actuator data
    1 # No. day types
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     1  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
# Function:Zone links
 2,1,1,2,2,2,1,2,1,1,2,1,1,1,2,1,2
```

4) *. b1.dbs – Case 1

```
# composite construction db defined in /home/george/six_seat/dbs/b1.constrdb
# based on materials db /home/george/six_seat/dbs/six_seat.materialdb
  14    # no of composites
# layers  description   optics name   symmetry tag
   5    extern_wall   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  283    0.0380  Polystyrene
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   3    intern_wall   OPAQ  OPAQUE       int_wall_inv
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   1    door         OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    int_doors     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   3    d_glz        TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  247    0.0060  low_e_double
   0    0.0120  air  0.620 0.620 0.620
  247    0.0060  low_e_double
# layers  description   optics name   symmetry tag
   3    dbl_glz       TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  242    0.0060  Plate glass
   0    0.0070  air  0.070 0.070 0.070
  242    0.0060  Plate glass
# layers  description   optics name   symmetry tag
   6    grnd_floor    OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
   0    0.0500  air  0.170 0.170 0.170
   67    0.0190  Chipboard
  221    0.0060  Wilton
# layers  description   optics name   symmetry tag
```

```
    5    floor_1      OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
   37    0.1500  common_concrete
  283    0.0065  Polystyrene
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
    4    entry_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
   83    0.0240  White marble
# layers  description   optics name   symmetry tag
    5    susp_floor    OPAQ  OPAQUE       susp_flr_re
# mat ref thickness (m) mat descr & air gap R
  221    0.0060  Wilton
   67    0.0190  Chipboard
    0    0.0500  air  0.170 0.170 0.170
   32    0.1400  Heavy mix concrete
   42    0.0040  Steel
# layers  description   optics name   symmetry tag
    4    ceiling       OPAQ  OPAQUE       ceiling_rev
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
   37    0.1500  common_concrete
  110    0.0100  Plaster_cres
# layers  description   optics name   symmetry tag
    4    ceiling_rev   OPAQ  OPAQUE       ceiling
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    1    ficticious    TRAN  SC_fictit    SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  245    0.1000  fict
# layers  description   optics name   symmetry tag
    7    outer_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
  285    0.0200  Plastic_cres
  283    0.0600  Polystyrene
   21    0.1800  Light mix conc
   37    0.1500  common_concrete
  110    0.0100  Plaster_cres
```

5). *.b3a.dbs – Case 2

```
# composite construction db defined in /home/george/six_seat/dbs/b3a.constrdb
# based on materials db /home/george/six_seat/dbs/six_seat.materialdb
  22    # no of composites
# layers  description   optics name   symmetry tag
   5    extern_wall   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  283    0.0490  Polystyrene
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   3    insul_mtl_p   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  46    0.0040  Grey cotd aluminium
  281    0.0800  Glass Fibre Quilt
  47    0.0040  Wt cotd aluminium
# layers  description   optics name   symmetry tag
   3    intern_wall   OPAQ  OPAQUE       int_wall_inv
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   1    door         OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    int_doors     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    mass_part     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  35    0.2400  Block white ptd inner (3% mc)
# layers  description   optics name   symmetry tag
   3    d_glz        TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  247    0.0060  low_e_double
   0    0.0120  air  0.620 0.620 0.620
  247    0.0060  low_e_double
# layers  description   optics name   symmetry tag
   3    dbl_glz       TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  242    0.0060  Plate glass
   0    0.0120  air  0.165 0.165 0.165
  242    0.0060  Plate glass
```

```
# layers  description   optics name   symmetry tag
    4    roof_1        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  162    0.0500  Roofing felt
   21    0.3000  Light mix conc
    0    0.0500  air  0.170 0.170 0.170
  151    0.0080  Ceiling (plaster)
# layers  description   optics name   symmetry tag
    4    roof          OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   43    0.0030  Aluminium
    0    0.0250  air  0.170 0.170 0.170
  281    0.0800  Glass Fibre Quilt
   43    0.0030  Aluminium
# layers  description   optics name   symmetry tag
    3    roof_2        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  141    0.0150  Clay tile
  162    0.0050  Roofing felt
   72    0.0120  Plywood
# layers  description   optics name   symmetry tag
    6    grnd_floor    OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
    0    0.0500  air  0.170 0.170 0.170
   67    0.0190  Chipboard
  221    0.0060  Wilton
# layers  description   optics name   symmetry tag
    5    floor_1       OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  124    0.0100  Cement screed
   37    0.1500  common_concrete
  124    0.0250  Cement screed
  231    0.0300  ceramic_cres
  124    0.0500  Cement screed
# layers  description   optics name   symmetry tag
    4    entry_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
   83    0.0240  White marble
# layers  description   optics name   symmetry tag
    4    susp_ceil     OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
```

