Sustainable Façade Design and Virtue in Incarceration Architecture

The case of prison buildings in Abu Dhabi

Volume Two

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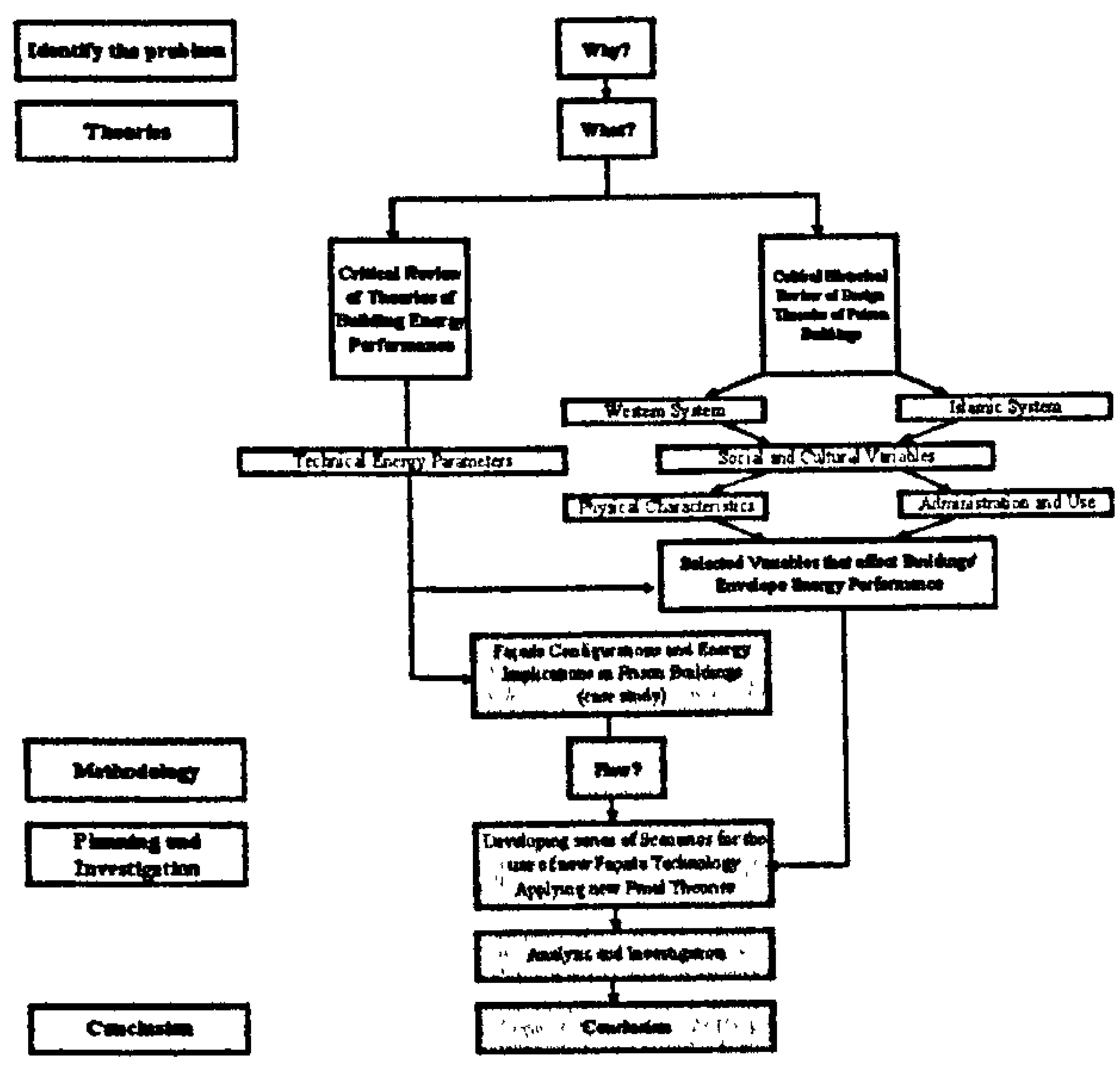

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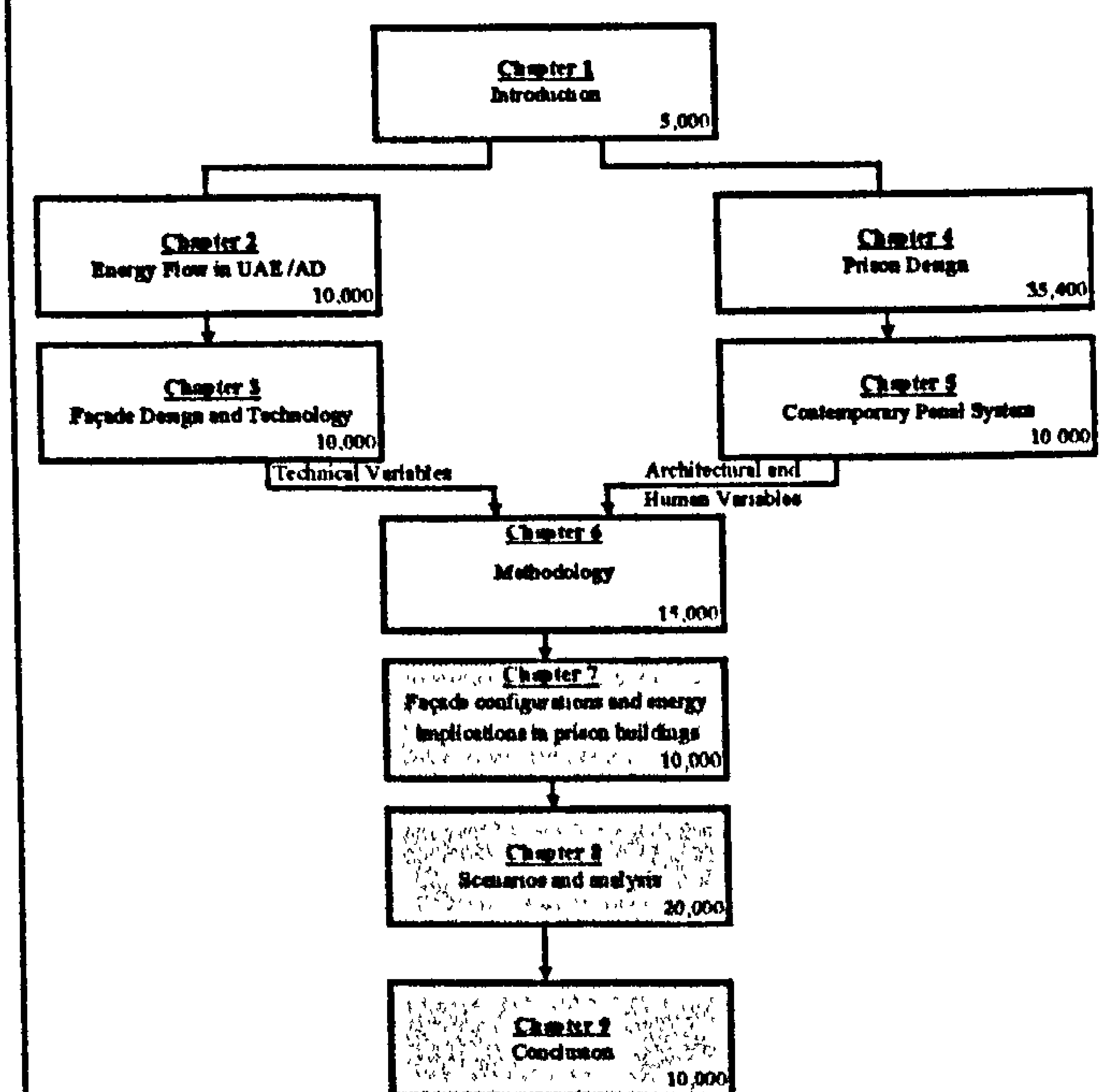

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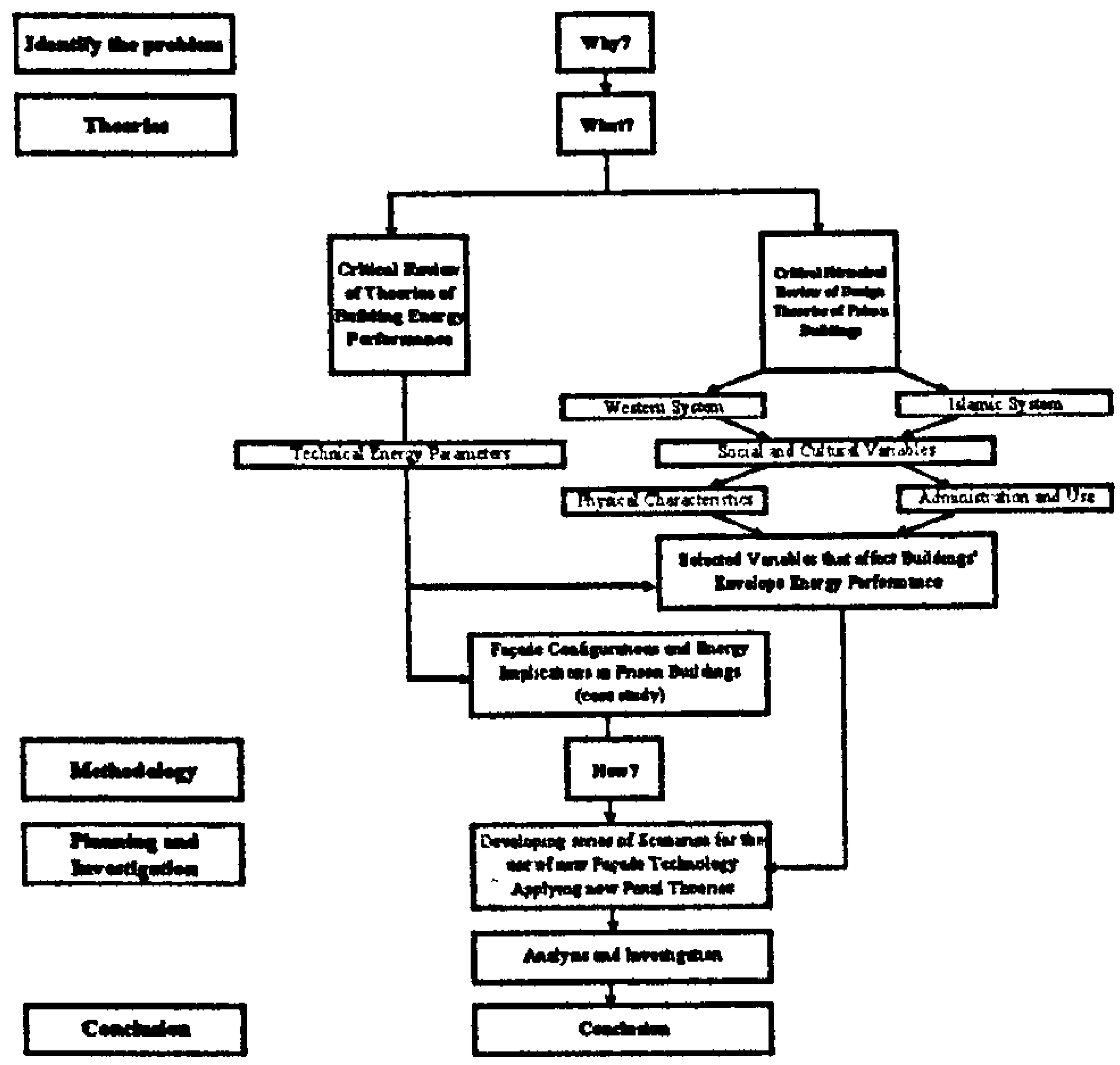
CHAPTER SEVEN

FAÇADE CONFIGURATIONS AND ENERGY IMPLICATIONS IN PRISON BUILDINGS



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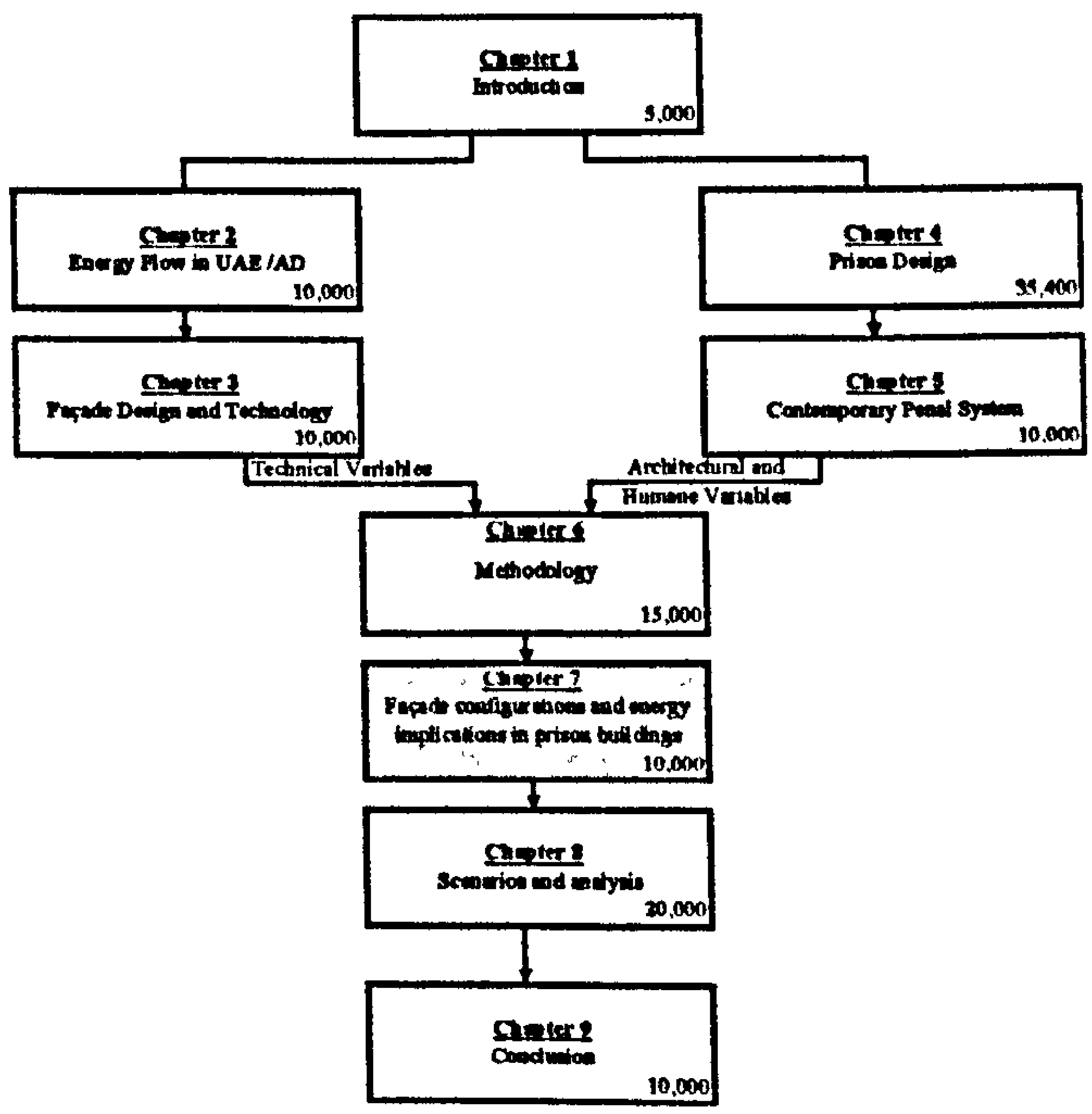

The Thesis Chapters Outline

7 Façade configurations and energy implications in prison buildings

7.1 Introduction

Previous chapters have emphasised the role of both technical and social variables in achieving a sustainable prison environment. This chapter explains how such variables were selected and the discussion used to relate the two groups of disparate variables to one other.

Prison buildings belong to a very specific typology. Different constraints are imposed on the designers and limit their freedom (Figure 68). Such limitation is related to the prison's mission statement and the philosophies adopted in that particular cultural context. It is therefore important to trace how architectural variables stem from such policies and regulations. The following sections follow the new penal philosophy in the UAE and its impact on the design variables. The discussion is also extended in Section 7.3 to explain how such philosophies influence social considerations, which in turn also have design implications.

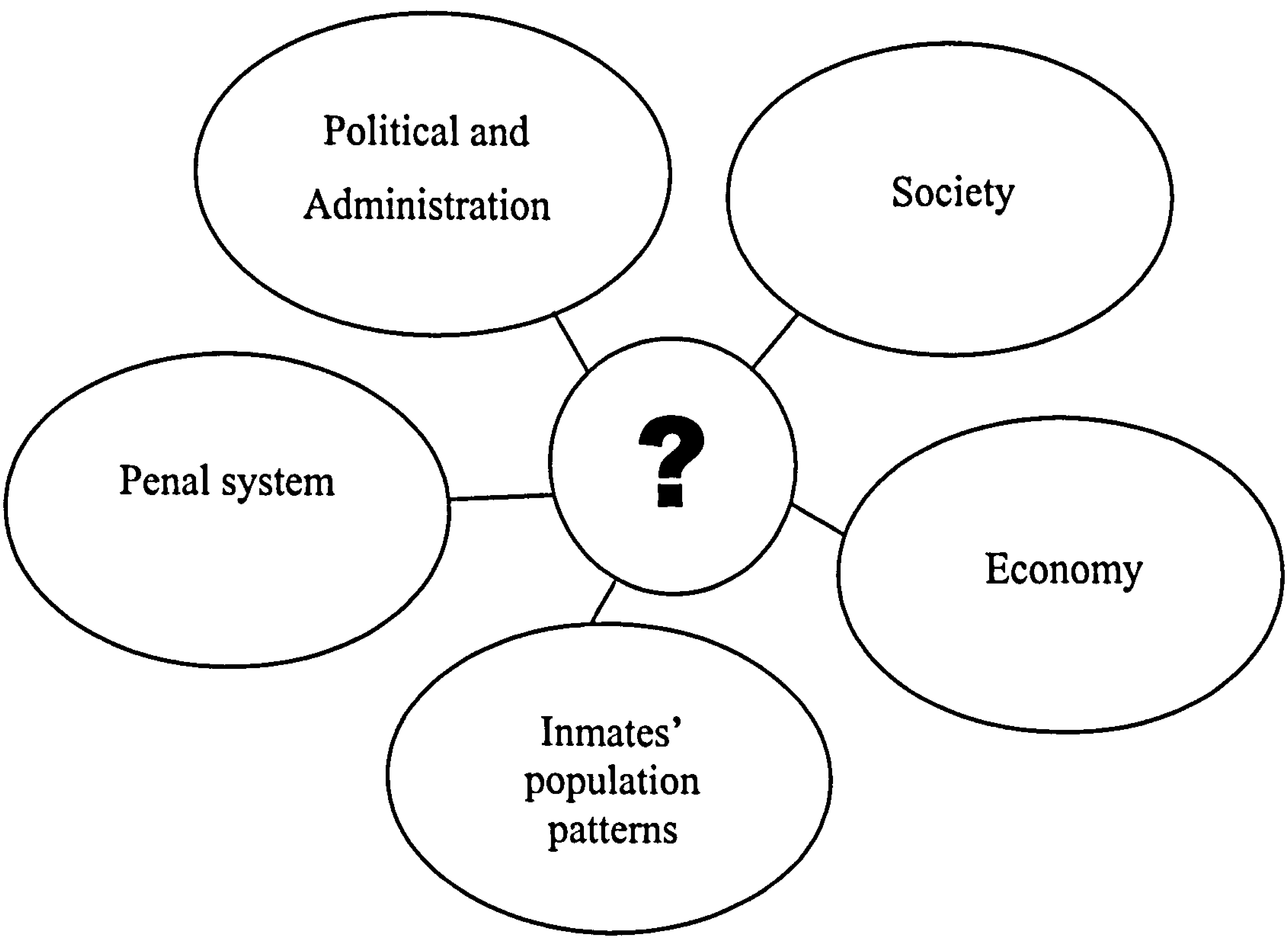

Figure 68: The main factors that influence the conceptual stage of the prison building design process

The variables having been identified, it was necessary to instigate a method to investigate the sensitivity of these variables. The reasons behind the decision to use a computer simulation technique are discussed in Chapter 6. The final section reviews the available alternatives in thermal analysis software, and the justification for using APACHE for the investigation and analysis of developed scenarios.

A pilot study was made to identify and test the relative importance of the energy related façade features, and to validate the choice of the simulation software APACHE. The pilot study is presented in Section 7.4.

Following the explanation of the technical and social variables, Section 7.6 summarises the findings and specifies the variables that influence the thermal performance of prison façades and hence affect the sustainability of a prison building as a whole. The variables are divided into different categories, in order to enable the testing and investigation of the case study in Chapter 8.

7.2 Architectural variables that influence the thermal performance of prison façades

Chapter four showed that prison buildings have specific architectural characteristics. The historical review, in chapter four showed that the design of prisons is mainly influenced by external forces that are related to history, social policy and bureaucracy in a certain context (Figure 69).

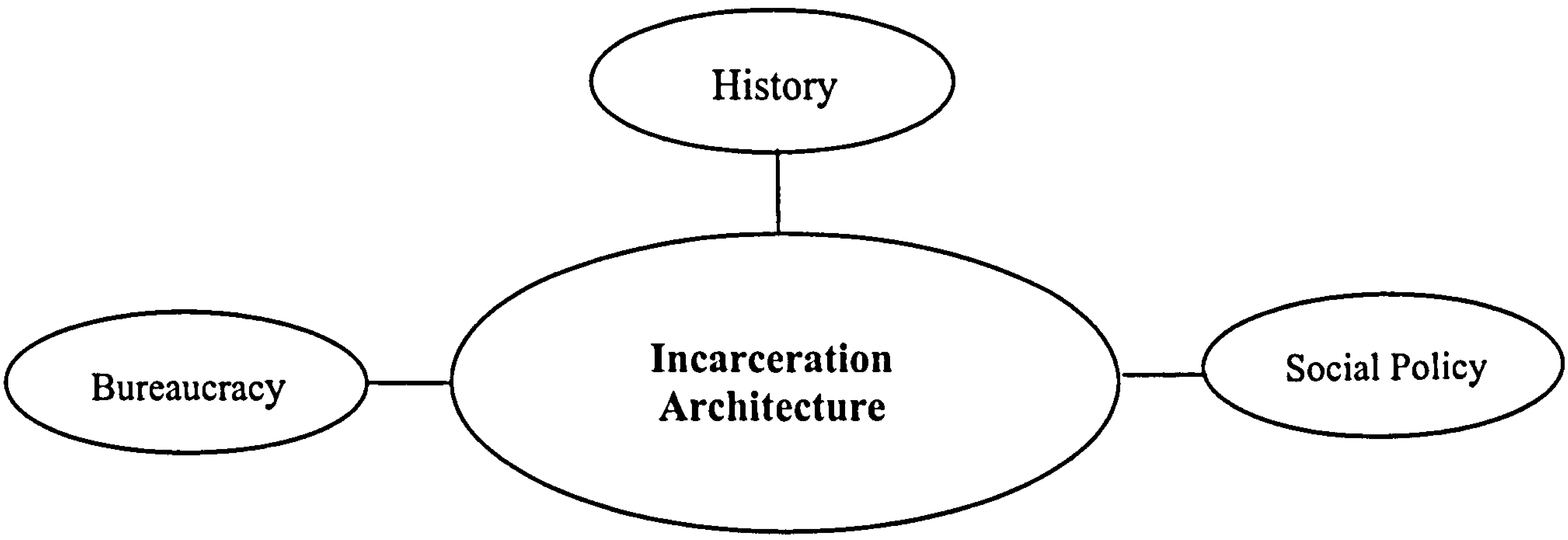

Figure 69: The external forces that influence prison design

The design of new correctional facilities is intimately bound to the institution's mission and goals. These goals can be divided into three main elements: the institutional **purpose,** its **responsibility** and **philosophical direction.** The success of the prison building design is a condition of its explicit adaptation to the goals of the facility. It is important to illustrate these different elements in detail:

1. **The purpose of the prison building**

In the contemporary world, prisons are built for two purposes. They are the confinement of offenders as a punishment, and the provision of humane treatment in order to rehabilitate the inmates. In several cases and for several reasons, however, prisons have been built for confinement and punishment only, with only minor consideration of the inmates' human needs. The latest and most famous example of this category is Guantanamo Bay prison (Cuba).

2. **The prison building's responsibilities**

The prison or correctional facility's responsibilities can be divided into three categories. These are **security, safety** and **service.** Each of these categories is divided into its own sub-categories. Prisons are divided according to their **security** measures into minimum, medium, maximum and super maximum. The prison is responsible for the **safety** of the public, the inmates' personal safety from suicide attempts, the inmates' personal safety from assaults, and staff safety. Prisons exist to provide **services** to the inmates, staff and visitors.

3. **Prison philosophical directions**

Prison philosophical directions are a combination of what have been labelled the five R's (Farbstein, 1986). These are: **Revenge, Reform, Rehabilitation, Reintegration** and **Restraint.** The prison's philosophical directions are the most influential element in the architecture of the buildings.

Punishment and deterrence are the only purposes of a facility that is designed to comply with the goal of **revenge.** Building prisons for **reform** means providing the inmates with vocational and educational skills. Inmates' **rehabilitation** can only be achieved by treating their social and psychological problems. Developing a cooperative relationship between inmates and society is the first step in their **reintegration** into the society. In a maximum security facility, **restraint** of dangerous inmates becomes a priority. This can be achieved by using tight control measures to maintain a calm environment.

The design of a prison building is directly related to its purpose, responsibilities and philosophical directions. A set of architectural variables that result from these elements can easily be identified.

7.2.1 Selection of architectural variables that affect façade design

The institution's mission and goals have direct impact on the architectural design of the facility. For example the security level of a prison building is reflected in:

1. The building location.
2. The building configuration.
3. The construction materials.

4. The façade design.
5. The façade materials.
6. The technology implemented.

The emphasis of this thesis is placed on the inmates housing unit and hence this section investigates the energy related architectural variables that affect façade design in this specific area.

Inmate housing units are generally composed of seven zones. These are: inmates' cells, staff accommodation area, multiuse or association area, vulnerable prisoner unit, segregation unit, special cells and safe cells (Table 9).

Table 9: The inmates housing unit architectural variables

Technical Variables	Indicators	Energy related architectural variables	Energy related façade variables
Inmates' Rooms	Cell variables Window availability Location Sanitary availability Users control Mechanical solutions Privacy	Glazing properties Envelope finishing Windows configuration Envelope elements Construction materials Shading devices Cell size Cell occupancy	Person per m^2 Person per room Fabric specification Wall mass Glazing specification Window dimensions Window location Façade height Inner grille specification
Vulnerable prisoner unit	Cell variables Window availability Room location Sanitary availability Privacy Users control Mechanical solutions Construction materials	Construction materials Glazing properties Envelope finishing Windows configuration Envelope elements Shading devices Cell size Cell occupancy	Person per m^2 Person per room Wall mass Window dimensions Window location Glazing specification Fabric specification Inner grille specification
Multiuse area	Room Location Room Size Ease of supervision Noise control Mechanical solutions	Glazing properties Envelope materials Windows configuration Envelope elements Shading devices Construction materials	Person per m^2 Fabric specification Wall mass Glazing specification Window dimensions Window location Façade height
Staff accommodation Offices Special room common room	Technology Sanitary availability Services Mechanical solutions Users control	Construction materials Glazing properties Envelope materials Windows configuration Shading devices	Fabric specification Wall mass Façade hight Window dimensions Glazing specification
Segregation Unit	Cell variables Window availability Room location Sanitary availability Construction materials Mechanical solutions	Construction materials Glazing properties Envelope materials Windows configuration Envelope elements	Person per m^2 Wall mass Window dimensions Glazing specification Window location Inner grille specification Fabric specification
Special Cells	Cell variables Window availability Room location Construction materials Mechanical solutions Sound proofing Sanitary unavailability	Construction materials Glazing properties Envelope materials Windows configuration Sound Insulation	Person per m^2 Wall mass Window dimensions Glazing specification Inner grille specification Fabric specification Window location
Safe Cells	Mechanical solutions Cell variables Window availability Room location Construction materials Emphasis on view Sanitary availability Ventilation Users control	Construction materials Glazing properties Envelope materials Windows configuration Ventilators Shading devices Cell size	Person per m^2 Wall mass Window dimensions Window location Glazing specification Fabric specification Inner grille specification Façade height

The **safe cells** are rooms designed to accommodate the inmates who demonstrate suicidal behaviour. The cell construction materials and design configuration are different from those of normal cells. Such cells need to be oriented to have good access to a view, and natural ventilation. The **special cells** are rooms designed to accommodate inmates with antisocial behaviour problems. The main characteristics of these cells are the unavailability of sanitary services, and the use of soundproof materials. The **segregation unit** has rooms used for disciplining inmates, for their causing serious problems to staff, other inmates, or for breaking the applied regime. This unit is sometimes located in a different building and provided with the minimum of comfort. Prisons generally have a unit to house vulnerable inmates. **Vulnerable inmates** are those who are in danger of being physically abused by other prisoners.

The **staff** offices and sometimes a small common room, are located within the inmates' housing unit. This helps the staff to have more direct contact with the inmates. The staff zone differs from the inmates' zone in the construction materials, the area per person, the window dimensions and the furniture.

The **multiuse** or association area is a key zone that has major impact on the success of the regime applied in the institution. The inmates spend most of their daytime in this zone. They talk, watch TV and socialise between themselves and with the staff in this area.

The inmates' rooms are the cells that accommodate the prisoners, for an average of 12 hours per day. The emphasis of this thesis is placed on the inmates' rooms and the multi use zone; hence the energy related architectural variables of these zones are investigated.

The institutional mission and goals are reflected in the architecture of the **inmates' cells**. This influence is evident in seven indicators: the cell variables, the window availability and configuration, the cell location, the sanitary availability, the inmates' control over their space, the provision of air-conditioning and the level of privacy that the inmates are entitled to. Several architectural variables can be derived from these indicators. Some of these variables have implications on the prison building's energy consumption. The third column in Table 9 shows these variables. These are the construction materials, the envelope finishing, the window configurations, the shading devices, the cells occupancy rate and the cells area.

A set of nine energy related technical façade variables can be identified from the previous elements. These variables are presented in column four, row two in Table 9. These variables can be divided into three categories: the cell variables, façade design, and façade materials. The person per m^2, person per room and façade height follows the cell variables. The window configurations and location, and the shading devices are all related to the façade design category. The fabric and the glazing specification are the identified variables in the material category.

7.3 Selection of prison buildings social variables

The mission and goals of the prison have direct impact on its social and humane aspects, which influence the architecture of the building. The prison's philosophical direction dictates the range of facilities that the prison is expected to provide to inmates, and the level of comfort which it is hoped the inmates are to receive. This section investigates the different social variables which are sensitive to the prison's objectives. These variables are then narrowed down to those which are related to the prison architecture. A list of elements that are related to the design of prison façades is consequently identified.

The social aspects of the prison building can be divided into two parts; environmental factors, and the social environment. The first is composed of six elements which are lighting, view, noise, thermal comfort, indoor air quality and sensory deprivation. The social environment of a prison building can be identified as four factors. These factors are: communication and social interaction, territoriality, privacy and feelings of control and the prison image. The following sections discuss these elements in detail.

7.3.1 Environmental factors in prison building and related architectural variables

The six environmental elements of the prison environment have considerable impact on the inmates' physical and physiological well being. This section illustrates in detail the impact of these elements on the inmates and the prison environment, and lists the related architectural variables for each one.

7.3.1.1 Lighting

The importance of providing adequate natural and artificial lighting for the inmates has been discussed in Chapter Four. Natural daylight is related to the inmates' visual comfort and psychological wellbeing. Adequate artificial lighting is measured by luminance balance, temporal uniformity and the avoidance of glare.

The existence of windows is the first indicator of the prison administrator's awareness of the importance of daylighting on the inmate's reform and rehabilitation efforts. The illuminance levels and the inmate's control of artificial light and daylight (for example by using blinds) are other indicators of the prison administrators' being aware of the importance of lighting.

Five architectural elements that are related to lighting have been identified. These are: planning, orientation, landscape, envelope configuration and the cells layout.

7.3.1.2 View

The provision of access to a view is gaining importance as a factor to influence inmate behaviour. Opening up the cells to access visual links provides inmates with the opportunity to feel attached to the outside world. From another point of view, opening up the prison building facilitates extending the outside to the inside. Prisons differ from each other according to their penal philosophy. The strength of the link between the indoor environment and the outside is controlled by the prison's goals.

Two indicators can be identified in relation to view; the existence and size of windows, and the inmate's control over the opening of their cells to the outside. The architectural variables that can influence the view are similar to those affecting lighting, i.e. planning, orientation, landscape, envelope configuration and cell layout. Another element which is influential in controlling the view is the type and construction of any fences.

7.3.1.3 Noise

Occupants' stress and discomfort are directly related to noise in an environment. In prison buildings where the inmates have no control over their environment, the negative impact of noise can be even more substantial. Noise in a prison may come from the enclosed spaces or from the surrounding area. Five indicators can be identified in relation to noise levels and sources. These are sound power, sound intensity, transmission of sound, inmates' control of noise sources and mechanical solutions.

Architectural elements like planning, orientation and landscape can be used to control the sources of external noise, while construction materials and space configurations aim to control noise in the indoor environment.

7.3.1.4 Thermal comfort

Thermal comfort has a major effect on an inmate's physical and psychological well-being. Thermal comfort mainly depends on, as shown in Chapter Two, air-temperature, humidity and air movement as well as activity, clothing, mean radiant temperature and psychological factors. In the prison environment two indicators confirm the prison administrators' concern with the inmates' thermal comfort. These indicators are the provision of mechanical solutions (AC) and the inmates' control of their thermal environment. Generally, passive architecture schemes can be utilised to achieve thermal comfort. However, it is difficult to apply passive cooling in the UAE prison environment. This is related to the specific function of prisons to provide a secure environment for the inmates. Opening windows can jeopardise the security of the institution. Another element that restricts using passive cooling devices in the UAE prison is the severity of the weather conditions in the region and the little variation in temperature throughout the day (Chapter Two).

7.3.1.5 Indoor air quality

Ensuring good indoor air quality is essential to an inmate's physical and psychological well-being. The indoor air quality is affected mainly by emissions from building materials, and odours. The source of odours can be internal or external. Mechanical solutions and inmate control of their space are two indicators that show that efforts are being made to enhance the indoor air-quality for the prisoners.

Good architectural planning can help to avoid any permanent odour or emission problems. Efficient ventilation can minimise indoor odours, and enhance the indoor air-quality. However for the reasons indicated in the thermal comfort section, natural ventilation is problematic, hence mechanical solutions are the only applicable technique to achieve desirable indoor air quality in the UAE prison.

7.3.1.6 Sensory deprivation

Sociologists and psychologists have emphasised the importance of minimising the impact of confinement on the inmate's sensory abilities. Sensory deprivation has a negative impact on physical and psychological well-being. Awareness of the consequences of such sensory deprivation can be identified by the following indicators: variations in space, activities, colour and texture. Allowing inmates to have control of different elements in their environment, and a certain level of privacy, are important variables to reduce the risks of sensory deprivation.

The layout of the different spaces and the planning of activities for inmates are vital architectural solutions to the problem of sensory deprivation in places of confinement.

7.3.2 The social environment of the prison building and related architectural variables

This section reviews in detail the four special characteristics of the prison building's social environment, which are: communication and social interaction, territoriality, privacy and feelings of control, and the prison image.

7.3.2.1 Communication and social interaction

The first step in providing a positive environment in a prison building in order to help reform and rehabilitate inmates, is to encourage positive social interaction between staff and inmates, staff with staff, inmates and inmates; and to discourage, at the same time, negative social interaction between the same categories. Such a positive environment would support the correctional efforts and assist security measures.

The indicators of social interaction between different categories can be traced in the nature of security, surveillance measures, the forms of contact and the users' control of their environment.

In architectural terms this can be traced in the planning of the facility, the space configuration, the room layout and the circulation routes.

7.3.2.2 Territoriality

Individuals and groups needs to feel in control of their personal territory. Sensitivity and understanding of this need can have a positive impact on correctional efforts. It would also help in clarifying and controlling the contact between different groups. Permitting individuals and groups to control their own territory is beneficial in reducing tension and stress among inmates, and hence enhances their psychological well-being.

The sizes of different zones and the inmates' control over their environment are indicators of sensitivity to the need for territoriality. In design terms this can be interpreted in the space configuration and layout of the different zones, the cell sizes and the number of housing units throughout the prison which would lead to a number of association areas where inmates spend long hours.

7.3.2.3 Privacy and feelings of control

Recent research related to the prison environment has emphasised the provision of a sense of privacy and control among inmates, in order to enhance their psychological well-being and reduce tension.

The social density, spatial density, inmates' control of their environment and surveillance measures are all indicative of the perceived privacy and feeling of control allowance to the prisoners.

Architectural elements such as planning, cell layout and cell variables are influential in achieving the balance between the inmates' need for privacy and control, and the security and safety measures of the institution.

7.3.2.4 The prison image

The prison image has to reflect the institution's purpose and philosophical direction. It needs to create expectations of the internal environment, to send messages to the public and reflect the style of treatment within.

The prison's image is dependant on prison architecture to spread its intended message. The prison facilities, size and shape, its façade colours and configuration and the symbols attached are all indicators of the prison image.

The architectural elements which are influential in providing the prison with the desired image are the site selection, façade design, construction materials, envelope configurations and the fence construction and type.

7.3.3 Selection of social variables that affect façade design

The previous sections provided a general illustration of the social variables that influence the architecture of prison buildings. In this section these variables are narrowed down to those which affect the façade design.

The previous discussion showed that prison building façade design is affected by eight social variables. These are: lighting, view, noise, thermal comfort, indoor air quality, sensory deprivation, privacy and feeling of control, and the prison's image.

Provision of adequate **lighting** is sensitive to window configuration and glazing properties. **View** is related to orientation, window configuration and shading devices.

Control of external **noise** is directly related to envelope materials, window configuration and sound insulation. **Thermal comfort** in UAE prison buildings can be achieved only by some mechanical means i.e. air conditioning. However, façade configurations and cell variables can influence the building's thermal performance. **Indoor air quality** is influenced by the envelope materials and its insulation. The configuration and the location of windows as well as the cell variables are directly related to the feelings of **sensory deprivation, privacy** and **feeling of control**. The **prison image** dictates the design of façades in many ways. It influences the façade configuration and elements, and the window configuration.

Following the identification of the façade related social variables, it is important to identify the energy impact of the selected variables, which represents the cost to society in this hypothesis.

7.3.4 Energy impacts of the selected variables

The selected variables which are related to façade design have impact on the prison building energy consumption, either directly or indirectly. Increased daylighting levels and access to view can only be achieved by increasing window area. In the UAE's severe climatic conditions, introduction of large windows will increase the solar gain and consequently increase the building cooling load. There are several technical variables that are essential to control external noise in the prison building. These are: wall mass, the façade height, the window area and both the fabric and glazing specifications. All these variables have influence on the prison building's energy consumption. Thermal comfort in a region such as the UAE can only be achieved by air conditioning, which as proven in the pilot study, section 7.5, would increase not only energy consumption in the prison building, but the whole of Abu Dhabi.

Selection of the envelope materials, and the appropriate insulation achieve suitable indoor air quality would also influence the thermal performance of the prison building.

As in the case of lighting and view, minimising sensory deprivation is related to the increase in cell and window size, and both variables are directly related to the energy performance of the prison building. The same discussion can be applied to privacy and feeling of control, which are directly related to cell and window area. The façade height and configuration, the window size and location, and the shading devices are all technical variables that communicate the prison's image to public, inmates and staff. These variables have direct influence on the energy performance of the building. Table 10 shows the prison social variables and their impact on the building and façade design.

These social variables, along with the architectural variables which were identified in the previous section are aimed to provide the boundaries for developing different scenarios for the Abu Dhabi prison building. Chapter Six showed that the only feasible method to investigate such scenarios is the energy simulation technique. It is therefore essential before illustrating and examining the developed scenarios, to review the different simulation software which is available. This is carried out in the next section.

Table 10: The prison social variables and its relation to the prison building and facade design

Social Variables	Impact	Indicators	Architectural Elements	Façade Elements	Technical Variables
Environmental Factors					
Lighting Provision of adequate natural lighting Provision of adequate artificial lighting	Visual comfort Psychological well-being Luminance balance Temporal uniformity Avoidance of glare	Windows Existence Illuminance Inmate control	Planning Orientation Landscape Envelope configuration Cell layout	Glazing properties window configuration Cell size Shading devices	Window height Window width Transmittance Shading devices Cell size
View Access to views	The extent of links to the outside The extent of links to the inside	Windows Existence Inmate control	Planning Orientation Landscape Envelope configuration Type and construction of fences	Window configuration Shading devices	window height window width Shading devices
Noise Minimise the noise	Noise in free field Noise in enclosed spaces	Sound power Sound intensity Transmission Inmate control Mechanical solutions	Planning Orientation Landscape Space configurations Construction materials	Envelope materials Window configuration Sound insulation	Wall area Wall mass Window height Window height Fabric specification Glazing specification Shading Devises
Thermal comfort Minimise thermal discomfort	Psychological well-being Physiological well-being	Air temperature Humidity Air movement Inmate control Mechanical solutions	Construction Materials Windows configuration Ventilation Room layout	Shading devices Façade configuration Glazing properties Windows configuration	Envelope material Window height Window width Transmittance Shading devices
Indoor air quality Ensure good indoor air-quality	Psychological well-being Physiological well-being	emissions of building materials Inmate control Mechanical solutions	Ventilation Planning	Envelope configuration Windows configuration Construction materials	Envelope material Insulation procedures
Sensory Deprivation Minimise the effects of confinement on sensory abilities	Psychological well-being Physiological well-being	Inmate control Variation in space Variation in texture and colour Privacy	Planning Room layout	Blinds Windows configuration	Opening location
Social Environment					
Communication and Social interaction Encourage positive social interaction between: Staff: Inmates, Staff: Staff, Inmates: Inmates Discourage negative social interaction between: Staff: Inmates, Staff: Staff, Inmates: Inmates	Support correctional efforts Assist security efforts	Security forms Surveillance measures Forms of contact Inmates control	Planning Space configuration Rooms layout Circulation routes	NA	NA
Territoriality Identify individual and group needs for personal territory	Clarify & control contact between groups Reduce tension Psychological well-being	Zone size Inmate control	Space configuration Cells layout Dayrooms layout	NA	NA
Privacy and feelings of control Emphasis on provision of sense of privacy and control	Psychological well-being Reduce tension	Social density Spatial density Inmate control Surveillance measures	Space configuration Planning Cells layout Cells variables	Window configuration Façade configuration	Window size Person per m^2 Person per cell
Prison Image Reflects the institute's purposes	Sets up expectations for internal environment Sends messages to the public Reflects the treatment style	Facility size Facility shape Façade colour Façade configuration Symbols	Site selection Façade design Construction materials Envelope configuration Fences construction & type	Façade elements Façade configuration Window configuration	Façade height Façade material Opening location Shading devices Window height Window width

7.4 Basic concepts and principles of building energy simulation

Approximately one third of the world's primary energy supply is consumed in buildings. Consequently, buildings are a primary contributor to global warming and ozone depletion. Since the 1970s, achieving better energy efficiency in buildings has become one of the world's major challenges. It is estimated that substantial energy savings can be achieved from a conventionally designed building through careful planning for energy efficiency. As heating, ventilating and air conditioning (HVAC) and lighting account for the major part of a building's energy use, it is vital that the performance of essential building services and systems be well understood and optimised in order that energy conservation can be achieved.

The energy requirements of a building depend not only on the individual performance of the envelope components (walls, windows and roofs) and HVAC and lighting systems, but also on their overall performance as an integrated system within the unique building. For a prison building, the complex and dynamic interactions the building has with its environment and its systems and plants need to be modelled and simulated for analysis. The technique available to architects, engineers and building managers concerned with energy conservation is computer-based building simulation.

The importance of computer-based modelling and simulation is increasing, especially for its role in the prediction of future energy and environmental performance of buildings and the systems that service them. Modelling and simulation can and indeed should, play an essential role in building and systems design, commissioning, operation and management. The building simulation programs running on personal computers allow architects and engineers to test out new designs before proceeding to construction and installation. Furthermore, through parametric analyses, professionals can extend their design concepts to incorporate new technologies and innovations thus creating opportunities for increased energy savings.

7.4.1 Properties of simulation design tools

The theory of building energy simulation is based on the traditional methods of load and energy calculations in heating, ventilating and air-conditioning (HVAC) design (ASHRAE, 1997). The load calculation is used to determine the peak design thermal loads of the HVAC systems, in order to size and design the equipment and plant. The energy calculation is used to estimate the energy requirements of the building to meet the required loads throughout the year. Building energy simulation is performed to analyse the energy performance of a building dynamically and to understand the relationship between the design parameters and energy use characteristics of the building. The effects of all kinds of changes can be simulated and observed in a fraction of time, and for a fraction of the cost it would take to study these alternatives in real life. Detailed information about building energy consumption, indoor environmental conditions and equipment and plant performance can be obtained for design evaluation and system selection. Consequently it can be argued that building energy simulation holds the key to improving building energy efficiency.

The first tasks of building energy simulation are to set the building design parameters and to identify the local climatic context of the building. Figure 70 presents a diagram of the major elements of building energy simulation (Clarke and Irving, 1988).

The inputs to the simulation system include the building description and design parameters, and the boundary conditions of the climatic context of the location. The outputs are the data of building energy consumption, peak demand and indoor environmental conditions. Usually, the modelling target is to provide comfortable indoor conditions while maintaining acceptable levels of fuel consumption; to optimise the system performance; or to compare different design options based on their life cycle costs. An additional module is required for the economic analysis.

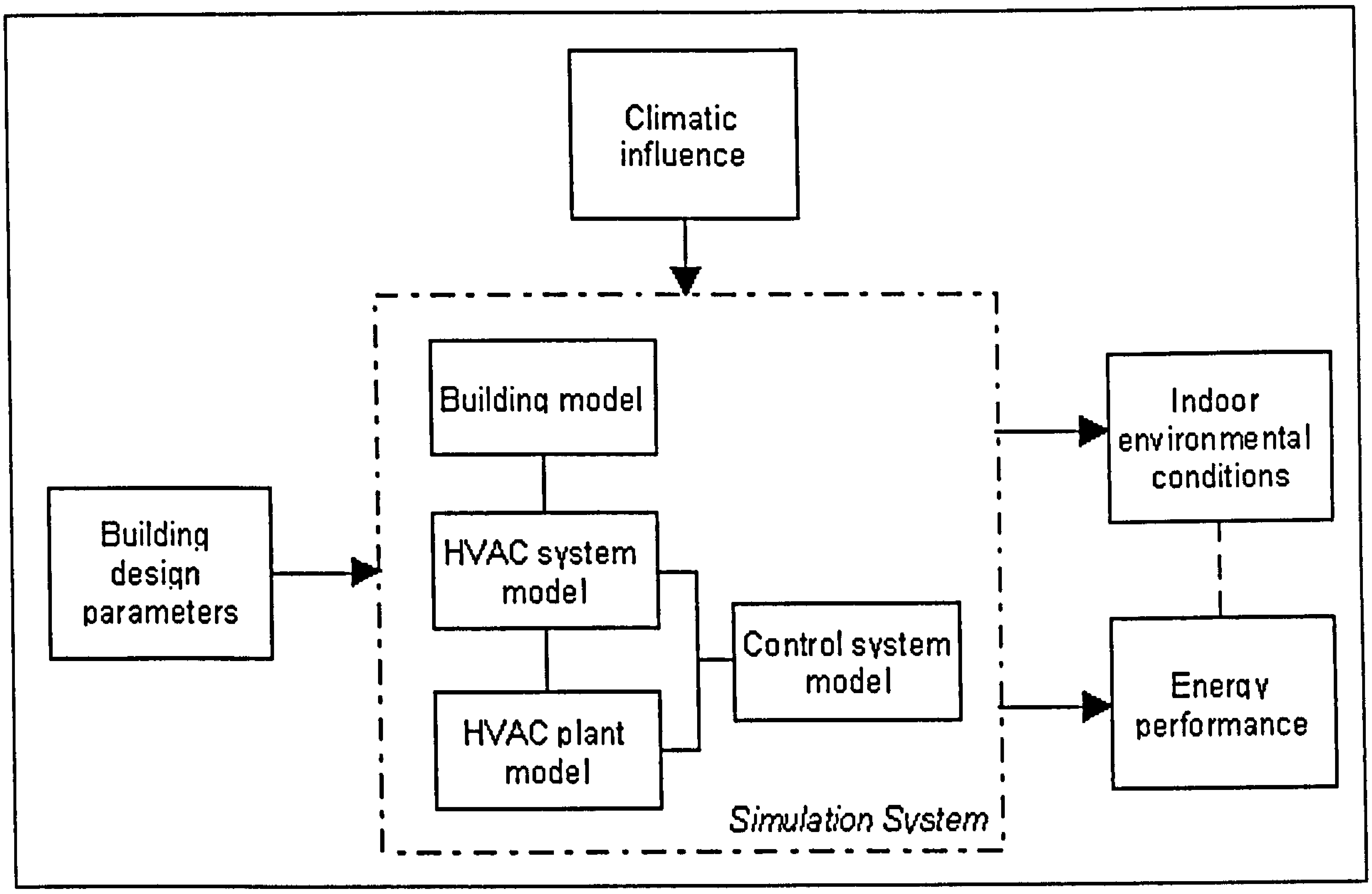

Figure 70: The major elements of building energy performance (Clarke and Irving, 1988)

To implement the simulation system on computer programs, different modelling approaches and solution techniques can be used (Crawley *et al.*, 2001; Donn, 2001; Zeisel, 1984). Within the same general approach to energy simulation, techniques and levels of detail may vary in different programs. The accuracy and properties of the simulation tool depends on the methods by which energy modelling is expressed and carried out.

7.4.1.1 The history of building simulation

Building simulation began in the 1960 s, and became the hot topic of the 1970 s within the energy research community. During these two decades, most research activities were devoted to studies of fundamental theory and algorithms of load and energy estimation. The studies resulted in many refinements of the transfer function technique, such as the studies carried out by Mitalas and Stephenson (Mitalas and Stephenson, 1967). Simplified methods such as the degree-day method, equivalent full load hour method, and the bin method to predict the energy consumption of buildings were also developed (ASHRAE, 1997). During this period, building simulation was regarded as the key to turning energy guzzling buildings into energy-efficient thermally conducive built environments (Hong *et al.*, 2000).

By the late 70s and early 80s building simulation began to receive renewed interest, brought about largely by advancements in desktop personal computing. During that same period, the US Department of Energy allocated major funds to research and development of projects on energy conservation and renewable energy. The result of this sponsorship was a series of popular detailed building and energy systems simulation programs such as DOE-2, ESP and TRNSYS. However, despite the availability of building simulation programs, they remained mostly in research laboratories, being rarely employed in building design practice because of the level of difficulty and high cost involved in their use (Hong *et al.*, 2000).

The situation has since changed. The beginning of the 1990s saw the growing global concern for protecting the environment. In the building sector, the challenge to professionals is to create a healthy and comfortable built environment with more efficient energy consumption and reduced negative impact on the environment. The demand for 'green' buildings has made the application of building simulation a must, rather than an option. Hence, building simulation programs have gained acceptance as routine analysis and design tools.

7.4.1.2 The range of application of building simulation

The use of building simulation has been broadened considerably. Building simulation can be applied throughout the life cycle analysis of a building, including design, construction, operation, maintenance and management. There are several popular applications, for example: building heating/cooling load calculation, energy performance analysis for design and retrofitting, building energy management and control system (EMCS) design, compliance with building regulations, codes, and standards, cost analysis, studying passive energy saving options and computational fluid dynamics (CFD).