```
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    susp_floor    OPAQ  OPAQUE       susp_flr_re
# mat ref thickness (m) mat descr & air gap R
  221    0.0060  Wilton
   67    0.0190  Chipboard
    0    0.0500  air  0.170 0.170 0.170
   32    0.1400  Heavy mix concrete
   42    0.0040  Steel
# layers  description   optics name   symmetry tag
    4    ceiling       OPAQ  OPAQUE       ceiling_rev
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
   37    0.1500  common_concrete
  110    0.0100  Plaster_cres
# layers  description   optics name   symmetry tag
    4    ceiling_rev   OPAQ  OPAQUE       ceiling
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    gyp_blk_ptn   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0130  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
   28    0.1000  Block inner (3% mc)
    0    0.0500  air  0.170 0.170 0.170
  108    0.0130  White ptd Gypboard
# layers  description   optics name   symmetry tag
    3    gyp_gyp_ptn   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0120  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
  108    0.0120  White ptd Gypboard
# layers  description   optics name   symmetry tag
    1    ficticious    TRAN  SC_fictit    SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  245    0.1000  fict
# layers  description   optics name   symmetry tag
    7    outer_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
  285    0.0200  Plastic_cres
  283    0.0600  Polystyrene
   21    0.1800  Light mix conc
   37    0.1500  common_concrete
```

110   0.0100 Plaster_cres

APPENDIX G – L-shape educational building esp-r files

1) *.cfg

```
* CONFIGURATION3.0
# ESRU system configuration defined by file
# 2nd_edu.cfg
*date Tue Sep 20 12:07:16 2005  # latest file modification
*root 2nd_edu
*zonpth ../zones                  # path to zones
*netpth ../nets                   # path to networks
*ctlpth ../ctl                    # path to controls
*radpth ../rad                    # path to radiance files
*imgpth ../images                 # path to project images
*tmppth ../temp                   # path to project scratch folder
*docpth ../doc                    # path to project documents
*dbspth ../dbs                    # path to local databases
*indx    1 # Building only
 37.900    6.300   # Latitude & Longitude (diff from meridian)
      1   0.200   # Site exposure & ground reflectivity
* DATABASES
*prm  /home/george/six_seat/dbs/six_seat.materialdb
*mlc  /home/george/six_seat/dbs/b1.constrdb
*opt  /usr/esru/esp-r/databases/optics.db2
*prs  /usr/esru/esp-r/databases/pressc.db1
*evn  /usr/esru/esp-r/databases/profiles.db1
*clm  /home/george/Greek_climate/GRC_Athens_IWEC/GRC_Athens_IWEC
*pdb  /usr/esru/esp-r/databases/plantc.db1
*ctl  ../ctl/2nd_edu.ctl
*calename standard weekday Sat & Sun
*calentag weekdays,weekdays (all year),260
*calentag saturday,Saturdays (all year), 53
*calentag sunday,Sundays (all year), 52
*list

2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,
1,1,1,

1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,
2,3,1,

1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,
1,1,2,

3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,
1,1,1,
```

```
1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,
3,1,1,

1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,
1,2,3,

1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,
1,1,1,
 2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2,3,1,1,1,1,1,2
*end_list
*year  2005 # assessment year
# sim setup: no. sets startup zone_ts plant_ts save_lv
*sps     1   12    1   10    4
  11   9  23  12  default  # period & name
*sblr 2nd_edu1.res
*sflr 2nd_edu1.mfr
*end_set
*end_sps
* PROJ LOG
2nd_edu.log
* Building
L-shape Educational Building
     14  # no of zones
*zon   1   # reference for unit_a
*opr ../zones/unit_a.opr  # schedules
*geo ../zones/unit_a.geo  # geometry
*con ../zones/unit_a.con  # construction
*obs ../zones/unit_a.obs  # obstructions
*tmc ../zones/unit_a.tmc  # transparent constr
*isi ../zones/unit_a.shd  # shading db
*zend
*zon   2   # reference for unit_c
*opr ../zones/unit_c.opr  # schedules
*geo ../zones/unit_c.geo  # geometry
*con ../zones/unit_c.con  # construction
*obs ../zones/unit_c.obs  # obstructions
*tmc ../zones/unit_c.tmc  # transparent constr
*isi ../zones/unit_c.shd  # shading db
*zend
*zon   3   # reference for unit_b
*opr ../zones/unit_b.opr  # schedules
*geo ../zones/unit_b.geo  # geometry
*con ../zones/unit_b.con  # construction
*zend
*zon   4   # reference for unit_b1
*opr ../zones/unit_b1.opr  # schedules
*geo ../zones/unit_b1.geo  # geometry
*con ../zones/unit_b1.con  # construction
*zend
```

```
*zon   5   # reference for unit
*opr ../zones/unit.opr  # schedules
*geo ../zones/unit.geo  # geometry
*con ../zones/unit.con  # construction
*zend
*zon   6   # reference for unit_a1
*opr ../zones/unit_a1.opr  # schedules
*geo ../zones/unit_a1.geo  # geometry
*con ../zones/unit_a1.con  # construction
*obs ../zones/unit_a1.obs  # obstructions
*tmc ../zones/unit_a1.tmc  # transparent constr
*isi ../zones/unit_a1.shd  # shading db
*zend
*zon   7   # reference for unit_a2
*opr ../zones/unit_a2.opr  # schedules
*geo ../zones/unit_a2.geo  # geometry
*con ../zones/unit_a2.con  # construction
*obs ../zones/unit_a2.obs  # obstructions
*tmc ../zones/unit_a2.tmc  # transparent constr
*isi ../zones/unit_a2.shd  # shading db
*zend
*zon   8   # reference for unit_c1
*opr ../zones/unit_c1.opr  # schedules
*geo ../zones/unit_c1.geo  # geometry
*con ../zones/unit_c1.con  # construction
*obs ../zones/unit_c1.obs  # obstructions
*tmc ../zones/unit_c1.tmc  # transparent constr
*isi ../zones/unit_c1.shd  # shading db
*zend
*zon   9   # reference for unit_c2
*opr ../zones/unit_c2.opr  # schedules
*geo ../zones/unit_c2.geo  # geometry
*con ../zones/unit_c2.con  # construction
*obs ../zones/unit_c2.obs  # obstructions
*tmc ../zones/unit_c2.tmc  # transparent constr
*isi ../zones/unit_c2.shd  # shading db
*zend
*zon  10   # reference for unit_b2
*opr ../zones/unit_b2.opr  # schedules
*geo ../zones/unit_b2.geo  # geometry
*con ../zones/unit_b2.con  # construction
*zend
*zon  11   # reference for unit_e1
*opr ../zones/unit_e1.opr  # schedules
*geo ../zones/unit_e1.geo  # geometry
*con ../zones/unit_e1.con  # construction
*obs ../zones/unit_e1.obs  # obstructions
*tmc ../zones/unit_e1.tmc  # transparent constr
*isi ../zones/unit_e1.shd  # shading db
*zend
```

```
*zon  12   # reference for unit_e2
*opr ../zones/unit_e2.opr  # schedules
*geo ../zones/unit_e2.geo  # geometry
*con ../zones/unit_e2.con  # construction
*obs ../zones/unit_e2.obs  # obstructions
*tmc ../zones/unit_e2.tmc  # transparent constr
*isi ../zones/unit_e2.shd  # shading db
*zend
*zon  13   # reference for unit_d1
*opr ../zones/unit_d1.opr  # schedules
*geo ../zones/unit_d1.geo  # geometry
*con ../zones/unit_d1.con  # construction
*obs ../zones/unit_d1.obs  # obstructions
*tmc ../zones/unit_d1.tmc  # transparent constr
*isi ../zones/unit_d1.shd  # shading db
*zend
*zon  14   # reference for unit_d2
*opr ../zones/unit_d2.opr  # schedules
*geo ../zones/unit_d2.geo  # geometry
*con ../zones/unit_d2.con  # construction
*obs ../zones/unit_d2.obs  # obstructions
*tmc ../zones/unit_d2.tmc  # transparent constr
*isi ../zones/unit_d2.shd  # shading db
*zend
*cnn  2nd_edu.cnn  # connections
     1   # fluid flow network:
../nets/2nd_edu.afn    # leakage description
 5,8,1,2,3,4,5,7,8,3,13,14,10,11
```

2) *.cnn