Three types of application most commonly found in architectural design are:

1. **Building energy simulation** (whole building), which is the largest and most important application. Full hourly analysis (like BLAST, DOE-2 and ESP-r) or reduced hourly analysis (like Carrier HAP and TRACE 600) can be performed.

2. **Lighting and daylighting simulation,** which focuses on the analysis of the daylighting aspects and their effects on energy and visual performance. ADELINE, RADIANCE and SUPERLITE are examples of such software.

3. **Solar system simulation** where the passive and active solar systems can be modelled using programs designed for solar components and equipment, such as TRNSYS.

Apart from energy analysis, many simulation programs also allow for standard design load calculations to determine the design capacities of equipment and plant. Although numerous building simulation programs are being used in building design and simulation, relatively few are in the public domain and accessible worldwide. Figure 71 lists some programs that are registered in IEA-ECBCS[10] Annex 1, 4, 12 and 21 (collected by Hong *et al.*, 2000).

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[10] The International Energy Agency (IEA)- Energy Conservation in Buildings and Community Systems Programme (ECBCS).

Program	Organizations
Annex 1	
ATKOOL	W S Atkins Group, UK
OFFICE	Electricity Council Research Centre, UK
THERM	British Gas Corporation, UK
HTB	UMIST, UK
ENPRO	Faber Computer Operations, UK
ESP	University of Strathclyde, UK
ANTS	Pilkington Flat Glass Ltd., UK
SCOUT	Gard Inc., USA
DOE-2	Lawrence Berkeley Laboratory, USA
ECUBE3	American Gas Association, USA
MS	Reid Crowther and Partners, USA
JULOTTA	Swedish Council for Building Research
VENTAC	AB Svenska Flaktfabriken, Sweden
WTEO1	TNO, Holland
LPB1	University of Liège, Belgium
Annex 4	
AMBER	Faber Computer Operations, UK
ATKOOL	W S Atkins Group, UK
DOE-2	EMPA, Switzerland
ENCO2	Pilkington Flat Glass Ltd., UK
ESP	University of Strathclyde, UK
LPB1	University of Liège, Belgium
TEMPER	CSIRO, Australia
THERM	British Gas Corporation, UK
WTEO1	TNO, Holland
Annex 21B benchmark tests	
BREADMIT	Building Research Establishment, UK
BLAST	ROM, Germany
ESP	Building Research Establishment, UK
ENERGY2	Ove Arup, UK
PR (BTP)	Tsinghua University, P.R. China
SERI-RES	Newcastle University, UK
TAS	Leicester Polytechnic, UK
TRNSYS	Brussels University, Belgium
VA114	TNO-Bouw, The Netherlands
Annex 21C/12B empirical validation benchmark	
SERI-RES	Building Research Establishment, UK
BTP	Tsinghua University, P.R. China
DOE-2	Lawrence Berkeley Laboratory, USA
TRNSYS	University of Wisconsin, USA
S3PAS	Escuela Superiore Ingenieros Industriales, Spain
TASE	Tampere University of Technology, Finland
BLAST	Colorado State University, USA
DEROB	Lund Institute of Technology, Sweden
ENERGY2	Arup R&D, UK
SUNCODE	Ecotope, USA
CLIM2000	Electricité de France
HTB2	University of Wales, UK
APACHE	Facet Ltd., UK
ESP	University of Strathclyde, UK
TAS*	De Montfort University, UK
BUNYIP	Swinburne Institute, Australia
WG6TC	Institute di Fisica Technica, Udine, Italy

Figure 71: IEA-ECBCS Annex 1, 4, and 21 participant programs

7.4.1.3 Limitations of building simulation programs

Using simulation models for building design has its limitations, mainly because existing models fail to tackle the issue of data preparation in the face of uncertainty in the design environment. Hui (1998) stated some of the major shortcomings of current simulation tools:

- The program input is voluminous and scientifically detailed. Data, which are usually unavailable during early design stages, have to be assumed when doing the analysis.
- In many cases understanding and interpretation of the simulation results is difficult, as the program output consists of bulky computer printouts that confuse the user.
- Many detailed design tools are research orientated. Learning to use them is difficult and a long time is required to become competent.
- Most the common building simulation programs neglect the user interface of the tools. Architects who are trained to express themselves graphically become frustrated by the strict data structure and requirements.
- The software is usually protected, and does not allow users the flexibility to do any programming easily to meet particular needs.
- Program validation and accreditation are lacking. Users are usually confused and uncertain about which programs will give better simulation results.

7.4.2 Building design and simulation in a multidisciplinary environment

7.4.2.1 The software selection

The historical review of the development of prison buildings (Chapter 4) showed how prisons offered a difficult design problem. The simulation of such a complex building typology also rendered a challenging task. The comparison between different building simulation programs is difficult as each program has its advantages and disadvantages (Hong *et al.*, 2000). The case is even more difficult, in finding software to simulate prison buildings. Prisons present an interesting multidisciplinary environment simulation problem. Most available software does not offer multi-zone models. In the prison environment, where there are variations in zone temperatures, occupancy patterns and rates throughout the day, the need for a multi zone modelling system is essential. Integrated building design modelling is thus essential to simulate the energy performance of prison buildings.

The aim of integrative modelling, as Clarke (2001) described it, is to "preserve the integrity of the entire building/plant system by simultaneously processing all energy transport paths at a level of detail commensurate with objectives of the problem in hand, and the uncertainties inherent in the describing data" (Clarke, 2001: 7). Following Clarke's description, prison buildings should be regarded as being **systemic** with different zones making the whole, **dynamic** as zones function at different rates, with all its parameters depending on the **thermodynamic state** (non-linear) and most importantly **complex,** as there are myriad intra-and inter-part interactions. A thorough review of the existing software was carried out to identify a simulation program that would preserve these intrinsic characteristics of the prison building. The final choice was APACHE, or what is referred to now as Integrated Environmental Solutions (IES) Virtual Environment (VE).

The developers of the software claim this is the world's first and only commercially available integrated building analysis software system. It is an integrated suite of applications linked by a Common User Interface (CUI) and a single Integrated Data Model (IDM). This means that all the applications have a consistent "look and feel", and that data input for one application can be used by the others.

The advantage of IES in being fully integrated and interactive is not the only feature that distinguishes the software from most common simulation programs. The graphical user interface which streamlines the data and knowledge transfer also facilitate the use of the software.

The capability of building simulation programs to link with computer-aided design and drafting (CADD) tools is considered an essential factor in evaluating simulation programs in this study. Fully worked DXF files may be attached to "**ModelIT**", which is the application used in VE for input of 3D geometry used to describe the model, and using the tools provided, three-dimensional building spaces may be generated rapidly by tracing over the DXF outlines. Moreover, in the case of the optional **Construct/DXF** module a complete model including doors and windows may be generated from a DXF file, entirely automatically. VE applications have the ability to export results to text files and databases that can be processed by spreadsheet or graphical computer software (such as MS Excel).

Another important feature in IES VE is its database support. **APcdb** is the construction database manager in the Apache applications. It provides access to two system databases: the System Opaque and Glazed materials, and the System Opaque and Glazed constructions. These facilities were used extensively in this thesis in developing the different scenarios, as well as for the proposed design.

In addition to the previous advantages, the IES software developer and customer services have been supportive with training and updating to the software. Abu Dhabi has specific climatic data that could not be obtained through any commercial software. Customer service support was therefore an essential element in the choice of software for this thesis, as climatic data had to be compiled. As the simulation was carried out for academic purposes, the software was provided for a small fraction of its original price. The decision was taken to use IES virtual environment to simulate the base case and the developed scenarios. The following section illustrates briefly the procedure that was followed to simulate the energy performance of Abu Dhabi prison building.

7.4.2.2 Using IES to simulate the Abu Dhabi prison building

Setting the location and climatic context of a building is the first step in modelling a scenario. **APlocate** is the weather and site location editor in the IES suite. Hourly weather data (for the air temperature, relative humidity, direct and diffuse solar radiation, and wind speed and direction) for a typical year in Abu Dhabi were created and fed into the APlocate database.

The prison building is composed of different zones which vary in their construction materials, occupancy patterns, cooling profiles, etc. **APpro** (The Apache Profiles Database) is the profiles database manager for the Apache applications APcalc and APsim. It provides access to two system databases:

- Profile primitives - represent a 24 hour period and are referred to as Daily Profiles.
- Profile groups - may be weekly or monthly, and are compiled using profile primitives.

Various daily, weekly and monthly profiles were created for the different zones. The profiles covered the occupation patterns, cooling, lighting and comfort levels. The model was then created using "**ModelIT**", and its construction materials were assigned using the Apache Constructions Database **(APcdb)** which is used to create and edit the construction types assigned to the building elements.

The thermal analysis of the model is the last and most important step. Two types of thermal analysis may be carried out in the Apache view: CIBSE heat loss and heat gain **(APcalc)**, and Apache simulation **(APsim)**. The first (APcalc) carries out heat loss and heat gain calculations in accordance with procedures laid down by CIBSE. Results from APcalc are then viewed in the program **APreview**.

Apache simulation **(APsim)** performs simulations of building thermal performance based on dynamic thermal analysis. Results from APsim are viewed in the programs **Vista, OutView** and **PlotView**.

It was decided that it would be useful to test and validate the software in a pilot study, before carrying out the final analysis for the thesis. The following section presents the pilot study and its results and analysis. The pilot study is based on the proposed UAE prison. The mission and goals of and the UAE prison prototype is also examined in the same section.

7.5 Energy impacts of the selected variables: the pilot study

The institute mission and goals statement that was developed by the UAE Ministry of Interior for Abu Dhabi Central prison, clearly addressed the previous three elements. The UAE proposed prison objectives and goals were presented in Chapter Two. However, it is essential to re-state some of them in this section:

- The design of a humane environment whilst attaining the required level of security.
- The incorporation of the latest thinking and methods into a flexible layout.
- Creating planning parameters that will comfortably adapt to change.
- Planning for adequate security and control with low maintenance.
- Achieving a long-term built environment sympathetic to the changing needs and demands of the client/users.

It is clear that although keeping inmates in custody is a purpose of the institution, it is not the main one. Correctional treatment with the aim of rehabilitation is emphasised as the main aim of the institution.

The following section identifies the main technical variables, and investigates in detail their relative importance on thermal performance of façades in the UAE environment. The prototype of prison buildings in the UAE is taken as a case study for the following pilot exercises. The pilot exercise will help to set the boundaries for the developed scenarios in Chapter 8.

7.5.1 The case study

The feasibility study that was made for the project of the Central Prison indicates that the building was designed for 1200 inmates. The design is meant to be a prototype that will be replicated in different Emirates. Heating at night, as well as cooling load during the day are considered and calculated in the new proposal.

The cooling loads for the proposed central prison are assumed to be 4 MW with 2 MW for heating load. This will add up to a total of 230 KWH/m^2. The estimated prison population for the Emirates of Abu Dhabi is approximately 5000 prisoners. The international standard for average floor area per inmate is 38 m^2 (Chapter 2). According to the proposed design, the total energy required to provide air-conditioning to all prisoners in the Emirate of Abu Dhabi should therefore be 43.7 GWH. This is, approximately, 0.6% of the total energy consumption in the Emirate of Abu Dhabi. The building envelope in the prison building is responsible for 21% of such energy consumption, i.e. this could be as much as 0.192% of the total electric consumption in Abu Dhabi (Figure 72) (Al-Hosany and Elkadi, 2000).

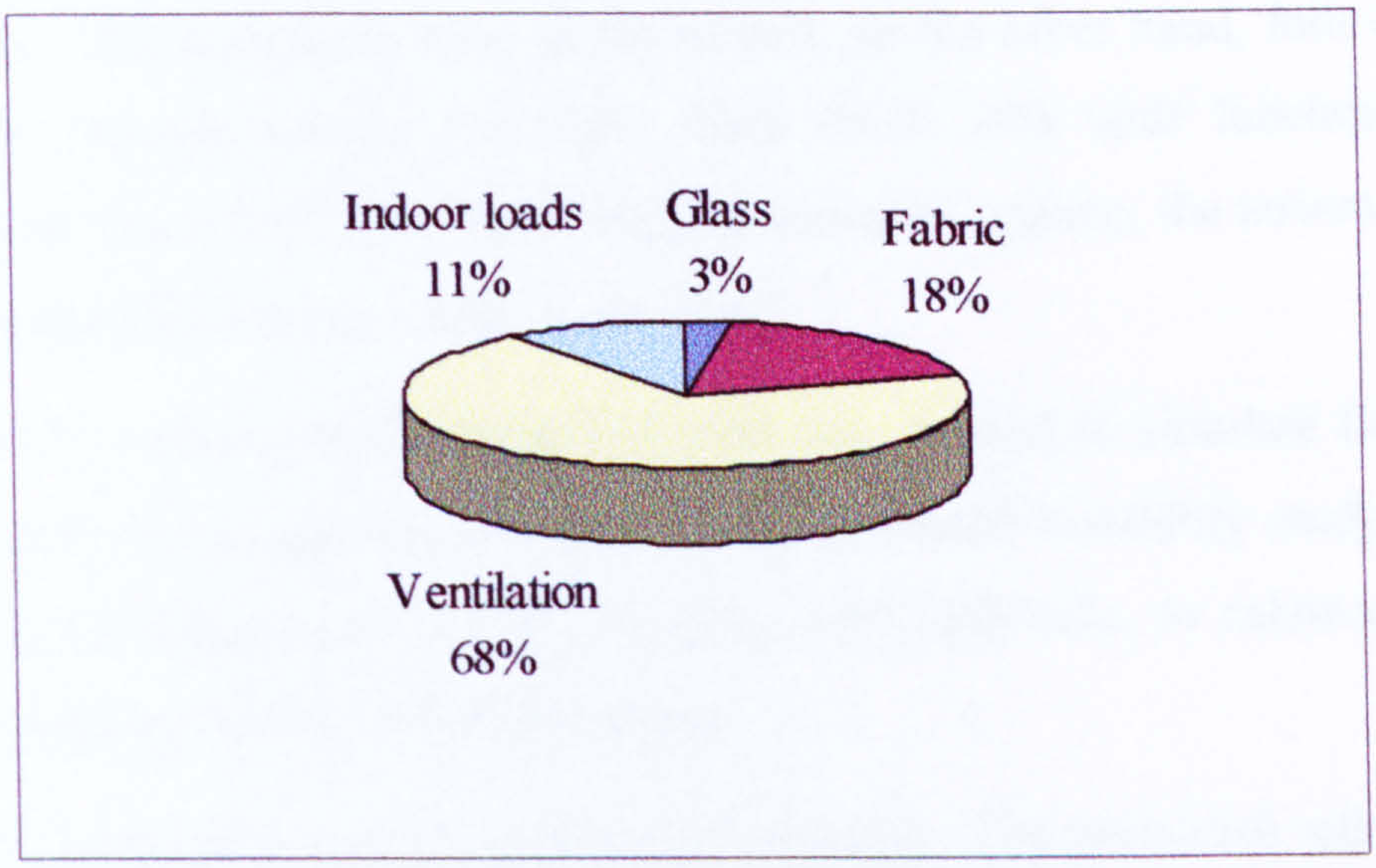


Figure 72: Skin role in electricity consumption in prison buildings

7.5.2 Methodology

The thermal properties of this prototype are examined in the pilot exercise using APACHE, simulation-modelling software. The proposed prototype was built using the model builder "Model-IT". A weather file for Abu Dhabi was generated using "APlocate", the weather and site location editor of the APACHE suite. Detailed hourly weather data for the air temperature, relative humidity, direct and diffuse solar radiation and wind speed and direction, were all fed into the software. The climate in Abu Dhabi is hot and dry for most of the year. As illustrated in Chapter two January represents the coldest month and the highest temperatures are recorded in August. January, February, and March in respect to the mean temperature value are classified within the human comfort range, and where the indoor thermal comfort can be achieved with natural ventilation.

As occupancy profiles are one of the main characteristics that distinguish prison buildings, primitive (daily) and group (weekly and monthly) profiles were composed using the APACHE Profiles Database (APpro). The profiles were used to distinguish the different zones and activities in the prison building. They reflect the daily and weekly routine of the prison inhabitants, as well as the occupancy and operating patterns in the different zones. For example, the profile reflects the continuous operation of air-conditioning in the "cooling zones". The occupancy rate varies, following the inmates' daily routine. In the cellblock, the occupation rate is 100% between 08:00 PM and 06:00 AM when the inmates start their activities. The inmates go back to the cells after lunch and remain there until 04:00 PM. In summery, the cells are fully occupied for almost 12 hours per day. The occupancy time of the atrium, on the other hand, follows a different pattern. The inmates occupy the place from 08:00 AM until lunchtime, and start gathering again from 04:00 PM. Following the inmates' regime, the atrium is planned to be 100% occupied for almost 7 hours every day.

The APACHE Construction Database (APcdb) was utilised to simulate the opaque and glazed materials and constructions based on the proposed feasibility study. A dynamic analysis of the building was carried out using APACHE-calc, to calculate the cooling loads of the building and the individual rooms.

Conducting a parametric analysis was the second step. The base-case reference building envelope input parameters were then varied over selected variables. The aim of this parametric analysis was to assess the influence of each input parameter upon the building's total and peak cooling loads, with the intention of investigating how different parts of the prison reacted to changes in different variables. The input parameters for the computer simulation were categorised into three main clusters: the wall U value, the window Ug and the window solar heat gain factor (SHGF). Three different values were suggested for each category (Table 11). A total of 18 scenarios were simulated.

Table 11:The selected thermal parameters

Uo (W/m² °C)	Ug (W/m² °C)	SHGF
0.22	1.898	0.0345
		0.052
1.477	2.801	0.052
		0.255
2.151	5.65	0.3755
		0.405

Five rooms in the prison building were selected to examine the sensitivity of different architectural configurations to the cooling load (i.e. volume, orientation and occupancy patterns). All the cells were located in the north west, south west and east facades. Elkadi *et al.* (1999) showed that, in Abu Dhabi, the north elevations contribution to total solar thermal load is limited to 15.5 % of the façades thermal load in buildings, while the east and west façades contribute as much as 31.2 % each (Elkadi *et al.*, 1999). It was decided, therefore, to examine the performance of cells situated on the east and north-west façades where effects of façade design would be of significance for energy savings.

The rooms simulated were:

- Two cells (A = $10m^2$) for one inmate: one situated on the eastern façade and the other on the north-west.
- Two cells (A= 20 m^2) which are used for four inmates' occupation. Again in order to investigate the orientation impacts on the cooling load of the building they were chosen from different façades (east and north-west).
- The atrium was the fifth room to be simulated.

Results of the ninety runs of all scenarios were analysed.

The investigation identified three variables that reflect the special characteristics of prison buildings: the **occupancy rate**; the **limited glass area**; and the **large differences in volumes in different parts of the prison.** Sensitivity tests were conducted to examine the impacts of these variables on energy efficiency in prisons.

7.5.3 Analysis

As previously indicated, combinations of eighteen scenarios were developed from various values for the thermal properties of the building envelope (Table 11). The analysis of the ninety runs showed that the total peak-cooling load was most sensitive to the change in the U value. Although it has been proven that solar heat through fenestration plays a major role in determining the thermal performance of a building in a hot arid region (Li and Lam, 2000), the limited glass area in the prison building minimises the influence of these variables. Consequently the major element in the envelope thermal parameters in the prototype prison building is the U value for walls and roofs.

By studying the total hourly cooling load on the peak day in the eighteen scenarios and the per square metre load in the ninety simulated rooms, the scenarios were narrowed down to three. The rooms were compared and analysed for the selected scenarios.

Different materials were assigned to the different scenarios. A super insulated external wall was selected for Scenario 1, and 10 mm single panes with 50 mm cavity glazing were assigned for the windows. In Scenario 2, the walls were assumed to be brick cavity with dense plaster, and the window glazing was Pilkington rw 36 double-glazing (10 mm + 4 mm). Finally, Scenario 3 was composed of brickwork, single-leaf construction with dense plaster walls and 6 mm Pilkington single-glazing. Table 12 gives a description of the thermal properties of the three scenarios.

Table 12: Thermal properties of the façades the chosen scenarios

Scenario	Uo	Ug	SHGF
Scenario 1	0.22	1.898	0.052
Scenario 2	1.477	2.801	0.255
Scenario 3	2.151	5.65	0.3755

Figure 73 shows the hourly cooling load per square metre in the three scenarios. These plots indicate that Scenario 1 achieved the minimum-cooling load, while Scenario 3 scored the highest load. The difference is however not significant. The best scenario (Scenario 1) reduced the total load on the peak day by 9%. However, this can be explained by the fact that the most dominant load in the prison building is the ventilation load (ranging from 68% to 74%), while the total fabric load ranges between 13% and 18% of the total peak load (Figure 72).

The analysis of the hourly cooling load per square metre of the chosen rooms in the different scenarios highlighted the importance of two design parameters: building volume and orientation.

Figure 74-Figure 76 illustrate the cooling load per square metre in the different rooms in the three studied scenarios. The inmates' daily routine is reflected in the charts. The mechanical ventilation operating patterns follows the occupancy patterns of the different zones. The impact of orientation is very noticeable. Figure 74-Figure 76 show that between 7 AM and 12 AM, there is a major increase of thermal load in the eastern facades. Appropriate design of shading devices in the eastern façades could, therefore, result in substantial energy savings.