```
*connections  for 2nd_edu
*Date Tue Sep 20 12:07:16 2005
   139   # number of connections
  1   1   0   0   0  #   1  1a in unit_a is External
  1   2   3   3   7  #   2  2a in unit_a >|< 2a in unit_b
  1   3   1   0   0  #   3  3a in unit_a >|< Identical environment
  1   4   0   0   0  #   4  4a in unit_a is External
  1   5   3   6   6  #   5  aceil in unit_a >|< afloor in unit_a1
  1   6   4   2   0  #   6  afloor in unit_a >|< ground profile 2
  1   7   0   0   0  #   7  a_win in unit_a is External
  1   8   3   3   8  #   8  a_dr in unit_a >|< a_dr in unit_b
  2   1   3   3  11  #   9  1a in unit_c >|< 1a in unit_b
  2   2   3   3   9  #  10  2a in unit_c >|< 2c in unit_b
  2   3   0   0   0  #  11  3a in unit_c is External
  2   4   0   0   0  #  12  4a in unit_c is External
  2   5   3   8   6  #  13  aceil in unit_c >|< afloor in unit_c1
  2   6   4   2   0  #  14  afloor in unit_c >|< ground profile 2
  2   7   0   0   0  #  15  a_win in unit_c is External
  2   8   3   3  10  #  16  a_dr in unit_c >|< c_dr in unit_b
  3   1   3   5   7  #  17  b3 in unit_b >|< b3 in unit
  3   2   0   0   0  #  18  b7 in unit_b is External
  3   3   0   0   0  #  19  b12 in unit_b is External
  3   4   3   4  18  #  20  bceil in unit_b >|< b1floor in unit_b1
  3   5   4   2   0  #  21  bfloor in unit_b >|< ground profile 2
  3   6   3   5   8  #  22  b_door in unit_b >|< b_door in unit
  3   7   3   1   2  #  23  2a in unit_b >|< 2a in unit_a
  3   8   3   1   8  #  24  a_dr in unit_b >|< a_dr in unit_a
  3   9   3   2   2  #  25  2c in unit_b >|< 2a in unit_c
  3  10   3   2   8  #  26  c_dr in unit_b >|< a_dr in unit_c
  3  11   3   2   1  #  27  1a in unit_b >|< 1a in unit_c
  3  12   0   0   0  #  28  3a in unit_b is External
  3  13   0   0   0  #  29  b7_dr in unit_b is External
  4   1   0   0   0  #  30  b3 in unit_b1 is External
  4   2   0   0   0  #  31  b4 in unit_b1 is External
  4   3   0   0   0  #  32  b7 in unit_b1 is External
  4   4   0   0   0  #  33  b12 in unit_b1 is External
  4   5   3  10   6  #  34  bceil in unit_b1 >|< b2floor in unit_b2
  4   6   1   0   0  #  35  3a in unit_b1 >|< Identical environment
  4   7   3   6   2  #  36  2a in unit_b1 >|< 2a in unit_a1
  4   8   3   6   8  #  37  a_dr in unit_b1 >|< a_dr in unit_a1
  4   9   3   8   2  #  38  2b in unit_b1 >|< 2a in unit_c1
  4  10   3   8   1  #  39  1a in unit_b1 >|< 1a in unit_c1
  4  11   3   8   8  #  40  a_dr in unit_b1 >|< a_dr in unit_c1
  4  12   3  11   3  #  41  3e in unit_b1 >|< 3a in unit_e1
  4  13   3  11   2  #  42  2e in unit_b1 >|< 2a in unit_e1
  4  14   3  11   8  #  43  a_dr in unit_b1 >|< a_dr in unit_e1
  4  15   3  13   1  #  44  1a in unit_b1 >|< 1a in unit_d1
```