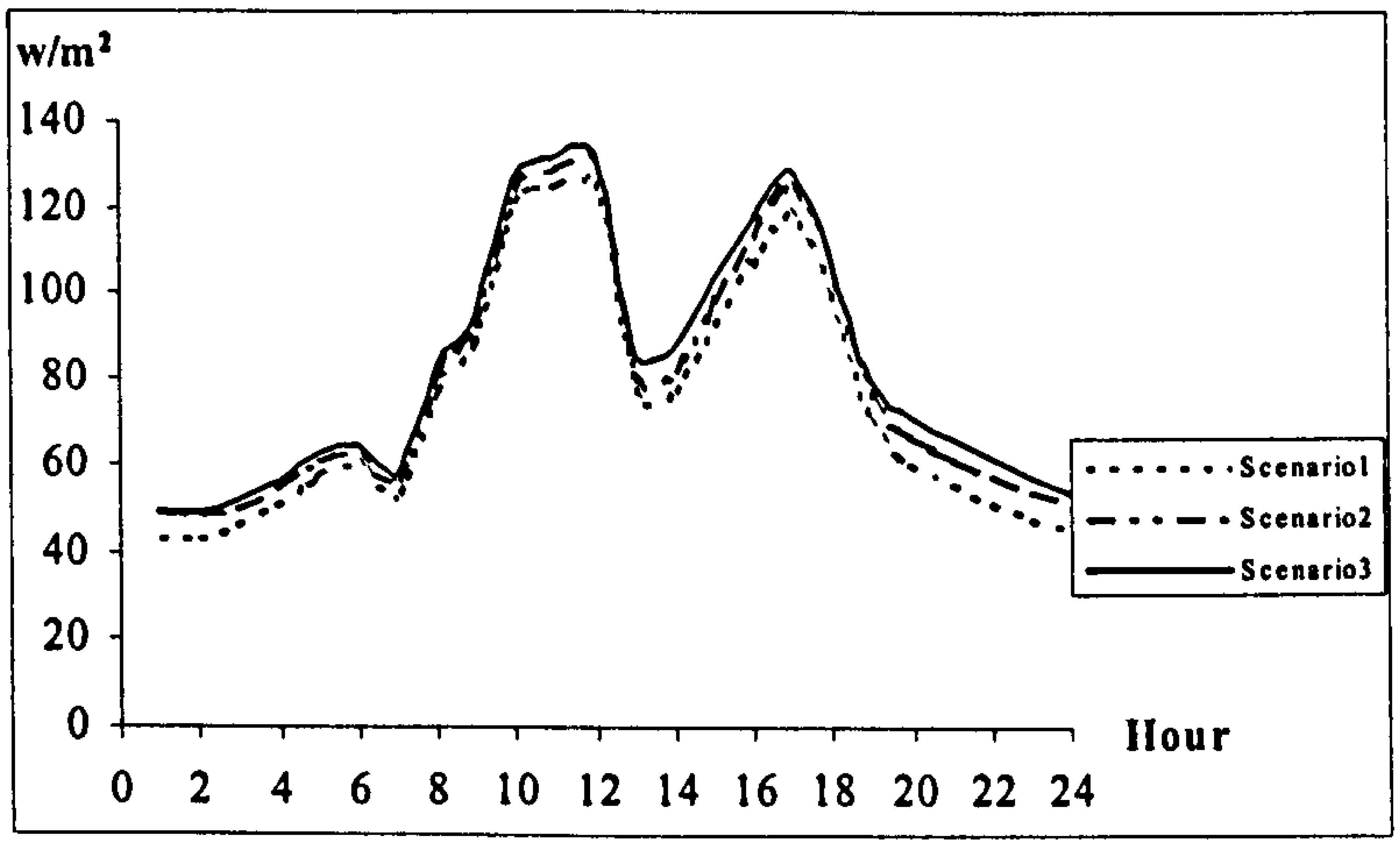


Figure 73: The total hourly cooling load on peak day

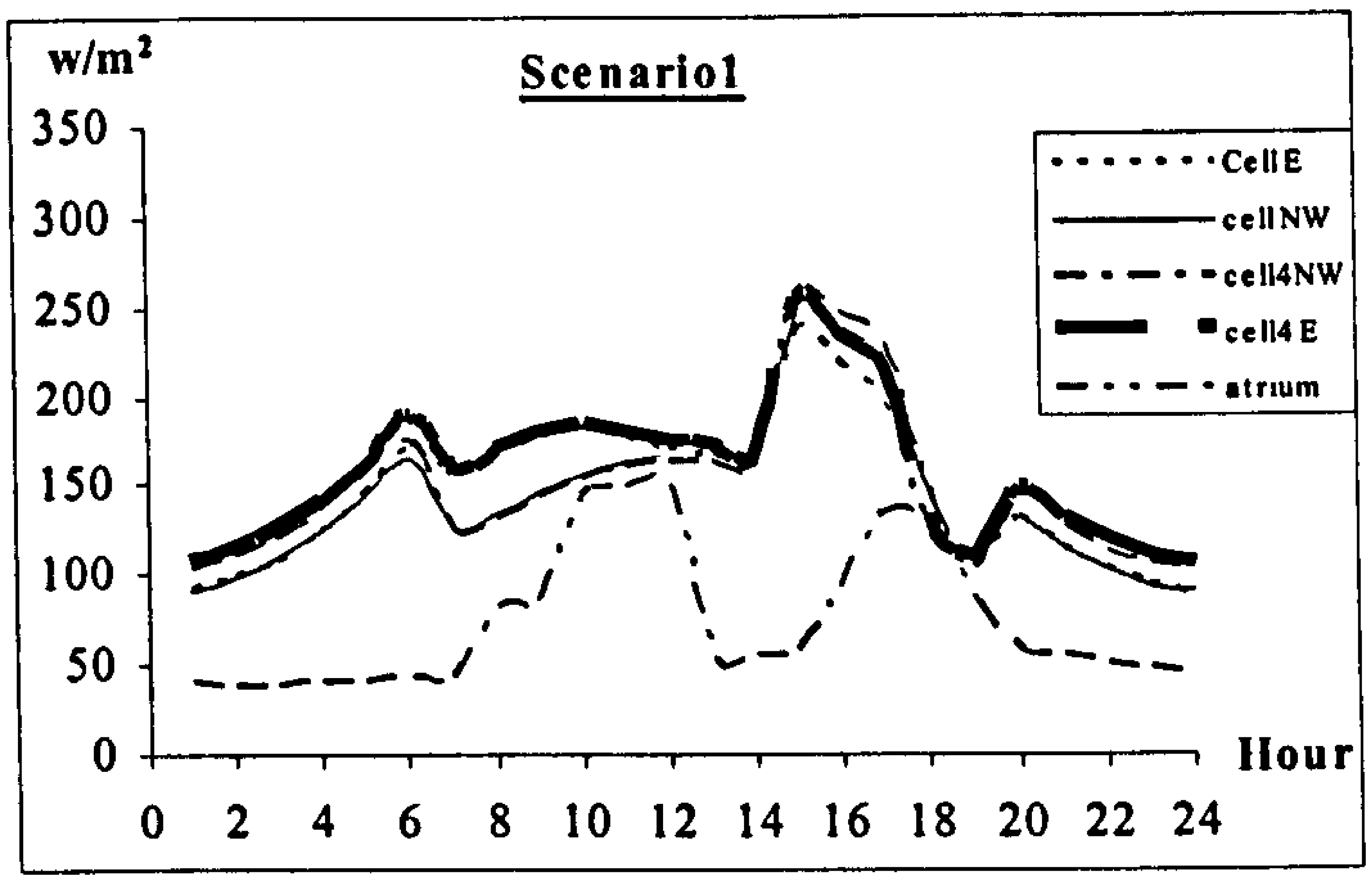


Figure 74: Scenario 1 hourly load

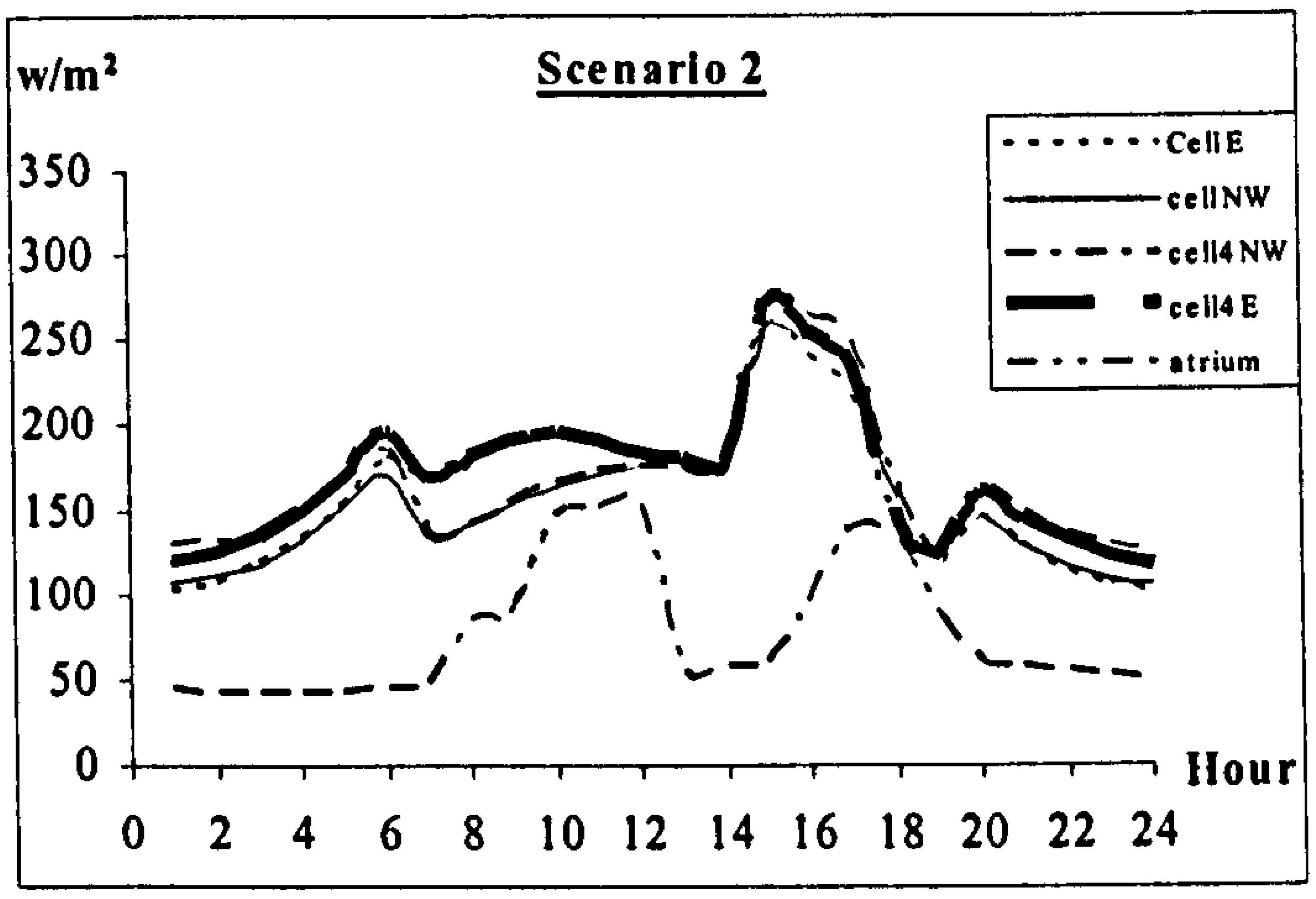


Figure 75: Scenario 2 hourly load

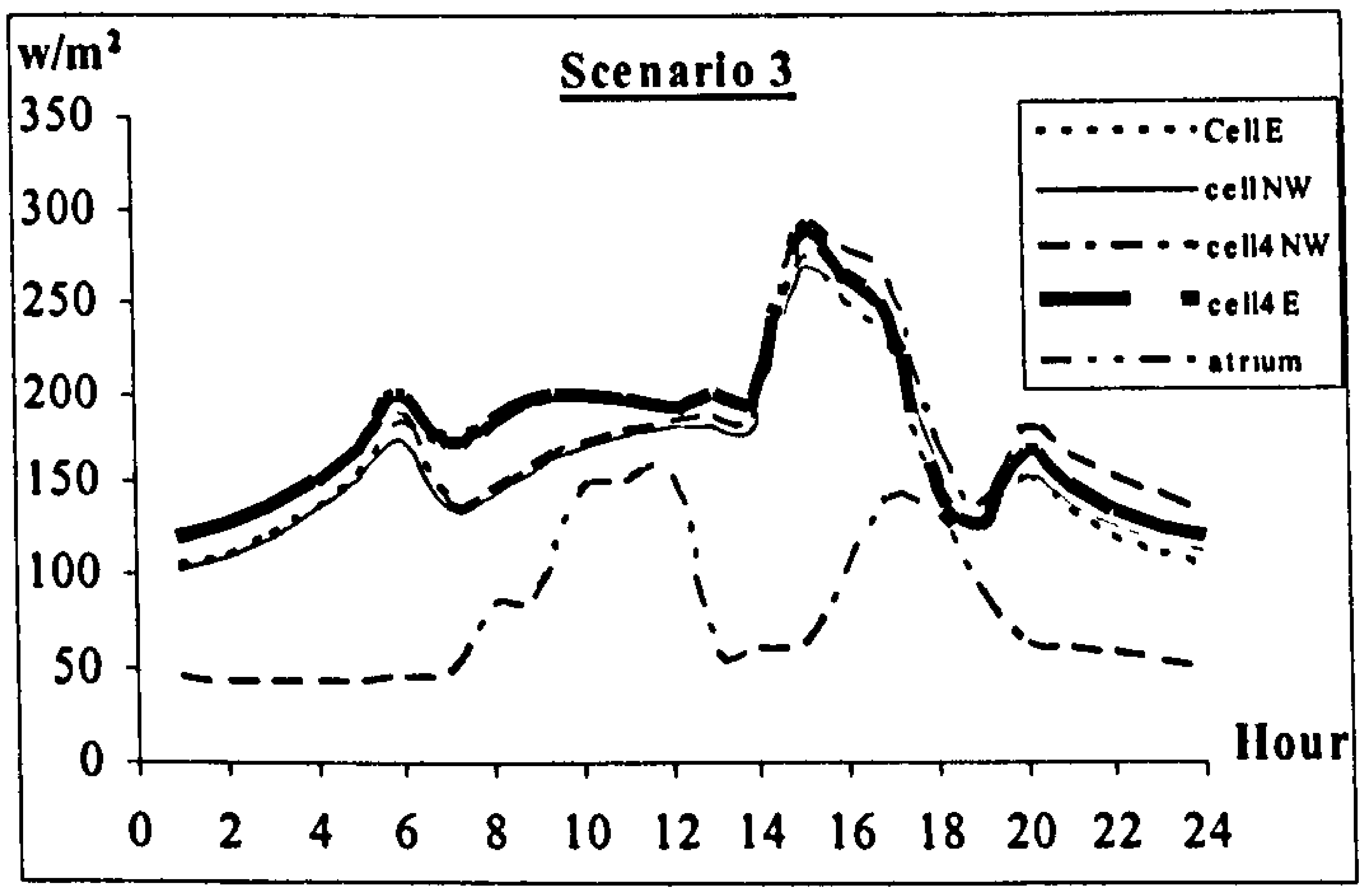


Figure 76: Scenario 3 hourly load

The relationship between the occupancy rate and the peak-cooling load followed a similar pattern in the eighteen scenarios. A bar graph representing the impact of the occupancy rate on the peak cooling in Scenario 2 is used as an example of this pattern.

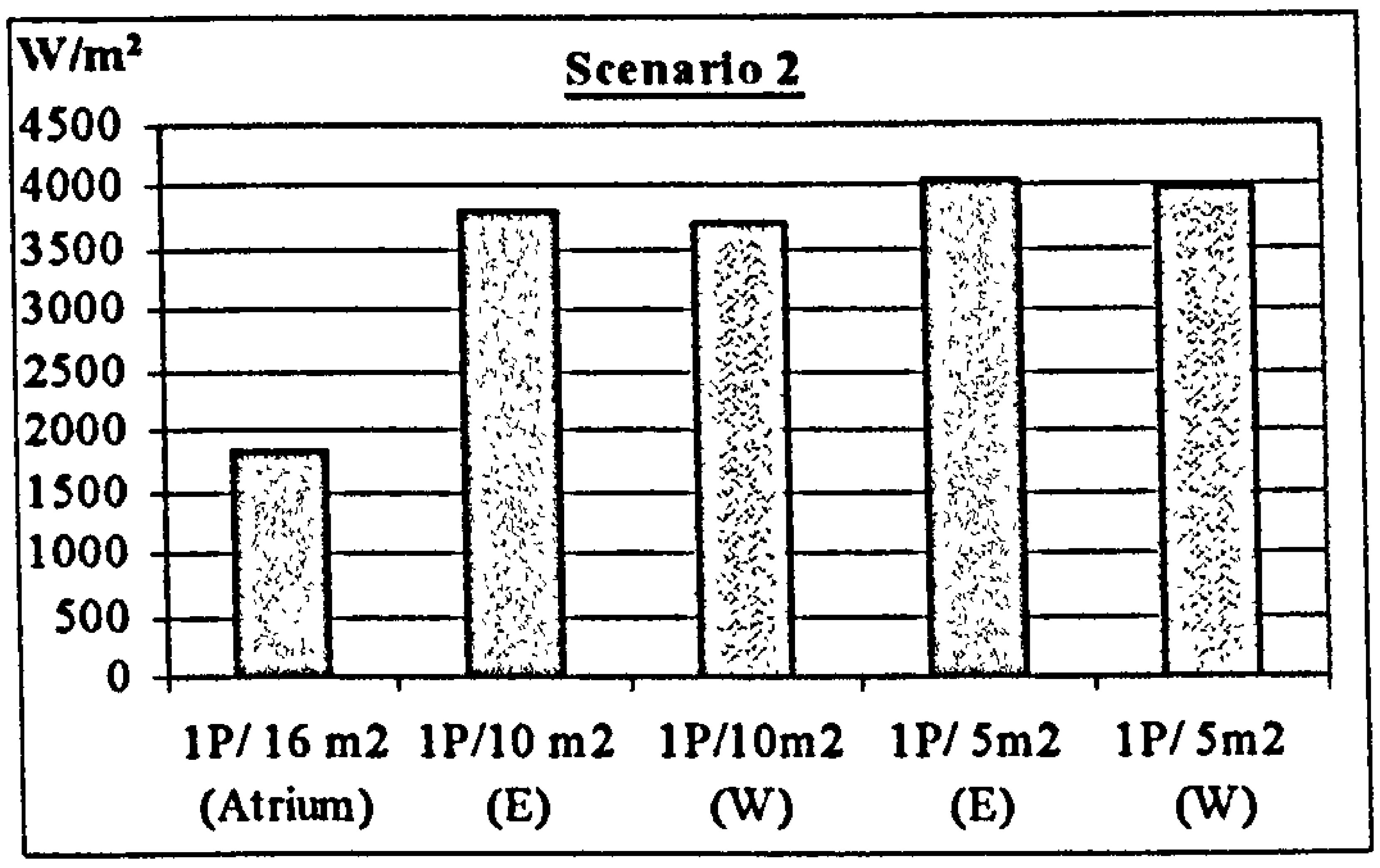


Figure 77: Impact of occupancy rate on peak load

Figure 77 shows that the cooling load is directly related to building volume, which is to be expected, but the important factor here is the orientation. It is noted that the cooling load was reduced by 3% for each person per 10 square metres and by 2% for each person per 5 square metres if located on the north-western façade.

A comparative analysis between the fabric loads in the different rooms in the different scenarios was conducted, to segregate the effect of the changes in U values on the fabric loads in the different rooms. Figure 78 shows that the increase in U value has resulted in

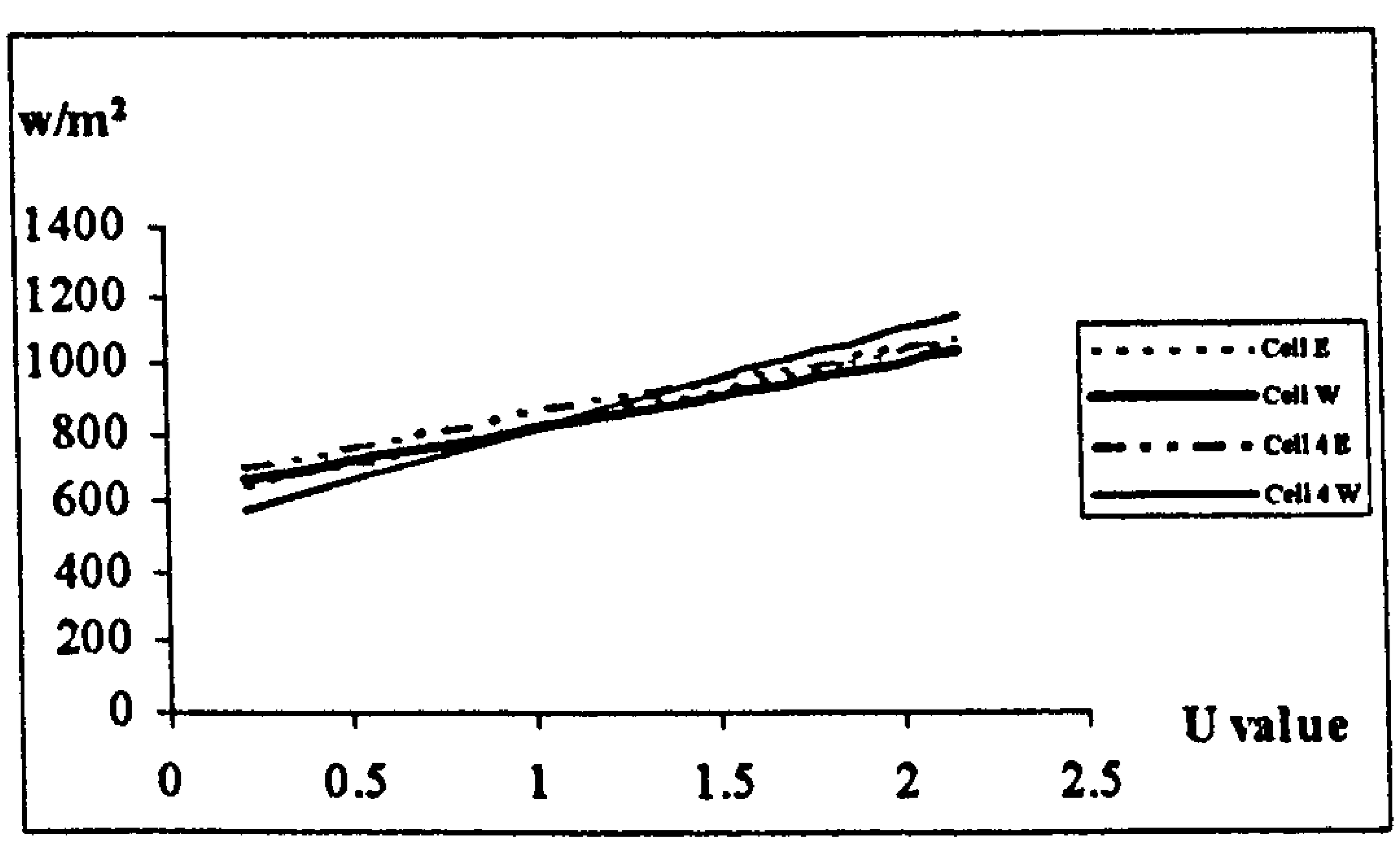


Figure 78: U Value and total fabric load on peak day

an increase in the fabric load in the chosen rooms. For example the change of U value from 0.22 to 2.151 has resulted in a total change of up to 40% in the Eastern cell.

More detailed analyses were carried out to check the hourly fabric behaviour in terms of cooling load. As shown in Figure 79-Figure 82, room orientation has a very high impact on the peak hour and the peak load.

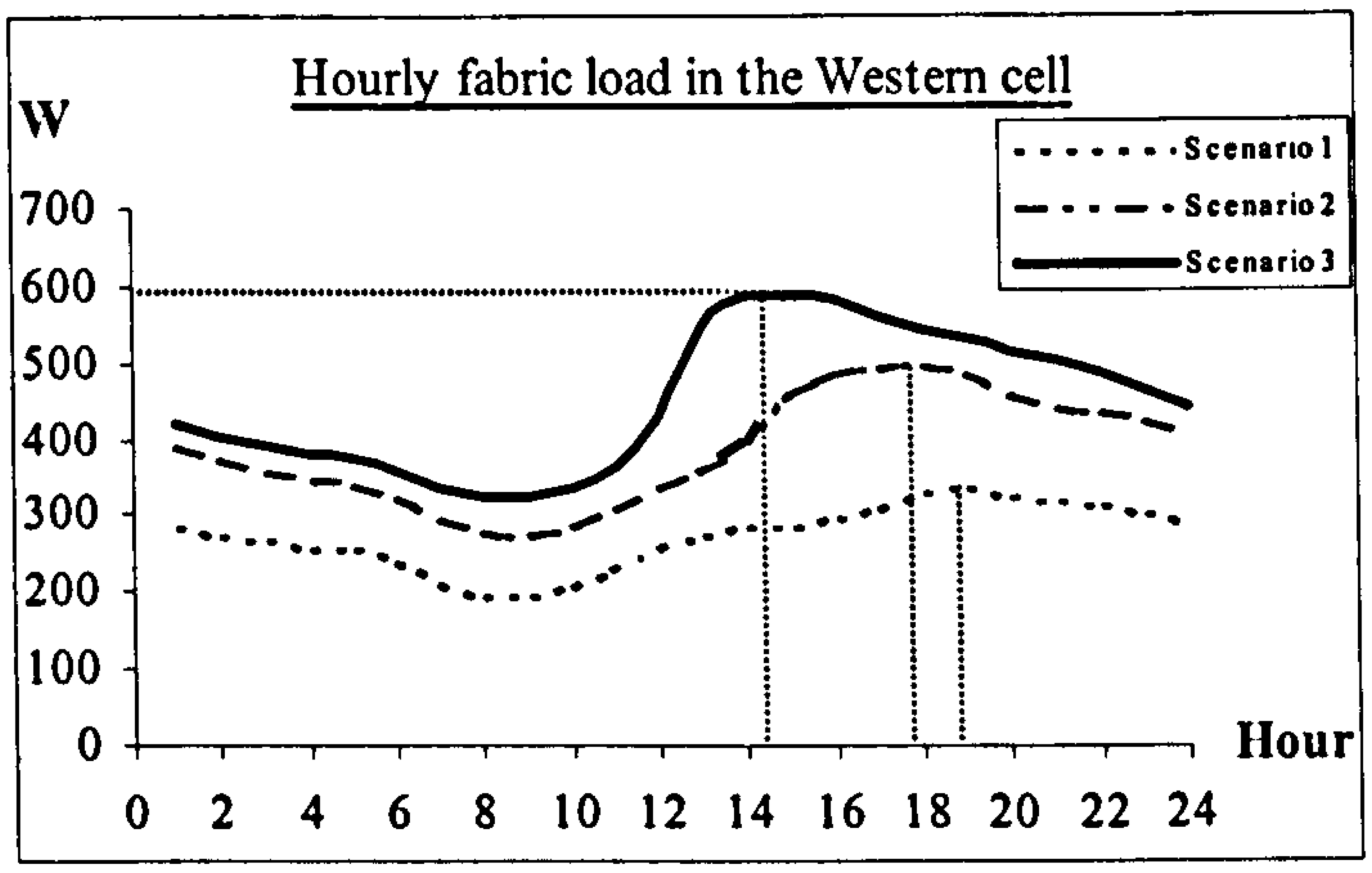


Figure 79: Fabric load in North West cell for one inmate

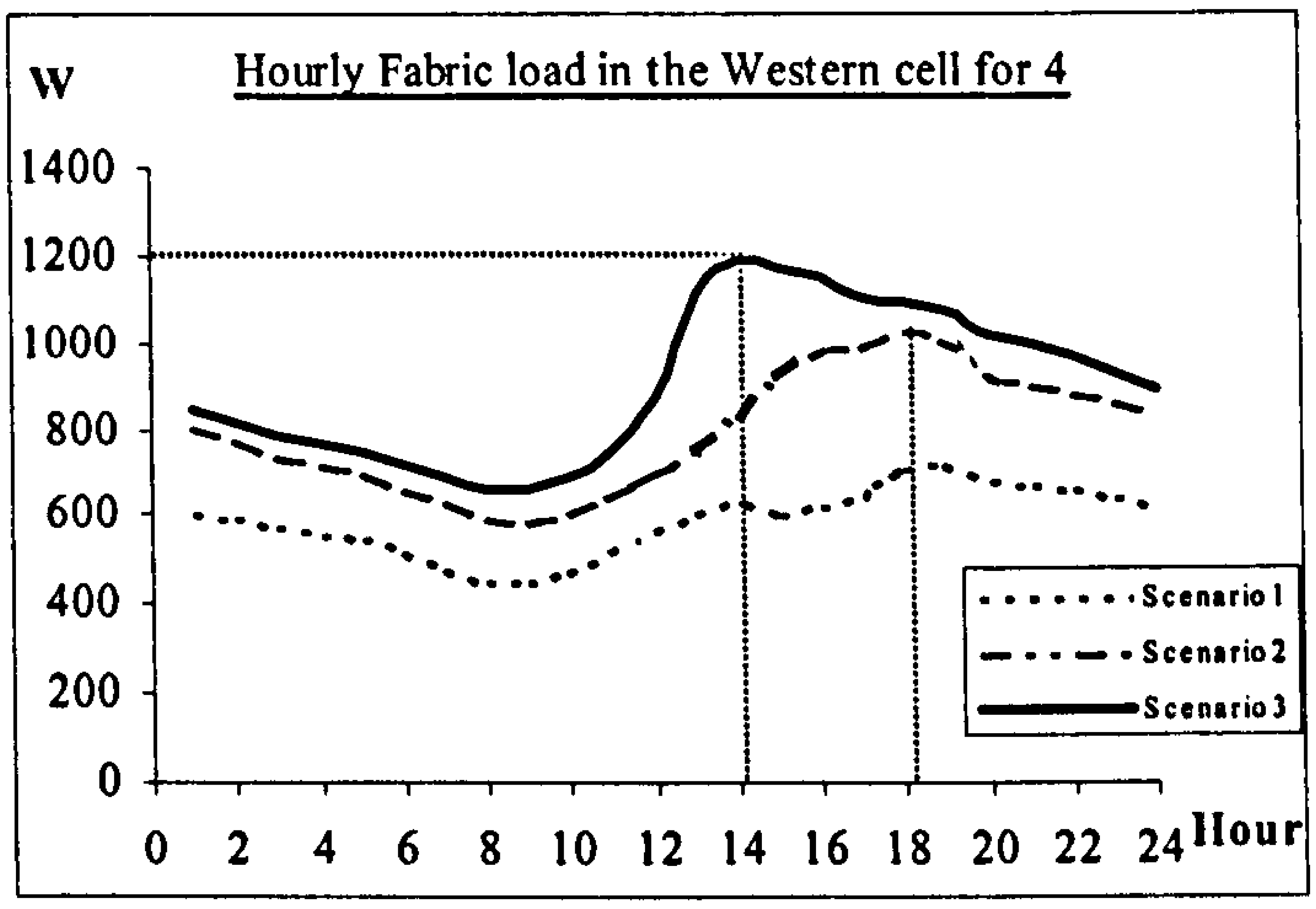


Figure 80: Fabric load in North West cell for four inmates

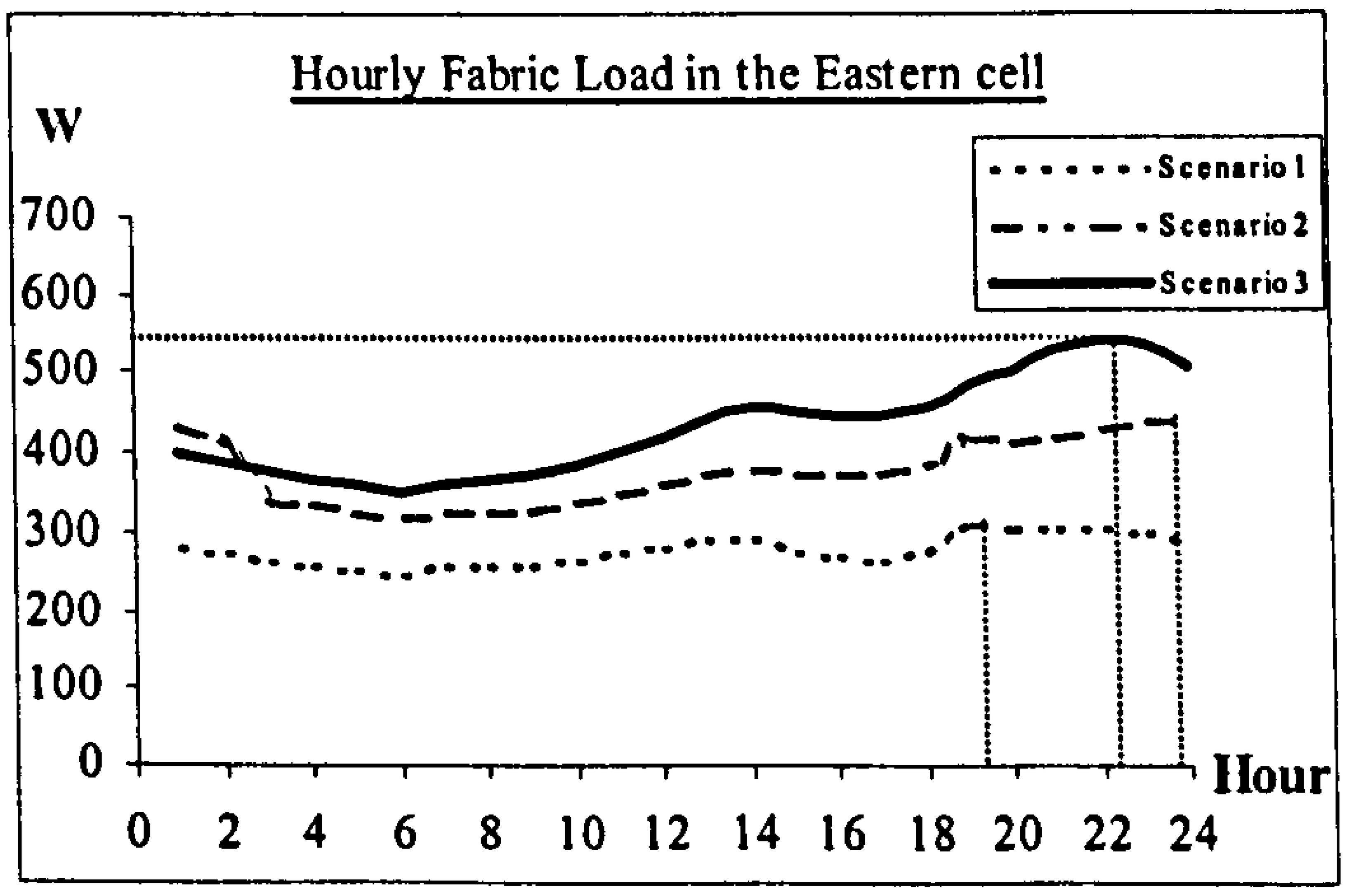


Figure 81: Fabric load in Eastern cell for one inmate

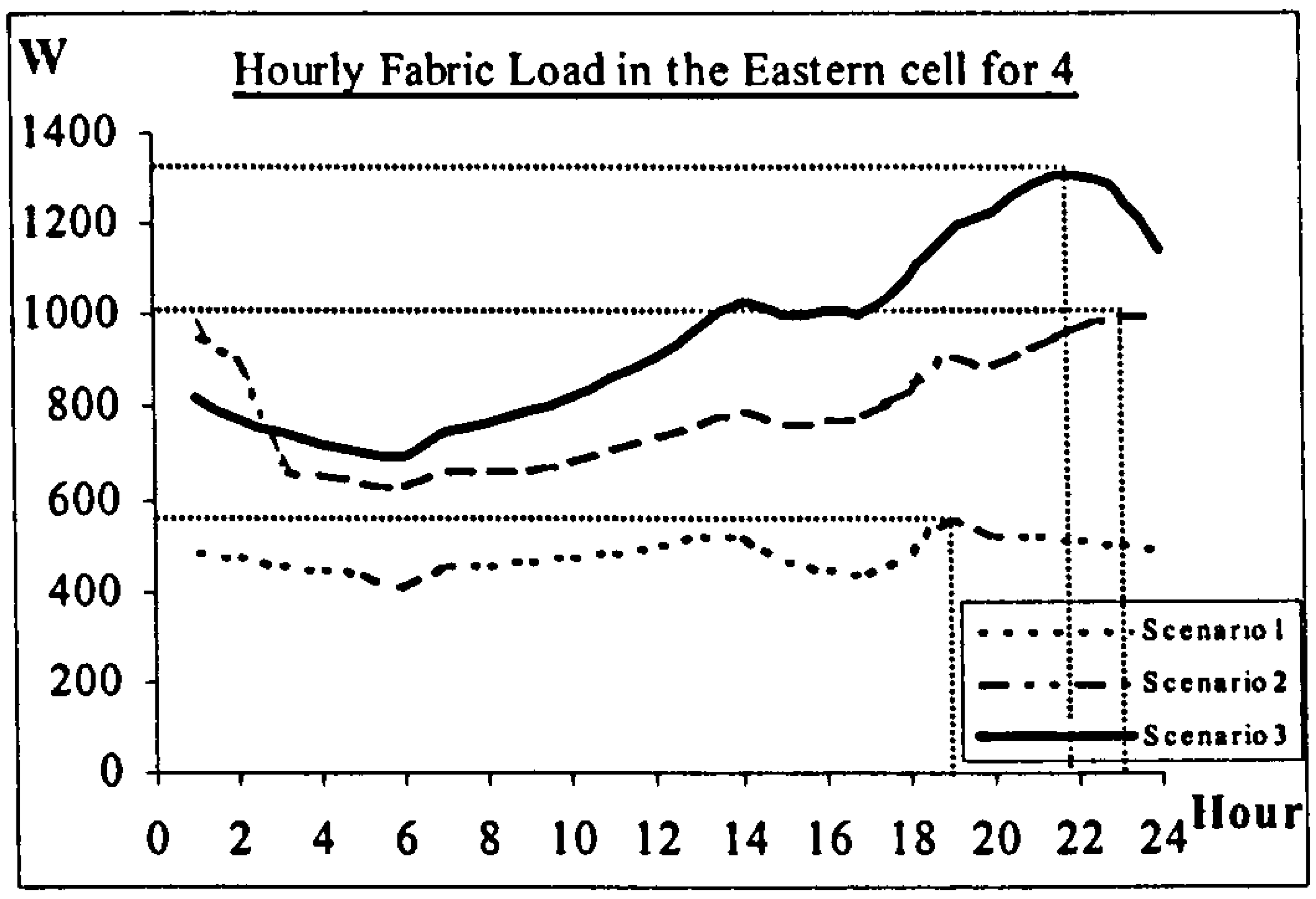


Figure 82: Fabric Load in Eastern cell for four inmates

Despite the fact that the overall profile of daily energy consumption showed that ventilation had a dominant effect on the profile, in-depth investigation showed that orientation could play a major role in shifting the peak load hour through the day. Figure 79, for example, shows that the peak hour in the North-West-located cell is between 2:00 – 5:30 PM while in the East-located cell (Figure 81) the peak hour occurs between 7:30-12 PM. This conclusion seems to contradict the previous results for total load. The analysis shows a reduction of the total load in individual cells located in North-West façades as compared to the eastern ones. It can be argued, however, that reducing the load in east located rooms could be achieved economically by using passive methods such as night cooling, while in the North-West situated rooms, air-conditioning is the main technique that can be used to reduce the peak load to achieve comfort levels during the hot hours. Other devices such as appropriate glazing materials and / or shading devices might help to reduce the thermal load. The data for peak hours, however, shows no relation between the sharp increase in peak load and the time of direct sunshine falling on north western facades.

7.5.4 Summary of the results

The small window area in the design of central prison in Abu Dhabi led to reducing the effects of the U glass and the solar heat gain factor on the total cooling load.

As the ventilation load dominated the total cooling load in the building by more than 70%, an efficient envelope design reduced the total energy load by only 9%. This is related to the introduction of air-conditioning in the atrium.

On the other hand, looking more specifically into loads resulting from the fabric of the individual rooms revealed that an efficient skin minimised the hourly fabric load on the peak day by more than 39%.

It was proven that reducing the person per-square metre rate would lead to an increase in the cooling load per square metre.

This pilot has demonstrated the importance of the prison configuration in providing comfort for the inmates. Appropriate design of prisons will ensure an efficient profile for occupancy and activities. The location of different activities can have great impact on the peak load energy consumption profile. It is therefore important to integrate an energy efficiency strategy during the early stages of prison design.

7.6 Energy related façade variables

The previous discussion showed how the prison architectural and social variables led to a set of technical variables that are related to façade design, and have impact on the prison building's energy consumption. An overall summary of the links is shown in Figure 83. In this section these variables are to be summarised and assigned into specific categories that define the boundaries for the selection of the scenarios examined in Chapter 8. These categories are: orientation, façade configuration, cell variables, and inmate's activities and programmes.

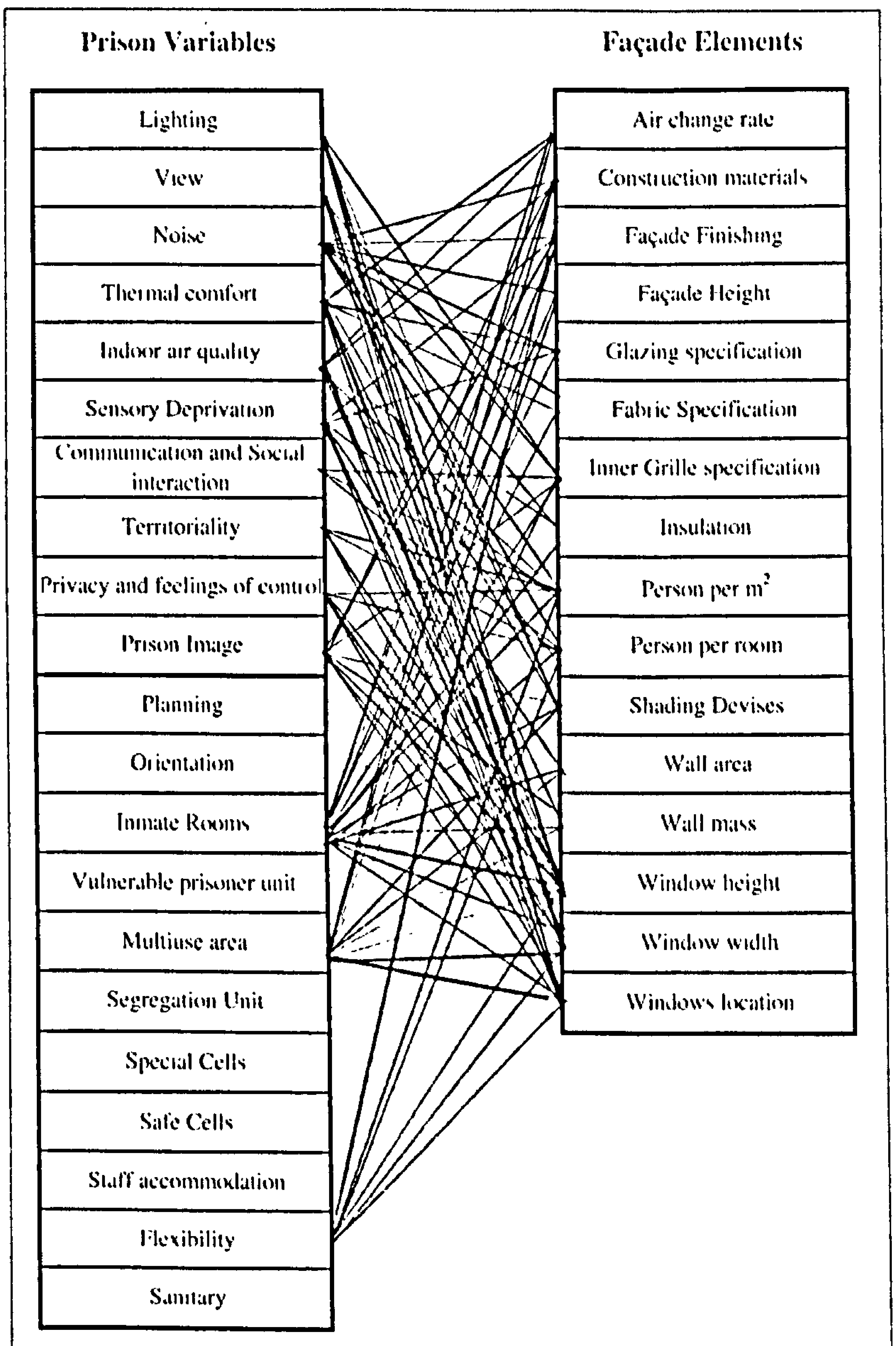


Figure 83: The relationship between façade elements and different prison variables

7.6.1 Orientation

It can be argued that orientation is technically not a façade variable, but the recognised importance of orientation on building sector energy performance in the Gulf region necessitated examining its impact on the prison buildings.

Orientation in prison building is not only related to the orientation of the building, but to the orientation of the different zones and activities following their occupancy patterns.

7.6.2 Façade configuration

Façade configuration is divided into two main categories; the façade design parameters and façade materials.

7.6.2.1 The façade design parameter

The energy related façade parameters are basically the room and window sizes and those façade elements which are **shading devices.** To examine the energy impact of the cell and window configuration, two variables can be identified. These are **Window to Wall Ratio** (WWR= glazing area/façade area) and the **Fenestration Factor** (FF) which is the relationship between the glazing area and the room area (FF= glazing area/room area).

7.6.2.2 The façade materials

This category investigates the impact of the façade's fabric and the glazing specifications. The technical variables for the thermal specification of these two which are most influential on the building's energy performance, are thermal transmittance of the opaque area **(Uo)**, the glazing area **(Ug)**, and the glazing shading co-efficient **(SC)**.

7.6.3 Cell variables

The results of the pilot study and the analysis of the social variables that were carried out in the previous section, emphasised the importance of a similar set of technical variables which are related to the façade design, and have impact on the building energy performance. These variables are **person per m^2**, **person per room**, and the cell dimension in relation to the window size which is the **FF**.

7.6.4 Activities and programmes

Variations of activities and programmes for the inmates are greatly emphasised by sociologists and psychologists undertaking research in the area of incarceration. The pilot study showed that mobility of activity can be beneficial in achieving social targets such as minimising sensory deprivation on one hand, and enhancing the building's energy efficiency on the other.

In summary, the prison's mission and goals are intimately bound to its architectural and social variables. Figure 84 shows the technical (architectural) and social variables that result from the prison's mission and goals. Two lists of indicators, one related to architectural and the other related to social variables, are presented along with their energy-related architectural variables. Both lists join to compose the energy-related façade variables which set the boundaries for the different scenarios that to be examined in Chapter 8. The variables which are shaded in the table are the ones that will not be investigated, for different reasons. For example, the proposed prison building is to host minimum security offenders, and hence specific cells such as safe and vulnerable cells will not be relevant. Technical variables such as **Thermal Mass** are not considered as unlike the, perception that temperature drop sharply during the night hours in the UAE. This turned not to be the case in the Abu Dhabi climate. Figure 21 (Chapter 2) shows that temperature in the peak day remains much higher than the comfort level for the whole 24 hours. There is very little variation in daily temperature. This would discourage the use of thermal mass, especially in prison buildings where inmates use the cell zone during night time. Accumulation of heat within the structure would lead to further discomfort during the evening and night.

Figure 84: The relation between prison mission and goals and its architectural and social variables

7.7 Chapter Conclusion

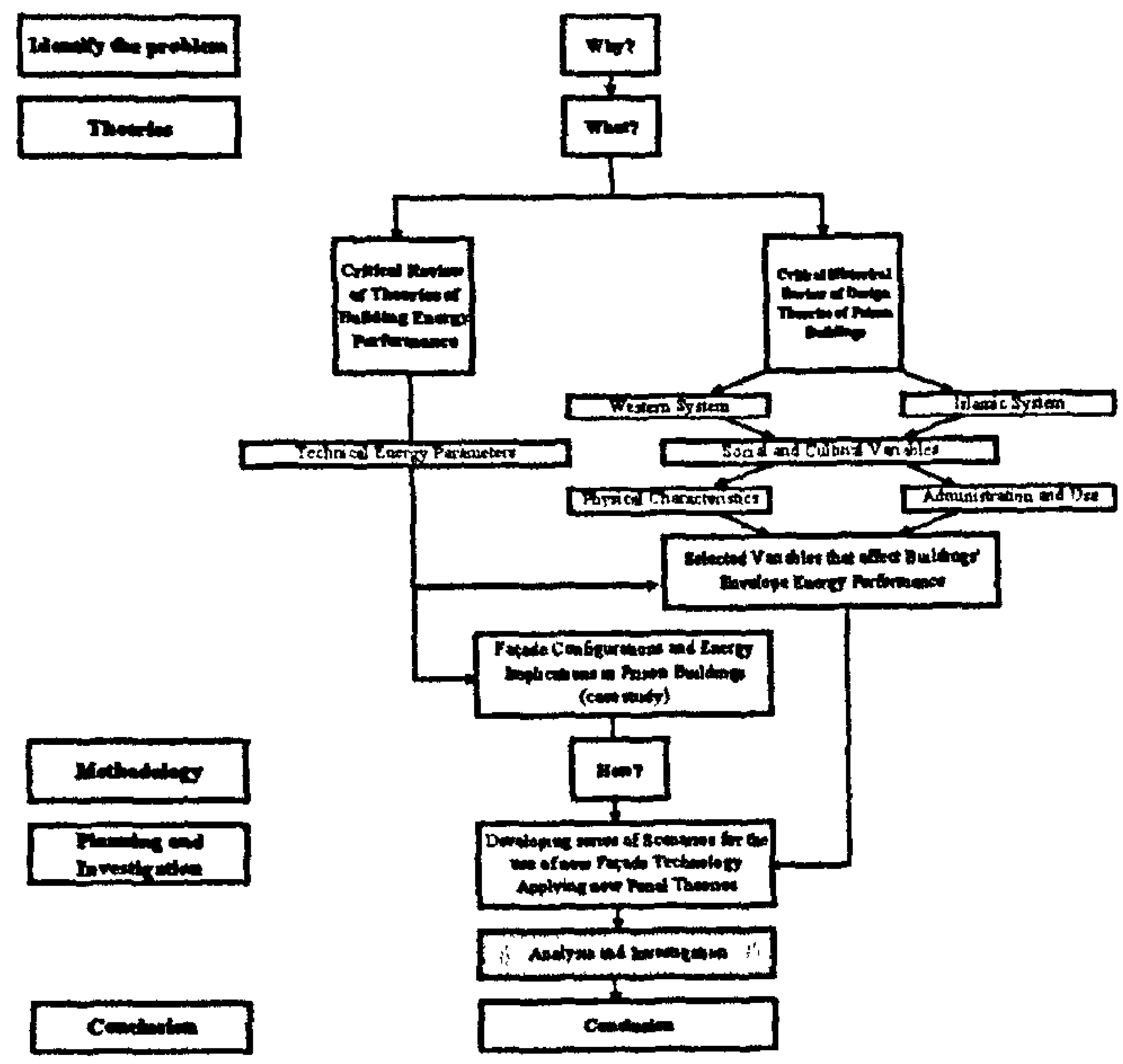
The role of prison as a rehabilitation centre can be influenced by a number of variables. These variables can be classified into two main categories, architectural variables and social ones. Some of those variables will influence energy conservation measures in prisons. The previous section has identified both architectural and social variables and the relevant indicators that have impact on energy-efficient design. The hypothesis that the need to achieve certain social variables in prisons means an increase in energy demands to meet such requirements might not be true; not all the social variables are necessarily achieved by increased demand for energy. In the UAE environment, improving lighting, views, and exposure to fresh air might actually emphasise the need for rational energy use rather than increasing it. On the other hand, architectural variables and careful, energy-conscious design does not necessarily mean a reduction in energy usage, in particular at the initial stage. An initial investment in good façade and layout design such as inmate rooms, proper allocation of activities and safety of cells could lead to better energy-efficient strategies in the long term.

Architectural and social variables that influence the role of prisons can therefore have positive, as well as negative impacts on energy usage. As the aims and objectives of this thesis are focussed on façade configuration and composition, the relevant façade elements of those indicators have been identified. The façade elements are organised under four groups; orientation, façade configuration, cell variables and activities.

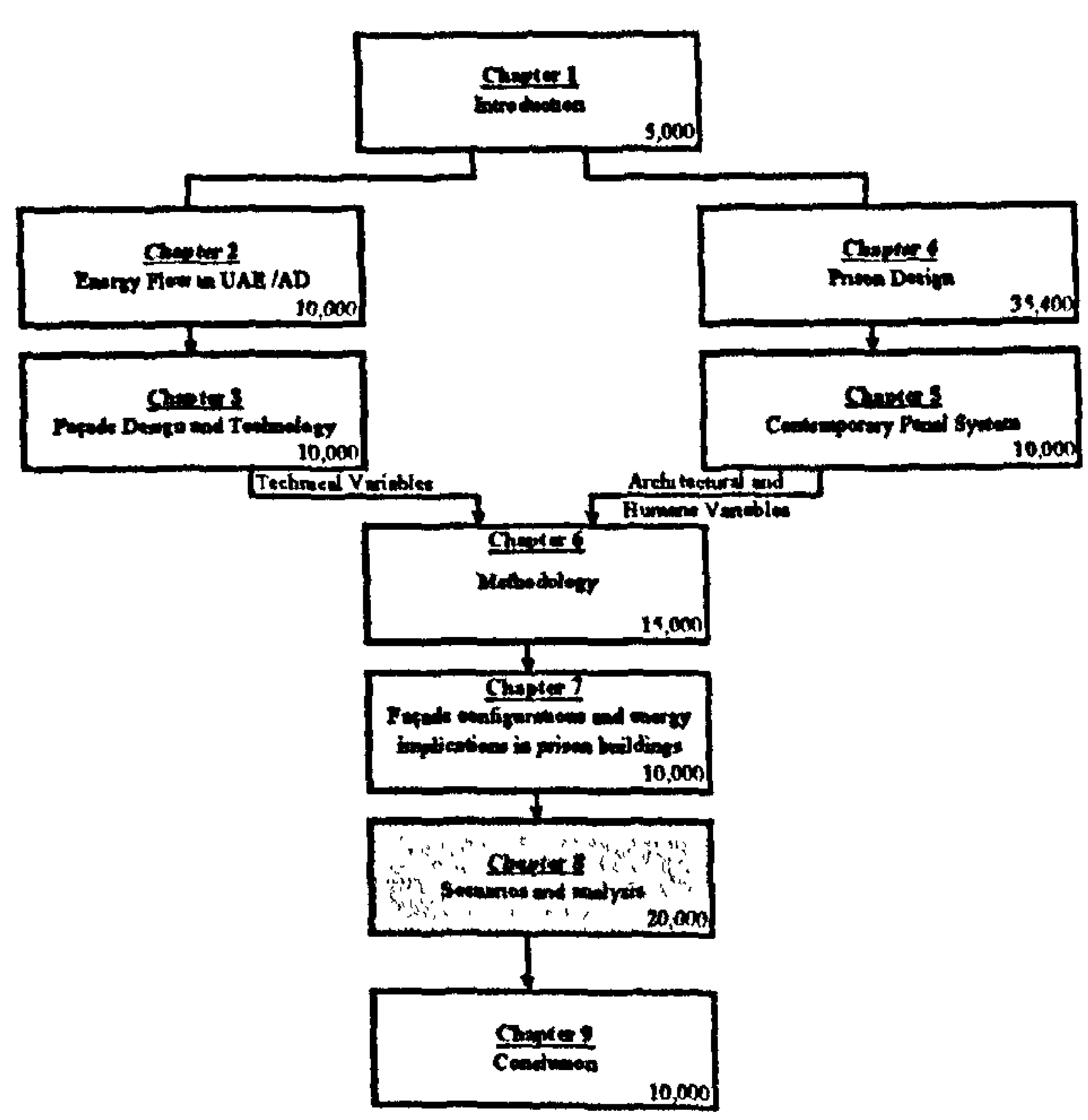
A series of different scenarios can be developed based on the social and architectural variables which were identified in this chapter. The following chapter aims to examine the thermal and energy performance of the developed scenarios and compares them to the base case, which is the proposed Abu Dhabi prison building.