```
 4  16   3  13   2  #  45  2d in unit_b1 >|< 2a in unit_d1
 4  17   3  13   8  #  46  a_dr in unit_b1 >|< a_dr in unit_d1
 4  18   3   3   4  #  47  b1floor in unit_b1 >|< bceil in unit_b
 4  19   3   5   5  #  48  tceil in unit_b1 >|< tceil in unit
 4  20   0   0   0  #  49  b1_exter in unit_b1 is External
 5   1   0   0   0  #  50  t2 in unit is External
 5   2   0   0   0  #  51  t3 in unit is External
 5   3   0   0   0  #  52  t4 in unit is External
 5   4   0   0   0  #  53  t5 in unit is External
 5   5   3   4  19  #  54  tceil in unit >|< tceil in unit_b1
 5   6   4   2   0  #  55  tfloor in unit >|< ground profile 2
 5   7   3   3   1  #  56  b3 in unit >|< b3 in unit_b
 5   8   3   3   6  #  57  b_door in unit >|< b_door in unit_b
 6   1   0   0   0  #  58  1a in unit_a1 is External
 6   2   3   4   7  #  59  2a in unit_a1 >|< 2a in unit_b1
 6   3   1   0   0  #  60  3a in unit_a1 >|< Identical environment
 6   4   0   0   0  #  61  4a in unit_a1 is External
 6   5   3   7   6  #  62  aceil in unit_a1 >|< afloor in unit_a2
 6   6   3   1   5  #  63  afloor in unit_a1 >|< aceil in unit_a
 6   7   0   0   0  #  64  a_win in unit_a1 is External
 6   8   3   4   8  #  65  a_dr in unit_a1 >|< a_dr in unit_b1
 7   1   0   0   0  #  66  1a in unit_a2 is External
 7   2   3  10   7  #  67  2a in unit_a2 >|< 2a in unit_b2
 7   3   1   0   0  #  68  3a in unit_a2 >|< Identical environment
 7   4   0   0   0  #  69  4a in unit_a2 is External
 7   5   0   0   0  #  70  aceil in unit_a2 is External
 7   6   3   6   5  #  71  afloor in unit_a2 >|< aceil in unit_a1
 7   7   0   0   0  #  72  a_win in unit_a2 is External
 7   8   3  10   8  #  73  a_dr in unit_a2 >|< a_dr in unit_b2
 8   1   3   4  10  #  74  1a in unit_c1 >|< 1a in unit_b1
 8   2   3   4   9  #  75  2a in unit_c1 >|< 2b in unit_b1
 8   3   0   0   0  #  76  3a in unit_c1 is External
 8   4   0   0   0  #  77  4a in unit_c1 is External
 8   5   3   9   6  #  78  aceil in unit_c1 >|< afloor in unit_c2
 8   6   3   2   5  #  79  afloor in unit_c1 >|< aceil in unit_c
 8   7   0   0   0  #  80  a_win in unit_c1 is External
 8   8   3   4  11  #  81  a_dr in unit_c1 >|< a_dr in unit_b1
 9   1   3  10  10  #  82  1a in unit_c2 >|< 1a in unit_b2
 9   2   3  10  11  #  83  2a in unit_c2 >|< 2c in unit_b2
 9   3   0   0   0  #  84  3a in unit_c2 is External
 9   4   0   0   0  #  85  4a in unit_c2 is External
 9   5   0   0   0  #  86  aceil in unit_c2 is External
 9   6   3   8   5  #  87  afloor in unit_c2 >|< aceil in unit_c1
 9   7   0   0   0  #  88  a_win in unit_c2 is External
 9   8   3  10  12  #  89  a_dr in unit_c2 >|< c_dr in unit_b2
10   1   0   0   0  #  90  b3 in unit_b2 is External
10   2   0   0   0  #  91  b4 in unit_b2 is External
10   3   0   0   0  #  92  b7 in unit_b2 is External
10   4   0   0   0  #  93  b12 in unit_b2 is External
10   5   0   0   0  #  94  bceil in unit_b2 is External
```

```
10   6   3   4   5  #  95  b2floor in unit_b2 >|< bceil in unit_b1
10   7   3   7   2  #  96  2a in unit_b2 >|< 2a in unit_a2
10   8   3   7   8  #  97  a_dr in unit_b2 >|< a_dr in unit_a2
10   9   0   0   0  #  98  3a in unit_b2 is External
10  10   3   9   1  #  99  1a in unit_b2 >|< 1a in unit_c2
10  11   3   9   2  # 100  2c in unit_b2 >|< 2a in unit_c2
10  12   3   9   8  # 101  c_dr in unit_b2 >|< a_dr in unit_c2
10  13   3  12   2  # 102  2e in unit_b2 >|< 2a in unit_e2
10  14   3  12   3  # 103  3a in unit_b2 >|< 3a in unit_e2
10  15   3  12   8  # 104  e_dr in unit_b2 >|< a_dr in unit_e2
10  16   3  14   1  # 105  1a in unit_b2 >|< 1a in unit_d2
10  17   3  14   2  # 106  2d in unit_b2 >|< 2a in unit_d2
10  18   3  14   8  # 107  d_dr in unit_b2 >|< a_dr in unit_d2
11   1   0   0   0  # 108  1a in unit_e1 is External
11   2   3   4  13  # 109  2a in unit_e1 >|< 2e in unit_b1
11   3   3   4  12  # 110  3a in unit_e1 >|< 3e in unit_b1
11   4   0   0   0  # 111  4a in unit_e1 is External
11   5   3  12   6  # 112  aceil in unit_e1 >|< afloor in unit_e2
11   6   0   0   0  # 113  afloor in unit_e1 is External
11   7   0   0   0  # 114  a_win in unit_e1 is External
11   8   3   4  14  # 115  a_dr in unit_e1 >|< a_dr in unit_b1
12   1   0   0   0  # 116  1a in unit_e2 is External
12   2   3  10  13  # 117  2a in unit_e2 >|< 2e in unit_b2
12   3   3  10  14  # 118  3a in unit_e2 >|< 3a in unit_b2
12   4   0   0   0  # 119  4a in unit_e2 is External
12   5   0   0   0  # 120  aceil in unit_e2 is External
12   6   3  11   5  # 121  afloor in unit_e2 >|< aceil in unit_e1
12   7   0   0   0  # 122  a_win in unit_e2 is External
12   8   3  10  15  # 123  a_dr in unit_e2 >|< e_dr in unit_b2
13   1   3   4  15  # 124  1a in unit_d1 >|< 1a in unit_b1
13   2   3   4  16  # 125  2a in unit_d1 >|< 2d in unit_b1
13   3   0   0   0  # 126  3a in unit_d1 is External
13   4   0   0   0  # 127  4a in unit_d1 is External
13   5   3  14   6  # 128  aceil in unit_d1 >|< afloor in unit_d2
13   6   0   0   0  # 129  afloor in unit_d1 is External
13   7   0   0   0  # 130  a_win in unit_d1 is External
13   8   3   4  17  # 131  a_dr in unit_d1 >|< a_dr in unit_b1
14   1   3  10  16  # 132  1a in unit_d2 >|< 1a in unit_b2
14   2   3  10  17  # 133  2a in unit_d2 >|< 2d in unit_b2
14   3   0   0   0  # 134  3a in unit_d2 is External
14   4   0   0   0  # 135  4a in unit_d2 is External
14   5   0   0   0  # 136  aceil in unit_d2 is External
14   6   3  13   5  # 137  afloor in unit_d2 >|< aceil in unit_d1
14   7   0   0   0  # 138  a_win in unit_d2 is External
14   8   3  10  18  # 139  a_dr in unit_d2 >|< d_dr in unit_b2
```

3) *.ctl

```
no overall control description supplied
* Building
no zone control description supplied
   2  # No. of functions
* Control function
# senses the temperature of the current zone.
    0    0    0    0  # sensor data
# actuates air point of the current zone
    0    0    0  # actuator data
    0 # No. day types
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     3  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
    0    1   8.000  # ctl type, law (basic control), start @
      7.  # No. of data items
  200000.000 0.000 200000.000 0.000 19.000 26.000 0.000
    0    2  17.000  # ctl type, law (free floating), start @
      0.  # No. of data items
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     1  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     1  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
* Control function
# senses the temperature of the current zone.
    0    0    0    0  # sensor data
# actuates air point of the current zone
    0    0    0  # actuator data
    1 # No. day types
    1  365  # valid Sat  1 Jan - Sat 31 Dec
     1  # No. of periods in day
    0    2   0.000  # ctl type, law (free floating), start @
      0.  # No. of data items
# Function:Zone links
 2,1,2,2,1,2,2,1,1,2,1,1,1,1
```

4) *.c1.dbs – Case 3