CHAPTER EIGHT

Investigation and Analysis



The Thesis Structure Outline



The Thesis Chapters Outline

8 Investigation and Analysis

8.1 Introduction

The critical reviews of façade design technologies and prison design theories, which are carried out in the previous chapters (2-5), has led to a set of technical and social variables that influence a sustainable prison façade design.

These variables, as illustrated in chapter seven, are classified into four categories: **orientation, façade configuration, cell variables** and **activities planning.** This chapter aims to investigate the impact of such variables on the energy performance of the prison building. An Integrated Building Analysis Software System (IES) is utilised to investigate the energy impact of each category and the combination of the different categories.

8.2 Setting the boundaries of the simulation

The base case, for the alternative thesis-simulated scenarios, is based on the final prototype design of Abu Dhabi Central Prison. It is, hence, essential to illustrate the related architectural design elements and the penal philosophy that this prototype adopts.

According to the proposal, the prison mission statement is summarised in five points. These are:

1. The design of a humane environment whilst attaining the required level of security.
2. The incorporation of the latest thinking and methods into a flexible layout.
3. Creating planning parameters that will comfortably adapt to change.
4. Planning for adequate security and control with low maintenance.
5. Achieving a long-term built environment sympathetic to the changing needs and demands of the client/users.

The previous aims are essential to the success of any correctional institute and, consequently, need to be respected in the developed alternative scenarios.

The design brief, which the proposal is based upon, reflects some fundamental new thinking regarding security and control measures. The principal goal of the prison design is to provide closed institutions for different categories of offenders. In order to ensure more effective classification of prisoners, it is recommended to divide the inmates' accommodation into social units. The importance of maintaining consistent control of the offenders to avoid unwanted contact with members of the community is emphasised. To preserve a safe controlled environment and, at the same time, ease access to all parts of the prison is highlighted. Ease of supervision and administration to minimise friction between prisoners and staff are important characteristics for prison buildings. Correctional treatment working towards rehabilitation is a main issue in the new prison policy in Abu Dhabi; prisons should prepare inmates for their return to the community.

Among the host of considerations which present themselves in the design of any correctional facility, local climatic conditions are important (Fairweather, 1975). As a result of the severity of climatic conditions in Abu Dhabi, the importance of developing suitable interior spaces for programme activities and functions becomes critical. In order to present a comfortable environment in such hostile climatic conditions, there is a need to provide air-conditioning in the UAE prison buildings.

The previous points indicate the purpose, the responsibility, and the philosophical direction of the proposed prison design and set out the general social boundaries of the investigation that is carried out in the course of this chapter.

Prison buildings are very complicated. They host a number of different facilities, which require special architectural solutions. In a general sense, a prison building is composed of six components. These are: inmate housing, inmate services, inmate programs, administrative functions, service facilities, and security features. This thesis' focus is on the inmate housing units. This is not to suggest that the other utilities are less important. The inmates spend most of their confinement time in the housing unit (85%), and hence it can be argued that this facility has a vital role in the success of the institution mission. Examining each one of these utilities is, however, beyond the capabilities of the researcher within the time line of this thesis.

The base case has been examined in the pilot study. Although it has been proved that the proposal will result in a substantial increase in the electricity consumption in Abu Dhabi (Al-Hosany and Elkadi, 1999; Al-Hosany and Elkadi, 2000), there are several architectural and social advantages to the proposed design that should not be ignored and should be retained in the design of the alternative scenarios.

The following section identifies the variables that are beneficial to the alternative scenarios and should be integrated in their design and the set of variables that can be manipulated in order to achieve a more sustainable prison façade design.

8.2.1 Base case input data

The layout of the inmates' housing unit in the base case is based on the "new generation prison" design movement (Figure 86). In defence of the new movement, Zupan described the situation in the new generation institutes as "architecture and inmate management style which shapes the environment in such a way that critical inmate needs for safety, privacy, personal space, activity, family contacts, social relations, etc., can be achieved through compliant behaviour" (1991:95-96).

The "triangular" housing unit that is presented in the design has been adopted internationally for its advantages in minimising blind spots and providing good sight lines to the cells as well as areas of activities (Figure 85). For example, the triangular design has been adopted by the American Correctional association in their design guide for secure adult correctional facilities (ACA, 1983).

The living units in the base case are designed to house fifty inmates each, which is the capacity that is recommended by contemporary incarceration architecture theories. This approach, among its various virtues, allows effective inmate classification that is highly important for the UAE prison population (Chapter five).

The cells are situated on two sides of the triangular unit, on two levels. This design allows daylight access into all the cells and facilitates the direct supervision approach, which has been highly praised by both prison governors and inmates.

An "ideal" or preferable prison design solution is unfeasible unless it includes the previous set of architectural elements.

On the other hand, there are several other façade related variables which the base case hosts, that can be manipulated in order to enhance both the indoor comfort levels and the energy performance of Abu Dhabi prison buildings. These variables are illustrated in the following section.

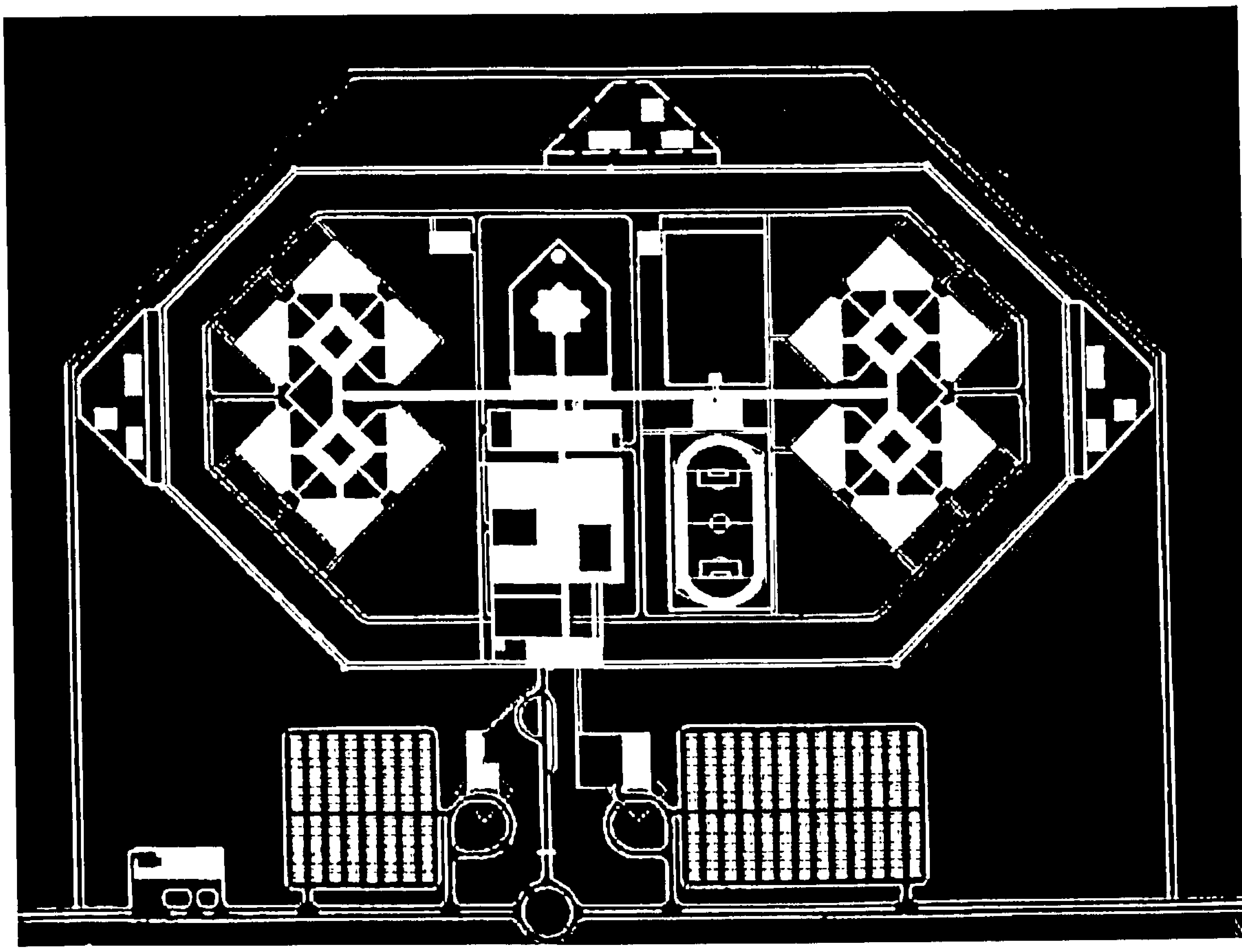


Figure 86: The proposed layout of central AD prison

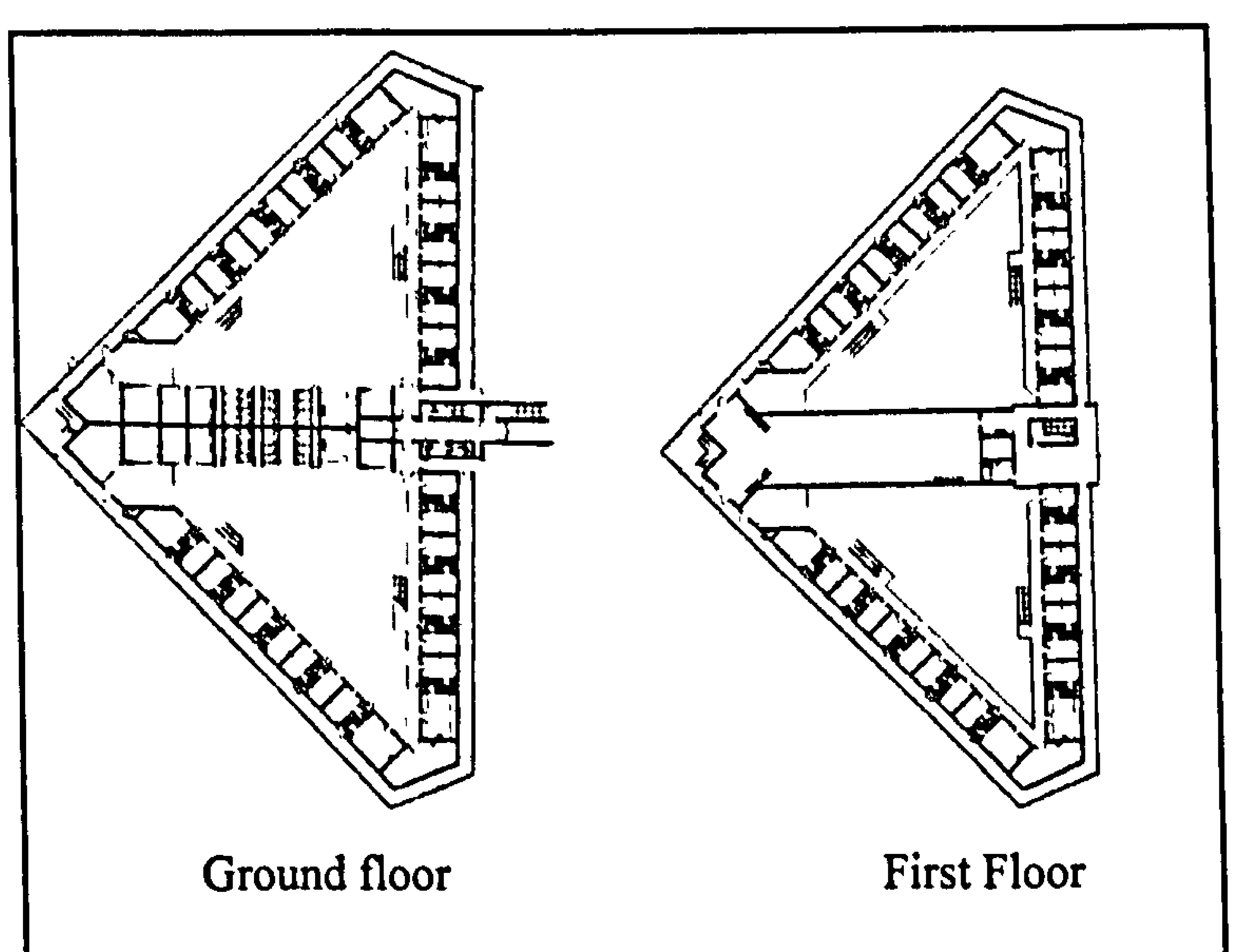


Figure 85: The inmates' housing unit in the proposed AD central prison

8.2.2 Orientation

It has been proved in previous studies that orientation can play a major role in the energy performance of prison building façades (Al-Hosany and Elkadi, 2000a; Al-Hosany and Elkadi, 2000b). Abu Dhabi prison buildings are usually situated in the desert where there are no constraints on the orientation choice and no absolute preference of views. Hence, the first step in this investigation is inevitably to decide on the ideal orientation to achieve all other goals of energy efficiency.

Figure 87 shows the base case, and three suggested different orientations. The three scenarios are simulated in order to identify the preferred orientation. The façade energy performance is to be the base for evaluation. The best orientation (in energy terms) is to be fixed along with the set of variables that are taken from the base case to provide the boundaries for the following investigations.

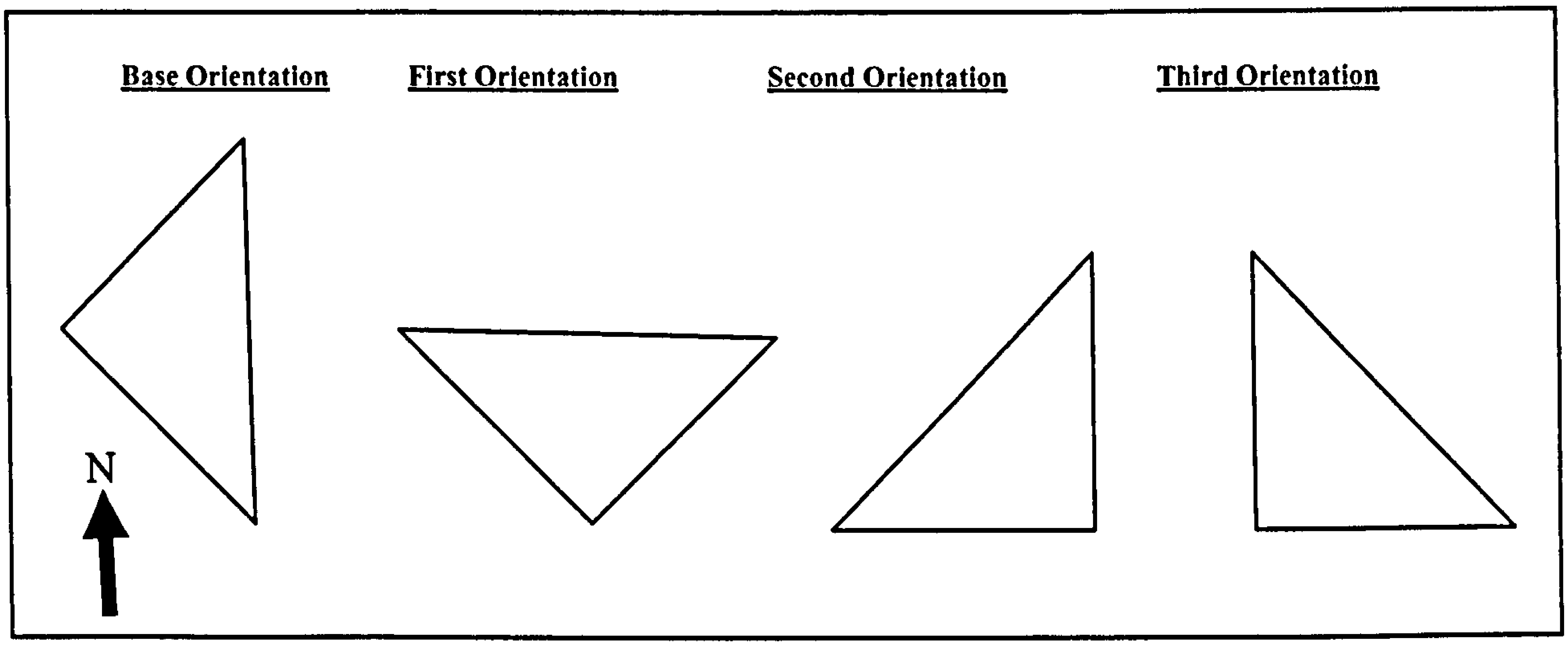


Figure 87: The suggested orientation scenarios

8.2.3 Façade configurations

The variables related to façade configurations are divided into two sections. The first is composed of the **input** or in other terms **design variables**, which are the window to wall ratio (**WWR**), the fenestration factor (**FF**) and **shading devices**. The second section is related to the **construction materials** properties, namely: opaque U value (**Uo**), glazing U value (**Ug**), and the shading coefficient (**SC**).

The sequence of runs and variation of the developed scenarios are illustrated in the following section.

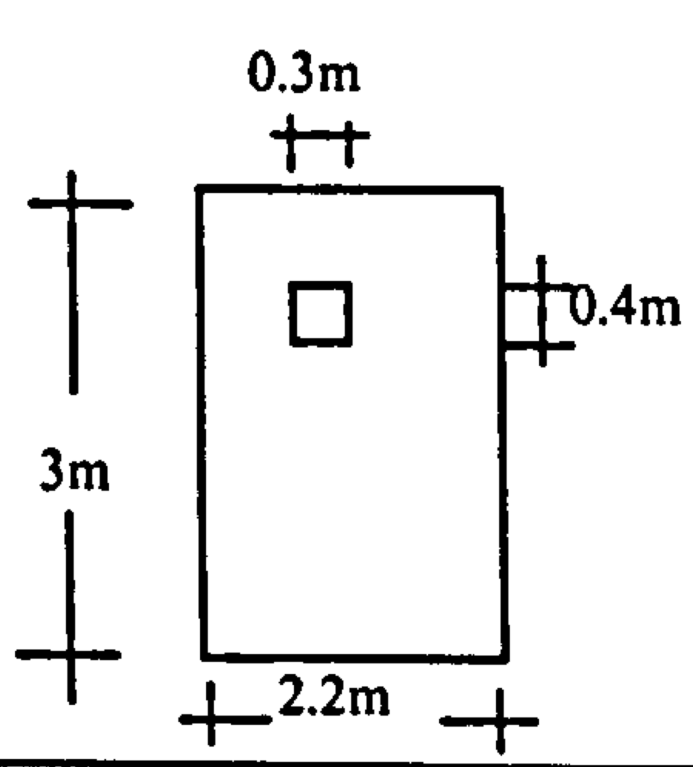
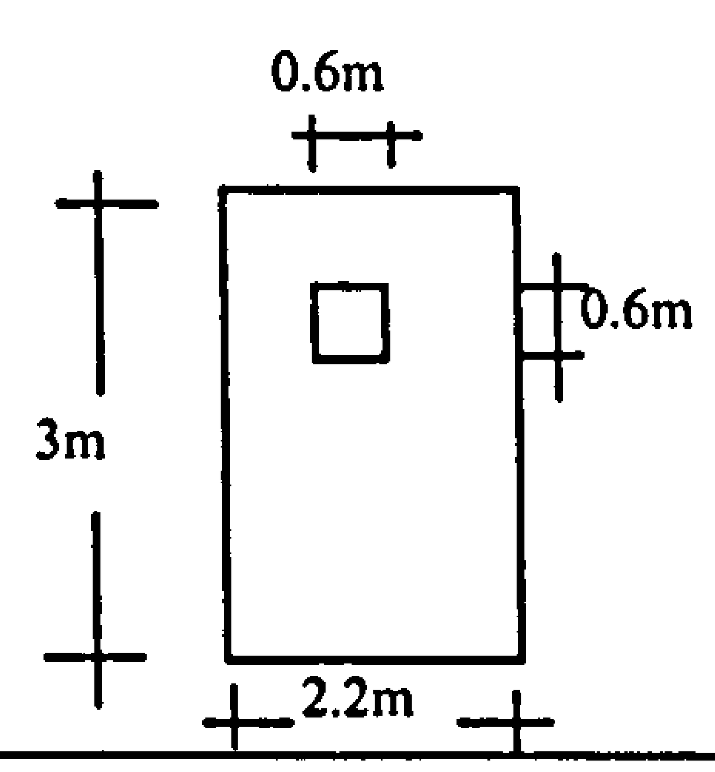
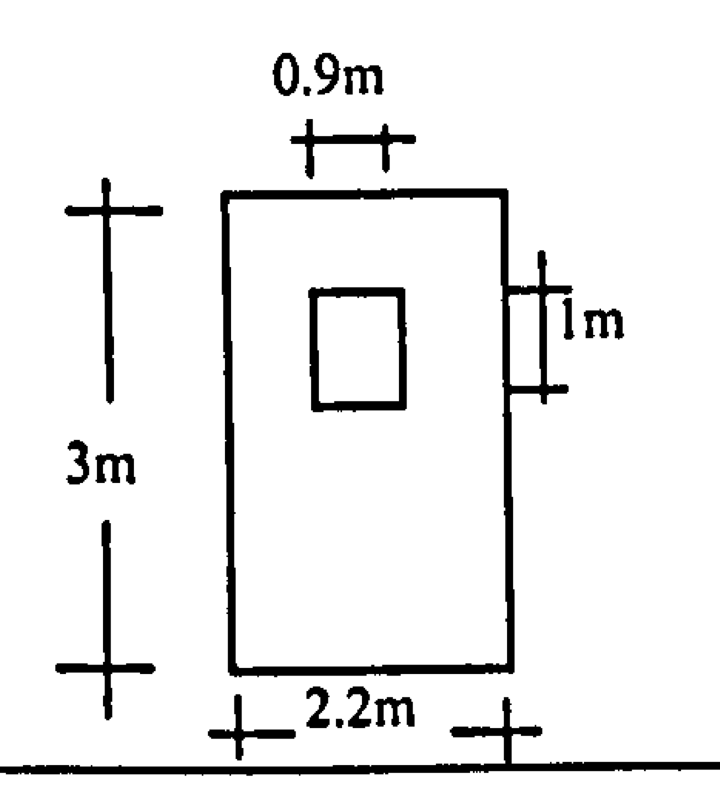
8.2.3.1 Design variables (Input)

8.2.3.1.1 Window to wall ratio (WWR)

The impact of the **window to wall ratio** is the first variable to be examined using the base case variables with the "ideal" orientation that resulted from the first analysis. This variable has major importance on both social and architectural needs in prison buildings. The importance of view and daylighting has been recognised to have positive influence on inmates' rehabilitation efforts. **Two alternative options** are investigated and compared to the base case.

The first alternative is based on the United Kingdom recommended window size which is **100 cm x 90 cm**. The window size in the base case is 30 cm x 40 cm, which means that the recommended window is considered "large" in comparison to the base case. Hence, an intermediate window size is suggested, that is **60 cm x 60 cm**. The different scenarios are illustrated in Table 13.

Table 13: The alternative scenarios for the WWR

WWR	0.01 (Base case)	0.04	0.11 (UK recommended win size)
Cell Elevation			

8.2.3.1.2 Fenestration Factor

The **fenestration factor** has gained importance in daylighting calculations, and as shown in Chapter seven, has both social and technical relevance in sustainable prison design. To investigate the impact of the fenestration factor on the energy load in prison buildings nine scenarios are examined. The scenarios are a combination from the three window sizes, which were presented in the WWR examination, and three different cell sizes. The cell dimensions are based on the base case (10.56 m^2), the UK recommended cell size

(6.8 m²) (Figure 88), and the UK minimum cell size (5.5 m²) (Figure 89). Table 14 shows the outline of the nine scenarios.

The minor difference in the façade area between the base case cell and the UK cells was treated as negligible in order to respect the dimensions that were set by the Home Office. However, the cells in both suggestions were arranged to host the same number of inmates, which the base case was designed to contain.

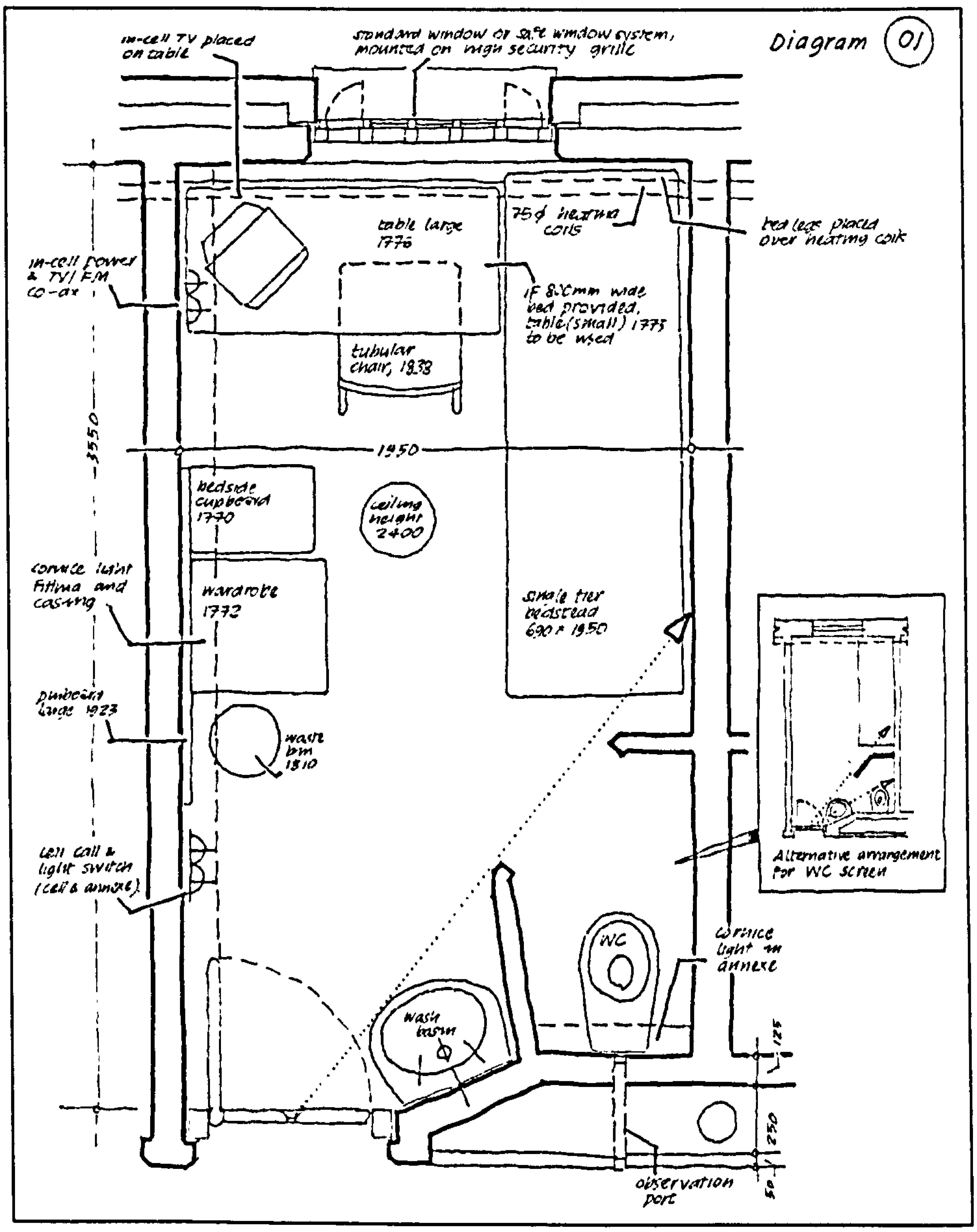


Figure 88: The UK recommended cell layout

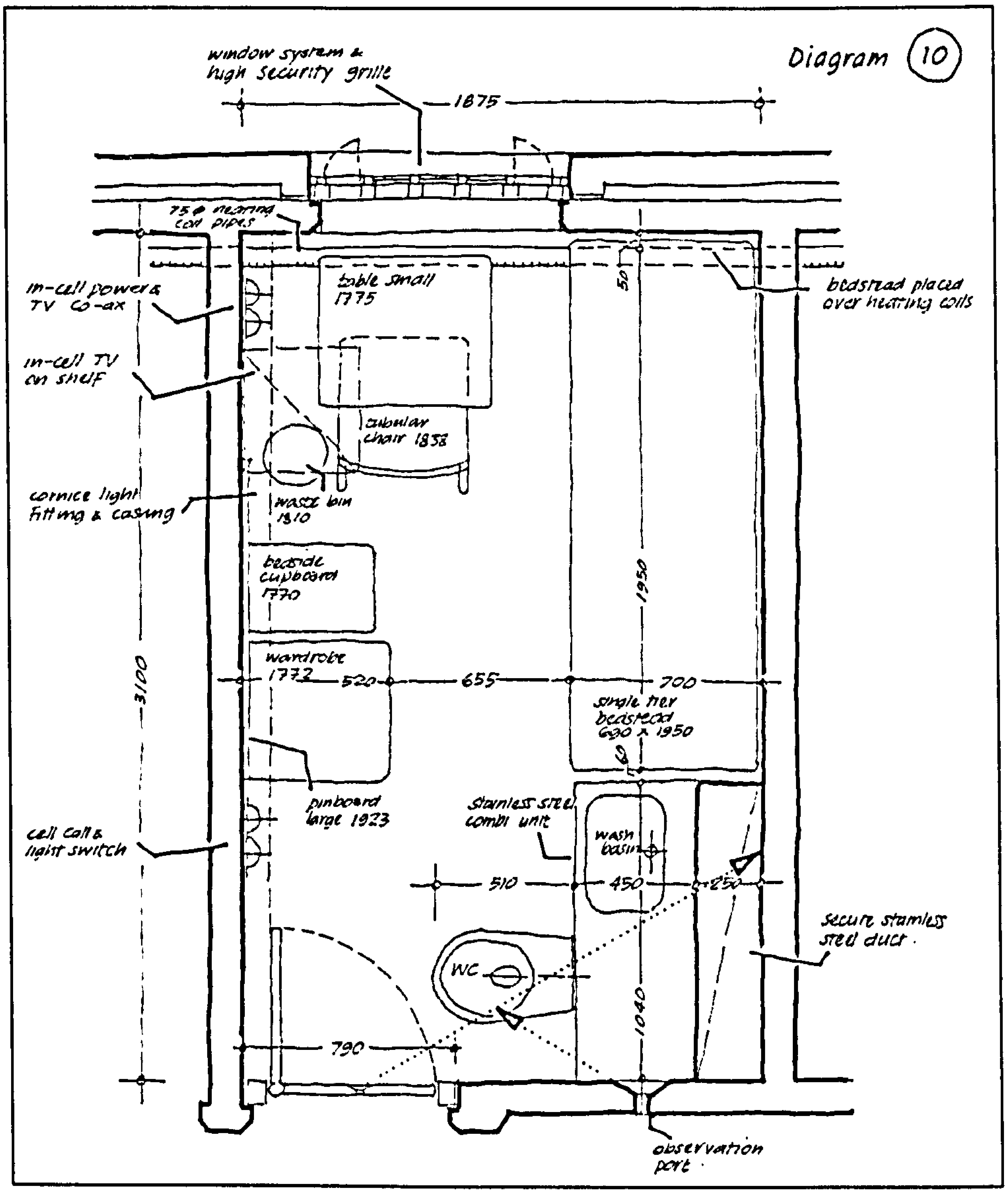


Figure 89: The UK minimum cell layout

8.2.3.1.3 Shading devices

The thermal effect of window size depends mainly on the shading conditions. The importance of shading devices is related to their control of solar radiation. Analysis of WWR and FF will show the impact of the increase of window size on the building solar heat gains. This section aims to investigate the impact of applying fixed shading devices to the proposed prison building.

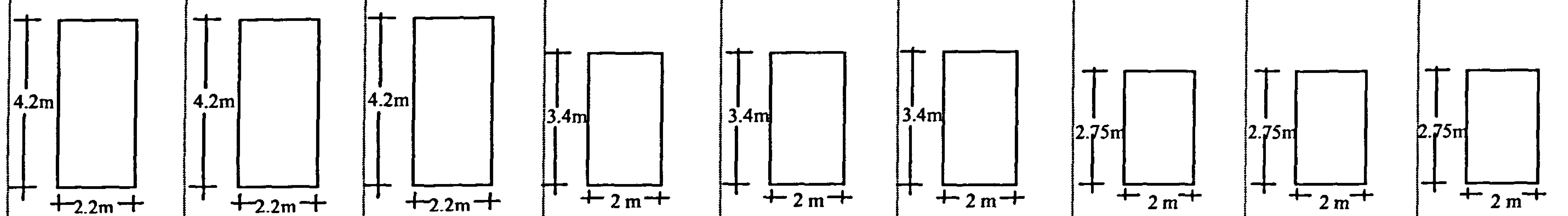
The effective length of the shading devices in the latitude in which Abu Dhabi is located is 360 mm (Monwar, 2001). Monwar followed the Utzinger method in his calculation of the effective size for the horizontal and vertical projection for the window opening in Makkah, which is located on the same latitude as Abu Dhabi.

Three scenarios are developed in this thesis. The 0.36 m shading devices are applied firstly on the UAE proposed window size (0.3m X 0.4m). The second simulation will examine the impact of the same shading device on the suggested window size (0.6m X 0.6m). The final scenario is based on the UK recommended window size (0.9m X 1 m).

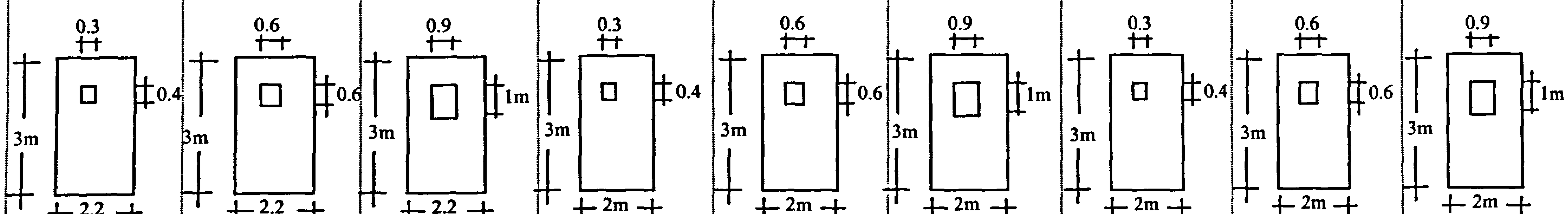
Table 14: The outline of the fenestration factor scenarios

	Base case cell size			UK recommended cell size			UK minimum cell size		
FF	**0.010** (Base case 1)	**0.030**	**0.076**	**0.016**	**0.047**	**0.118** (UK Recom Cell)	**0.019**	**0.058**	**0.146** (UK Min Cell)

The cell Plan



The cell elevation



8.2.3.2 Materials

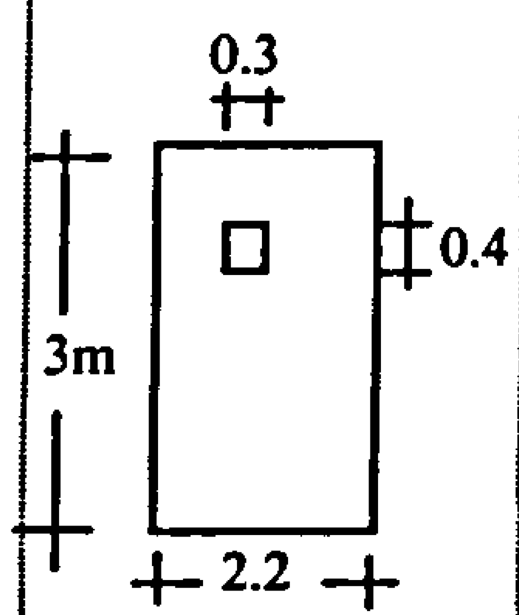
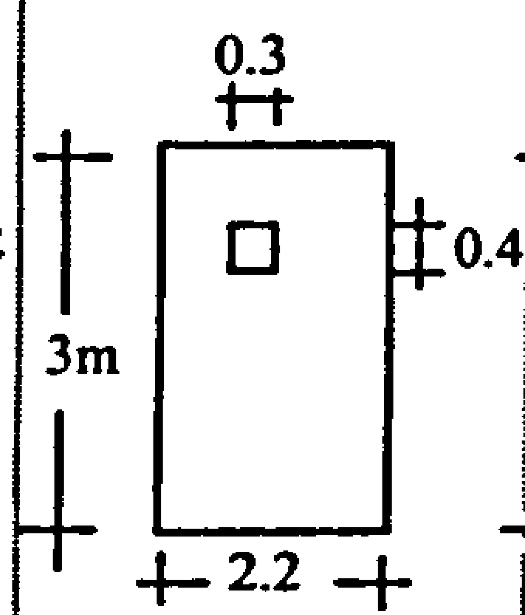
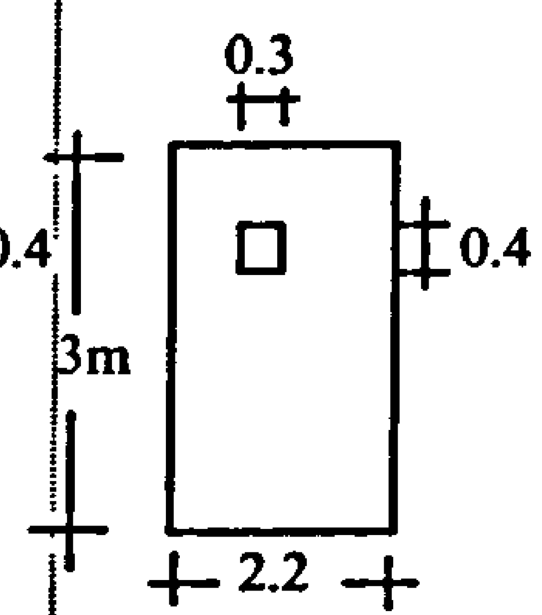
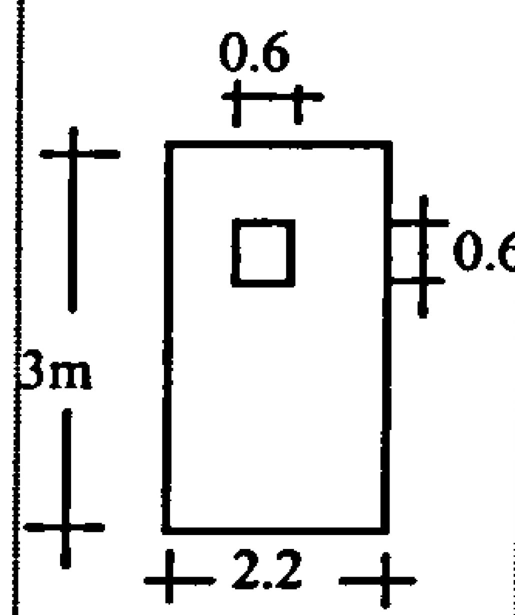
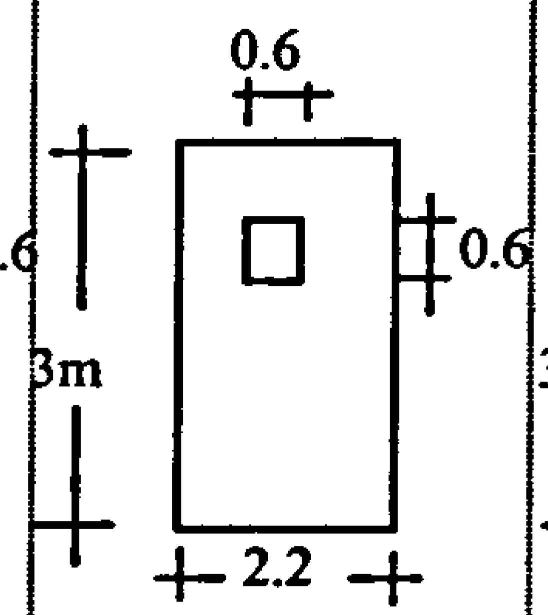
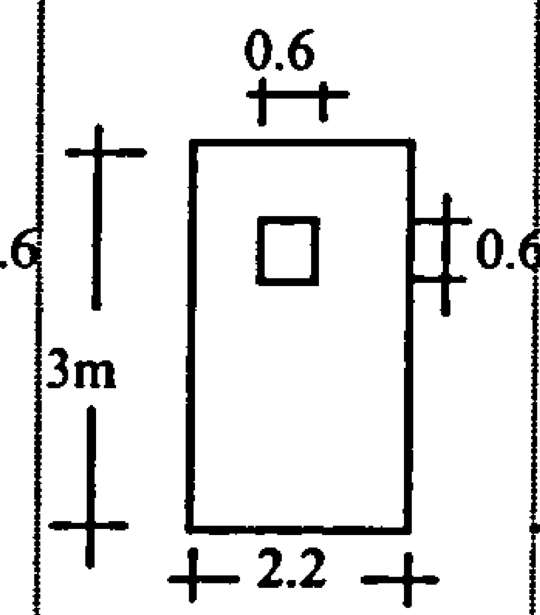
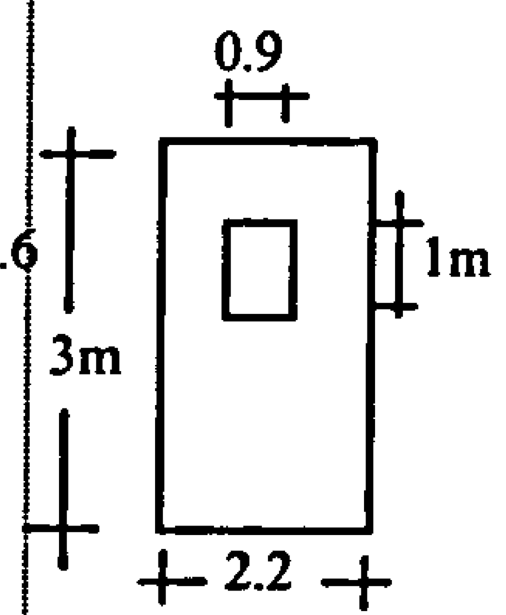
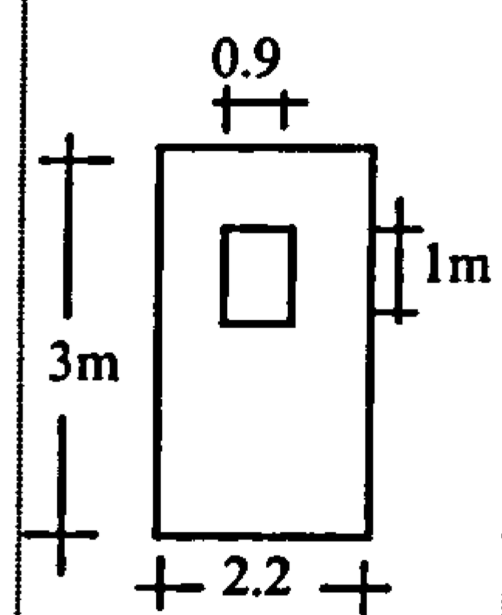
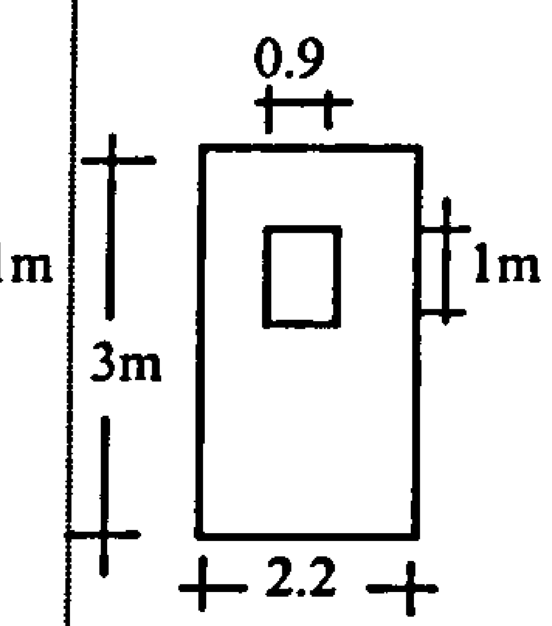
Prison buildings have a strict list of durable materials and glazing specification for the construction of their façades. The importance of the façade building materials on energy performance received early recognition in building energy performance studies. It is, hence, essential to investigate different material options in order to identify the most energy efficient combination of building materials. The thermal performance of the façade depends mainly on the following technical variables: **the envelope thermal transmittance (The glazing and the opaque U values), and the glass shading co-efficient**

8.2.3.2.1 The window thermal transmittance (Ug)

Studies carried out on office and residential buildings in hot climates have proved that the building envelope, primarily the glazing, is a major variable in determining the peak demands and energy consumption. It is essential to examine whether prison buildings follow the same pattern.

The glazing thermal transmittance is one of the important parameters that influence the windows' thermal performance. A comparison between nine scenarios is carried out in order to investigate the impact of glazing U value on the prison building's thermal performance. The outline of these scenarios is presented in Table 15. Three Ug values are examined. These are 2.801 (the base case Ug value) (double glazing (6mm+6mm)), 1.949 (low-e double glazing (6mm+6mm)), and 1.733 (low-e double glazing – domestic). The impact of Ug when the glazed area is increased is also examined. Six other scenarios are built, based on the alternative window sizes which are introduced in the WWR analysis (Table 15).

Table 15: The outline of the glazing thermal transmittance (Ug) scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Ug	**2.801** (Base case)	**1.949**	**1.733**	**2.801**	**1.949**	**1.733**	**2.801**	**1.949**	**1.733**
Window size	**Base case window**			**Suggested Window**			**UK recommended Window**		
The cell elevation									

8.2.3.2.2 The opaque thermal transmittance (Uo)

The low WWR in prison buildings makes thermal load of the envelope mainly dependent on the thermal performance of the wall opaque area. It is, hence, essential to search for the best (in both energy and security terms) material for the prison buildings' external walls. The opaque thermal transmittance (Uo) is very important in determining the thermal behaviour of the wall.

A comparison between nine scenarios is carried out in order to investigate the impact of opaque U value on the prison building thermal performance. The outline of the scenarios is presented in Table 16. Three Uo values are examined. These are **0.918** (the base case Uo value: brick-air l/w concrete block and l/w plaster), **0.772** (lightweight concrete block, air gap and plasterboard), and **0.651** (brick-air UF insulation l/w concrete block and l/w plaster). The impact of Uo when the glazed area is increased is also examined. Six other scenarios are built based on the alternative window sizes which are introduced in the WWR analysis (Table 16).

8.2.3.2.3 The shading co-efficient (SC)

The shading coefficient (SC) dominates solar gains in windows and thus affects the peak cooling demand and energy consumption. It is hence important to investigate the impact that SC has on energy performance of prison buildings.

Choosing alternatives for the SC proved to be a tricky task. It is important to isolate the influence of SC from the other technical variables of windows. The alternative SCs are very close to each other, as it was essential to keep Ug constant in the different scenarios.

The different SC alternatives are presented in Table 17. The three SC values examined are: **0.824** (the base case SC value), **0.769**, and **0.759**. The impact of SC when the glazed area is increased is examined in addition. Six other scenarios are built, based on the alternative window sizes which are introduced in the WWR analysis (Table 17).