```
# composite construction db defined in /home/george/six_seat/dbs/c1.constrdb
# based on materials db /home/george/six_seat/dbs/six_seat.materialdb
  22    # no of composites
# layers  description   optics name   symmetry tag
   5    extern_wall   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
 110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
 283    0.0490  Polystyrene
   8    0.0900  outer_brick_cres
 110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   3    insul_mtl_p   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  46    0.0040  Grey cotd aluminium
 281    0.0800  Glass Fibre Quilt
  47    0.0040  Wt cotd aluminium
# layers  description   optics name   symmetry tag
   3    intern_wall   OPAQ  OPAQUE       int_wall_inv
# mat ref thickness (m) mat descr & air gap R
 110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
 110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   1    door          OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    int_doors     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    mass_part     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  35    0.2400  Block white ptd inner (3% mc)
# layers  description   optics name   symmetry tag
   3    d_glz         TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
 247    0.0060  low_e_double
   0    0.0120  air  0.620 0.620 0.620
 247    0.0060  low_e_double
# layers  description   optics name   symmetry tag
   3    dbl_glz       TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
 242    0.0060  Plate glass
   0    0.0120  air  0.165 0.165 0.165
 242    0.0060  Plate glass
```

```
# layers  description   optics name   symmetry tag
    4    roof_1        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  162    0.0500  Roofing felt
   21    0.3000  Light mix conc
    0    0.0500  air  0.170 0.170 0.170
  151    0.0080  Ceiling (plaster)
# layers  description   optics name   symmetry tag
    4    roof          OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   43    0.0030  Aluminium
    0    0.0250  air  0.170 0.170 0.170
  281    0.0800  Glass Fibre Quilt
   43    0.0030  Aluminium
# layers  description   optics name   symmetry tag
    3    roof_2        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  141    0.0150  Clay tile
  162    0.0050  Roofing felt
   72    0.0120  Plywood
# layers  description   optics name   symmetry tag
    6    grnd_floor    OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
    0    0.0500  air  0.170 0.170 0.170
   67    0.0190  Chipboard
  221    0.0060  Wilton
# layers  description   optics name   symmetry tag
    5    floor_1       OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  124    0.0100  Cement screed
   37    0.1500  common_concrete
  124    0.0250  Cement screed
  231    0.0300  ceramic_cres
  124    0.0500  Cement screed
# layers  description   optics name   symmetry tag
    4    entry_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
   83    0.0240  White marble
# layers  description   optics name   symmetry tag
    4    susp_ceil     OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
```

```
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    susp_floor    OPAQ  OPAQUE       susp_flr_re
# mat ref thickness (m) mat descr & air gap R
  221    0.0060  Wilton
   67    0.0190  Chipboard
    0    0.0500  air  0.170 0.170 0.170
   32    0.1400  Heavy mix concrete
   42    0.0040  Steel
# layers  description   optics name   symmetry tag
    4    ceiling       OPAQ  OPAQUE       ceiling_rev
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
   37    0.1500  common_concrete
  110    0.0100  Plaster_cres
# layers  description   optics name   symmetry tag
    4    ceiling_rev   OPAQ  OPAQUE       ceiling
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    gyp_blk_ptn   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0130  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
   28    0.1000  Block inner (3% mc)
    0    0.0500  air  0.170 0.170 0.170
  108    0.0130  White ptd Gypboard
# layers  description   optics name   symmetry tag
    3    gyp_gyp_ptn   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0120  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
  108    0.0120  White ptd Gypboard
# layers  description   optics name   symmetry tag
    1    ficticious    TRAN  SC_fictit    SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  245    0.1000  fict
# layers  description   optics name   symmetry tag
    7    outer_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
  285    0.0200  Plastic_cres
  283    0.0600  Polystyrene
   21    0.1800  Light mix conc
   37    0.1500  common_concrete
```

110   0.0100 Plaster_cres

5) *.c3a.dbs – Case 4

```
# composite construction db defined in
/home/george/six_seat/dbs/c3a.constrdb
# based on materials db /home/george/six_seat/dbs/six_seat.materialdb
  22    # no of composites
# layers  description   optics name   symmetry tag
   5    extern_wall   OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  283    0.0650  Polystyrene
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   3    insul_mtl_p   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   46    0.0040  Grey cotd aluminium
  281    0.0800  Glass Fibre Quilt
   47    0.0040  Wt cotd aluminium
# layers  description   optics name   symmetry tag
   3    intern_wall   OPAQ  OPAQUE       int_wall_inv
# mat ref thickness (m) mat descr & air gap R
  110    0.0020  Plaster_cres
   8    0.0900  outer_brick_cres
  110    0.0020  Plaster_cres
# layers  description   optics name   symmetry tag
   1    door         OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    int_doors     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   69    0.0250  Oak (radial)
# layers  description   optics name   symmetry tag
   1    mass_part     OPAQ  OPAQUE       SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   35    0.2400  Block white ptd inner (3% mc)
# layers  description   optics name   symmetry tag
   3    d_glz        TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  247    0.0060  low_e_double
   0    0.0120  air  0.620 0.620 0.620
  247    0.0060  low_e_double
# layers  description   optics name   symmetry tag
   3    dbl_glz       TRAN  DCF7671_06nb  SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  242    0.0060  Plate glass
   0    0.0360  air  0.520 0.520 0.520
```

```
  242    0.0060  Plate glass
# layers  description   optics name   symmetry tag
    4    roof_1        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  162    0.0500  Roofing felt
   21    0.3000  Light mix conc
    0    0.0500  air  0.170 0.170 0.170
  151    0.0080  Ceiling (plaster)
# layers  description   optics name   symmetry tag
    4    roof          OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
   43    0.0030  Aluminium
    0    0.0250  air  0.170 0.170 0.170
  281    0.0800  Glass Fibre Quilt
   43    0.0030  Aluminium
# layers  description   optics name   symmetry tag
    3    roof_2        OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  141    0.0150  Clay tile
  162    0.0050  Roofing felt
   72    0.0120  Plywood
# layers  description   optics name   symmetry tag
    6    grnd_floor    OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
    0    0.0500  air  0.170 0.170 0.170
   67    0.0190  Chipboard
  221    0.0060  Wilton
# layers  description   optics name   symmetry tag
    5    floor_1       OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  124    0.0100  Cement screed
   37    0.1500  common_concrete
  124    0.0250  Cement screed
  231    0.0300  ceramic_cres
  124    0.0500  Cement screed
# layers  description   optics name   symmetry tag
    4    entry_floor   OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  263    0.2500  Common_earth
  262    0.1500  Gravel based
   32    0.1500  Heavy mix concrete
   83    0.0240  White marble
# layers  description   optics name   symmetry tag
    4    susp_ceil     OPAQ  OPAQUE       NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
```

```
  111    0.0250  Mortar_cres
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    susp_floor    OPAQ  OPAQUE        susp_flr_re
# mat ref thickness (m) mat descr & air gap R
  221    0.0060  Wilton
   67    0.0190  Chipboard
    0    0.0500  air  0.170 0.170 0.170
   32    0.1400  Heavy mix concrete
   42    0.0040  Steel
# layers  description   optics name   symmetry tag
    4    ceiling       OPAQ  OPAQUE        ceiling_rev
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
   37    0.1500  common_concrete
  110    0.0100  Plaster_cres
# layers  description   optics name   symmetry tag
    4    ceiling_rev   OPAQ  OPAQUE        ceiling
# mat ref thickness (m) mat descr & air gap R
  110    0.0100  Plaster_cres
   37    0.1500  common_concrete
  111    0.0250  Mortar_cres
  231    0.0300  ceramic_cres
# layers  description   optics name   symmetry tag
    5    gyp_blk_ptn   OPAQ  OPAQUE        SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0130  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
   28    0.1000  Block inner (3% mc)
    0    0.0500  air  0.170 0.170 0.170
  108    0.0130  White ptd Gypboard
# layers  description   optics name   symmetry tag
    3    gyp_gyp_ptn   OPAQ  OPAQUE        SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  108    0.0120  White ptd Gypboard
    0    0.0500  air  0.170 0.170 0.170
  108    0.0120  White ptd Gypboard
# layers  description   optics name   symmetry tag
    1    ficticious    TRAN  SC_fictit     SYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  245    0.1000  fict
# layers  description   optics name   symmetry tag
    7    outer_floor   OPAQ  OPAQUE        NONSYMMETRIC
# mat ref thickness (m) mat descr & air gap R
  231    0.0300  ceramic_cres
  111    0.0250  Mortar_cres
  285    0.0200  Plastic_cres
  283    0.0600  Polystyrene
   21    0.1800  Light mix conc
```

```
 37    0.1500  common_concrete
110    0.0100  Plaster_cres
```