Table 16: The outline of the opaque thermal transmittance (Uo) scenarios

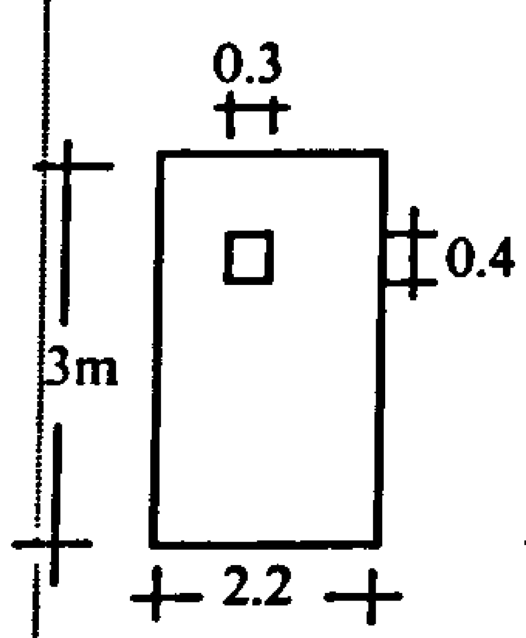
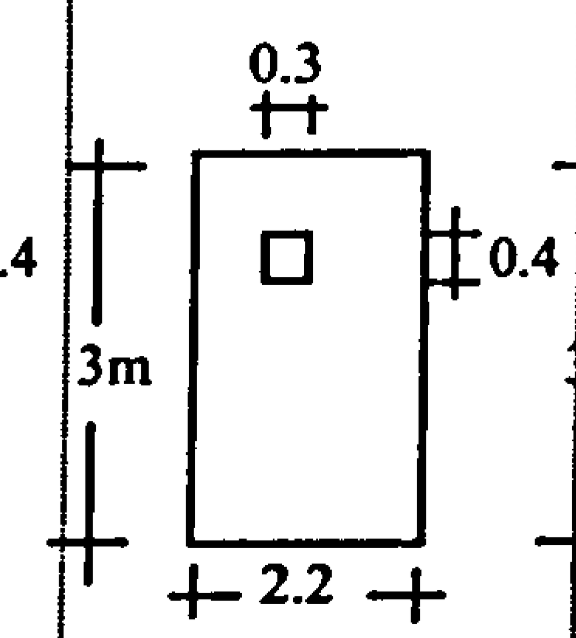
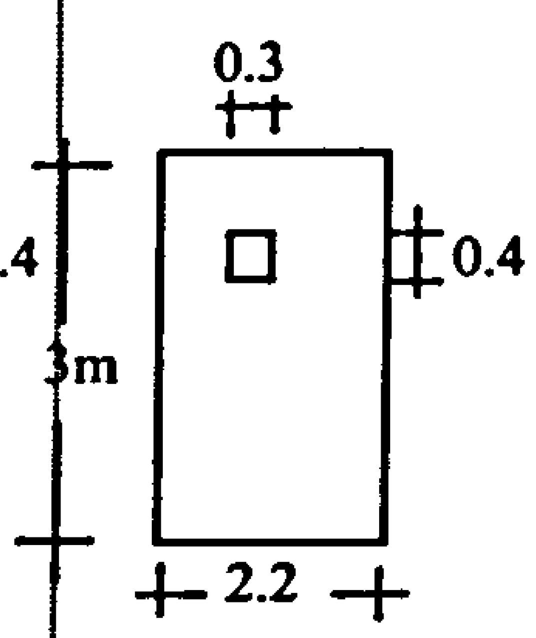
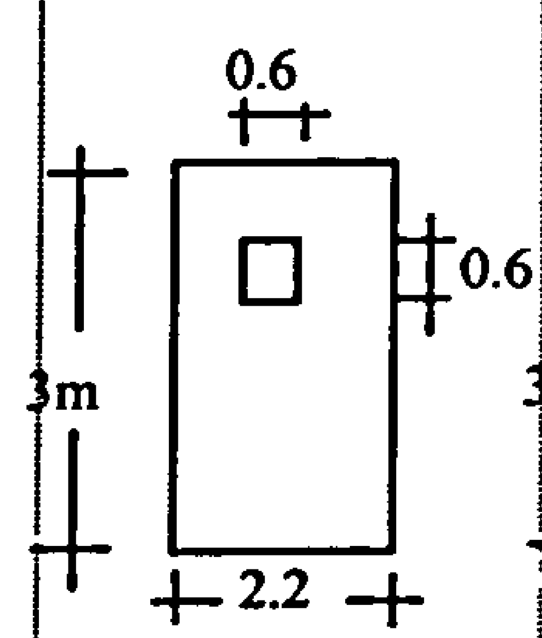
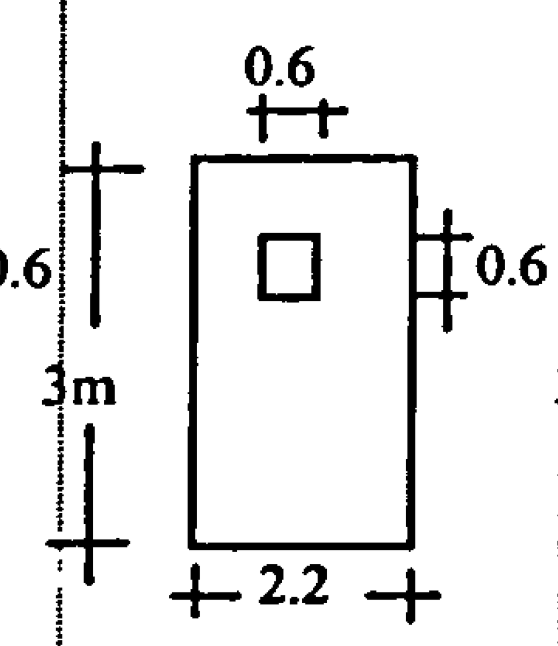
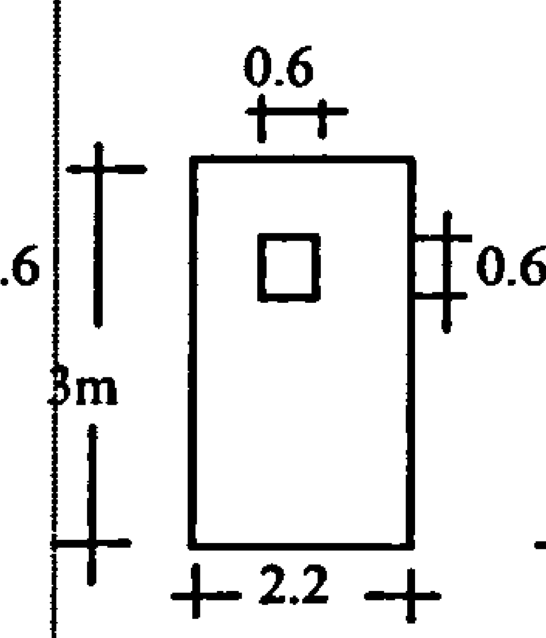
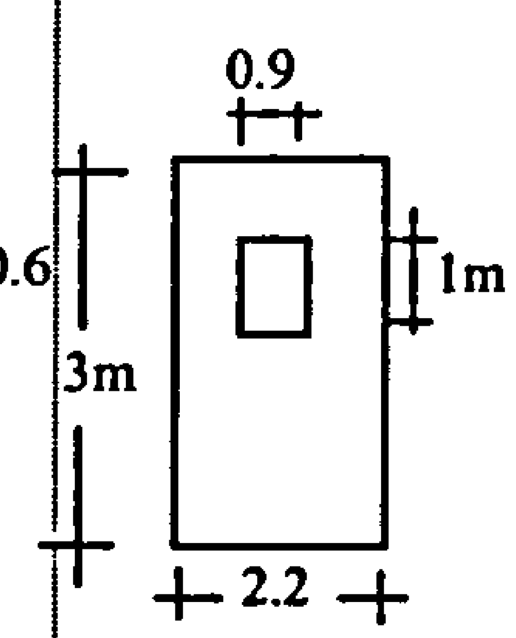
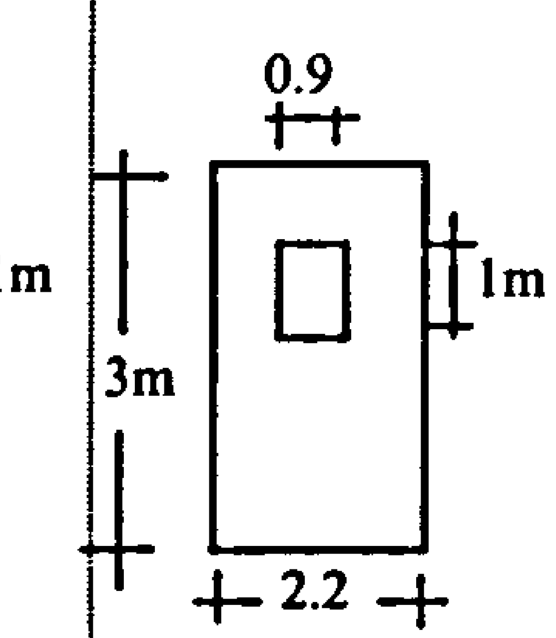
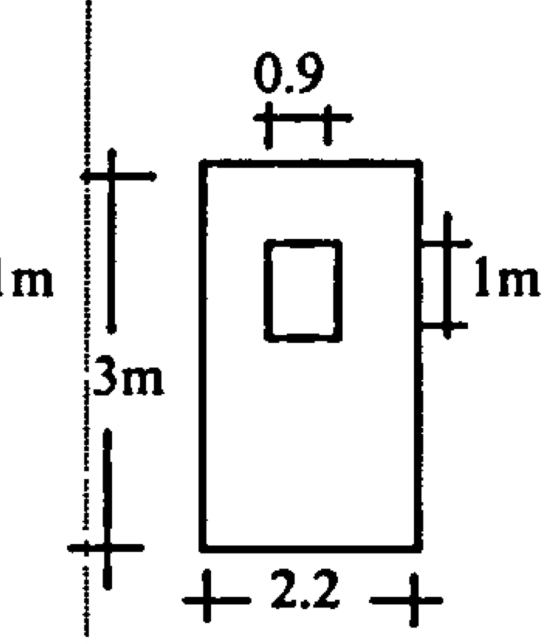
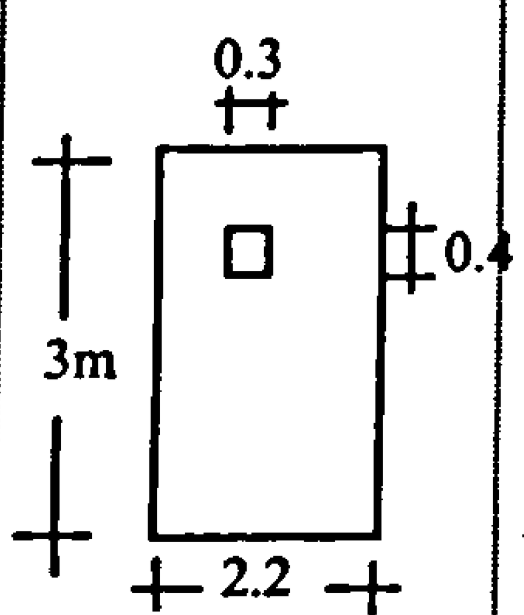
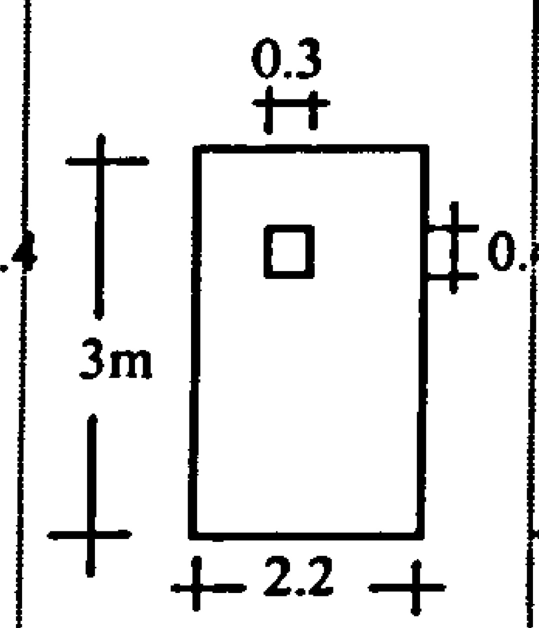
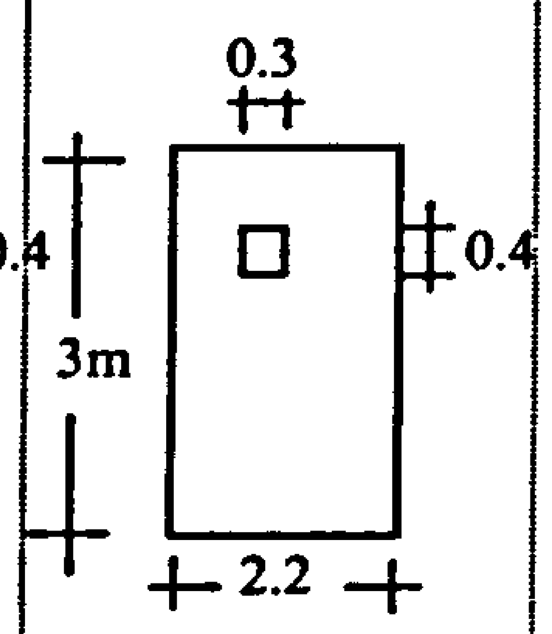
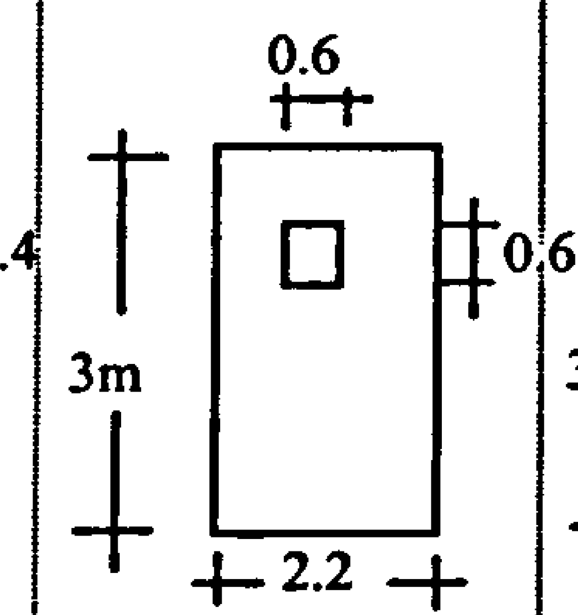
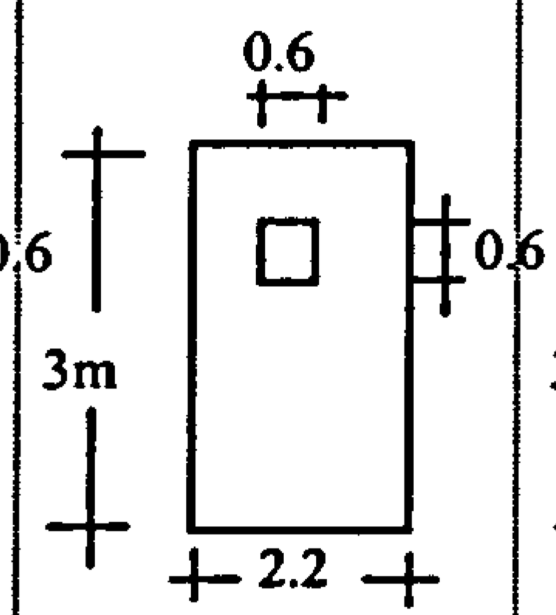
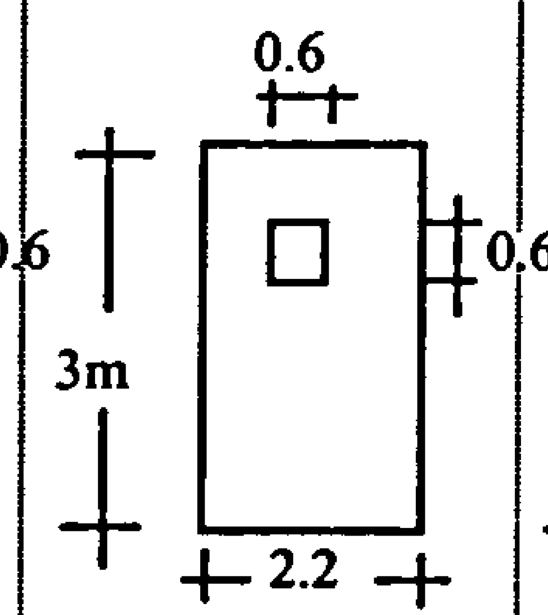
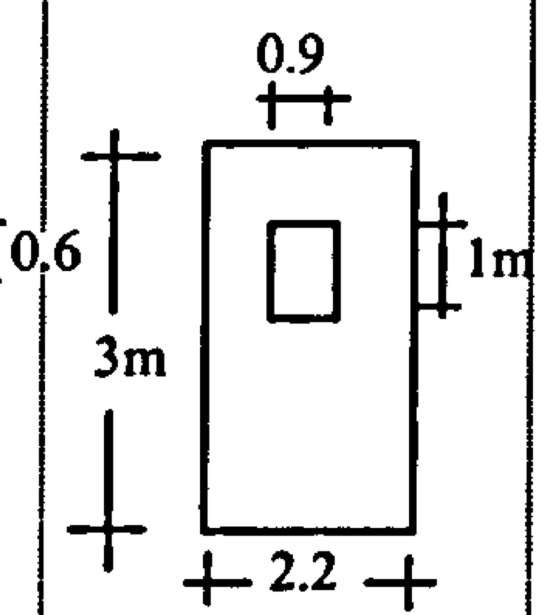
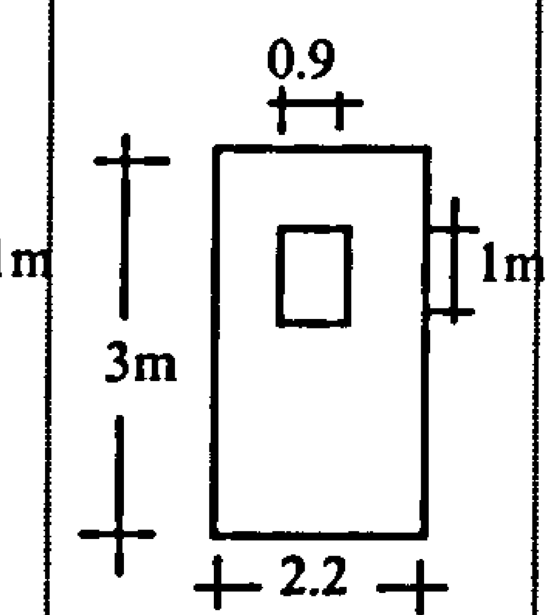
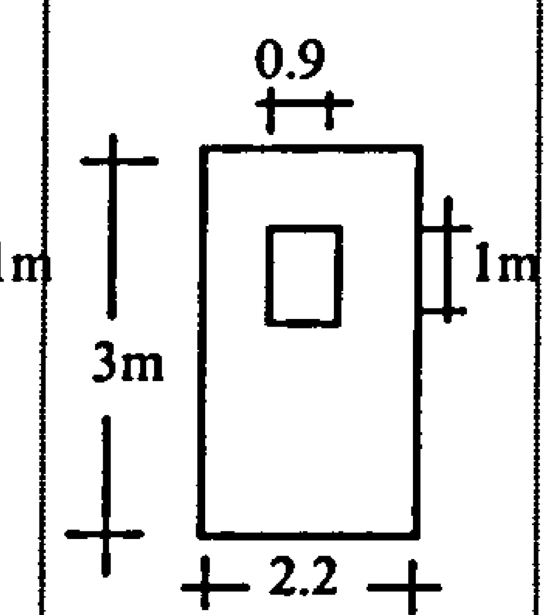
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Uo	0.918 (Base case)	0.772	0.651	0.918	0.772	0.651	0.918	0.772	0.651
Window size	Base case window			Suggested window			UK recommended window		
The cell elevation									

Table 17: The outline of the shading coefficient (SC) scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
SC	0.824 (Base case)	0.769	0.759	0.824	0.769	0.759	0.824	0.769	0.759
Window size	Base case window			Suggested window			UK recommended window		
The cell elevation									

8.2.4 Cell variables

The cell occupancy rate that the base case suggests is compatible with international standards. Most of the cells are designed for single occupation, however cells with capacity for four inmates' are provided in each unit, which can be utilised in special cases (two cells on each floor).

Four variables are investigated: the **Person per m^2, Person per Room, Elevation** and the **Fenestration Factor.**

8.2.5 Activities

The inmates' activities within the institute have major impact on the prison building energy performance (Al-Hosany and Elkadi, 2000a; Al-Hosany and Elkadi, 2000b). It is argued that relocation and mobility of activities helps, on one hand, to achieve energy efficiency and on the other, supports inmates' rehabilitation efforts (Al-Hosany and Elkadi, 2002).

Currently, there are no completely air-conditioned prisons in Abu Dhabi. Compiling data related to the inmates' daily profiles that can be applied in the scenarios was therefore not possible. Inmates in the existing prison institutions are allowed to move around the different parts of the building freely, throughout the day. Most of the inmate population were foreigners, and were to be deported after serving their sentence. It was believed, therefore, that rehabilitation programs would be wasted, as it would not benefit the society. The inmate population pattern has, however, changed. Still a minority, but UAE nationals compose 15% of the prison population (Figure 90 (CSD, 2000)). This dramatic change of the prison population pattern triggered a new penal thinking in the UAE, which needed to be reflected in the design of both the prison building and the inmates' programs. The inmates suffered major physical and physiological problems which resulted from the severe thermal discomfort. This led to serious riots and protest among the inmate population. However, thermal comfort cannot be achieved using only passive means in the harsh climatic conditions of Abu Dhabi (Chapter 2). The introduction of air-conditioning is the first step towards a positive environment that is sympathetic to the inmates' basic human needs.

A more systematic pattern for the inmates' daily activities is, however, essential in order to minimise energy consumption for air-conditioning.

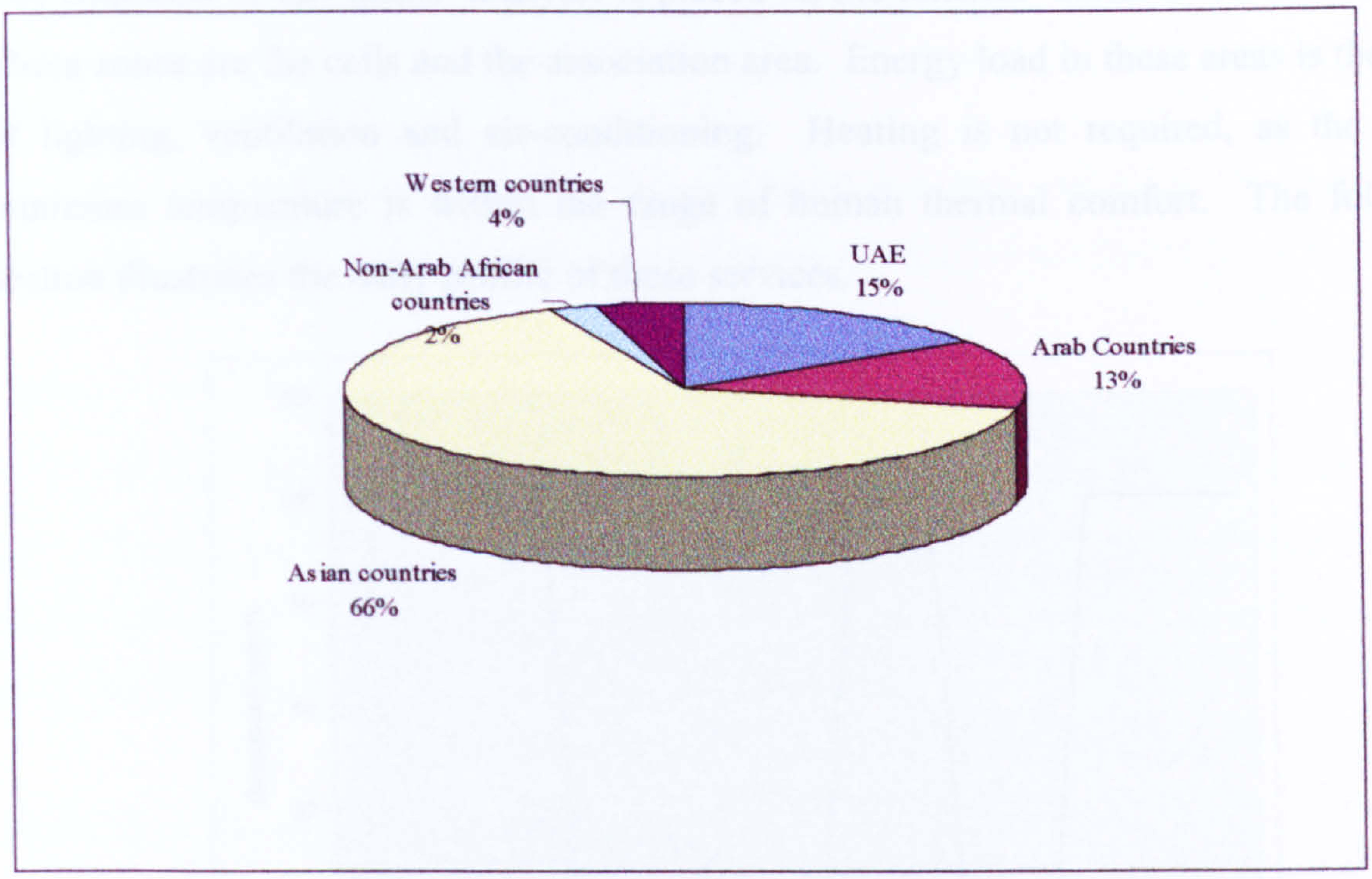


Figure 90: Nationalities of the UAE prison population

The daily, weekly and monthly profiles of inmate activities, and different zones cooling and lighting loads have been designed based on suggestions from prison governors in the UAE. The following section illustrates in detail the different profiles.

8.2.5.1 Inmates program

The inmates' daily routine begins at 06:00. The case, however, is different for "Muslim" inmates who start their day with the Morning Prayer, whose timing differs seasonally. 06:00 is, however, the time that the inmates are expected to leave their cells and head to the dining room to have breakfast.

Inmates are allowed to use the outdoor activity centre from 7:00 AM until 9:00 AM. The association area is open to the inmates starting from 08:00. However, all inmates are expected to be there between 09:00 and 12:30. Lunch is served at 13:00 and inmates return to their cells after lunch and stay until 16:00. Inmates have the choice either to spend their afternoon in the association area, or practice outdoor activities from 16:30 until 18:00. All inmates, however, must return to the association area at 18:00 and stay there until dinnertime, which is 20:00. The cell doors are locked at 21:00 and inmates are expected to be sleeping at 21:30. Figure 91 and Figure 92 show the occupancy profile in the cells and the association area respectively.

The emphasis of this thesis' analysis is placed on the inmates' zones in the housing unit. These zones are the cells and the association area. Energy load in these areas is the result of lighting, ventilation and air-conditioning. Heating is not required, as the winter minimum temperature is within the range of human thermal comfort. The following section illustrates the daily profile of these services.

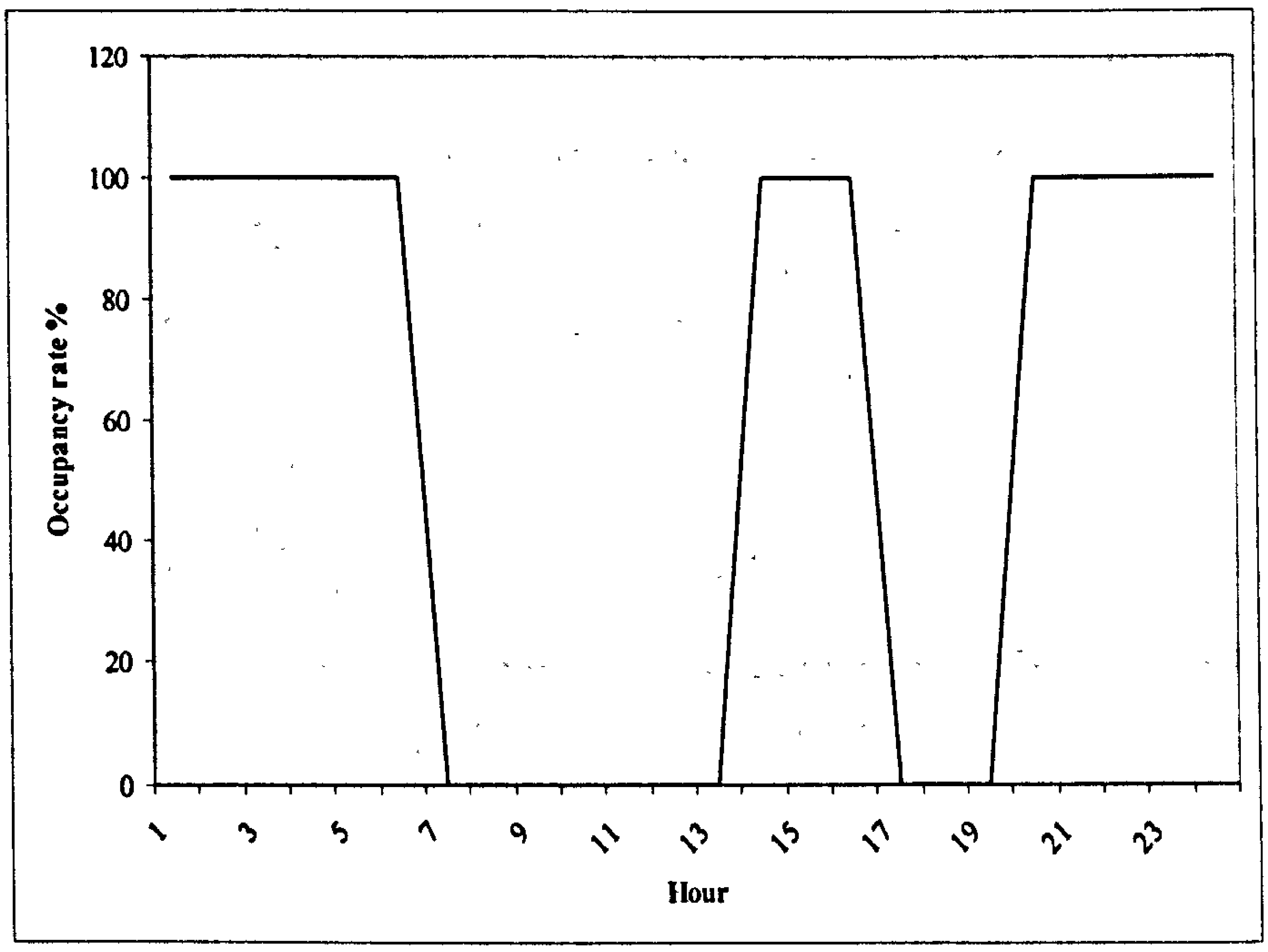


Figure 91: The cells daily occupancy profile

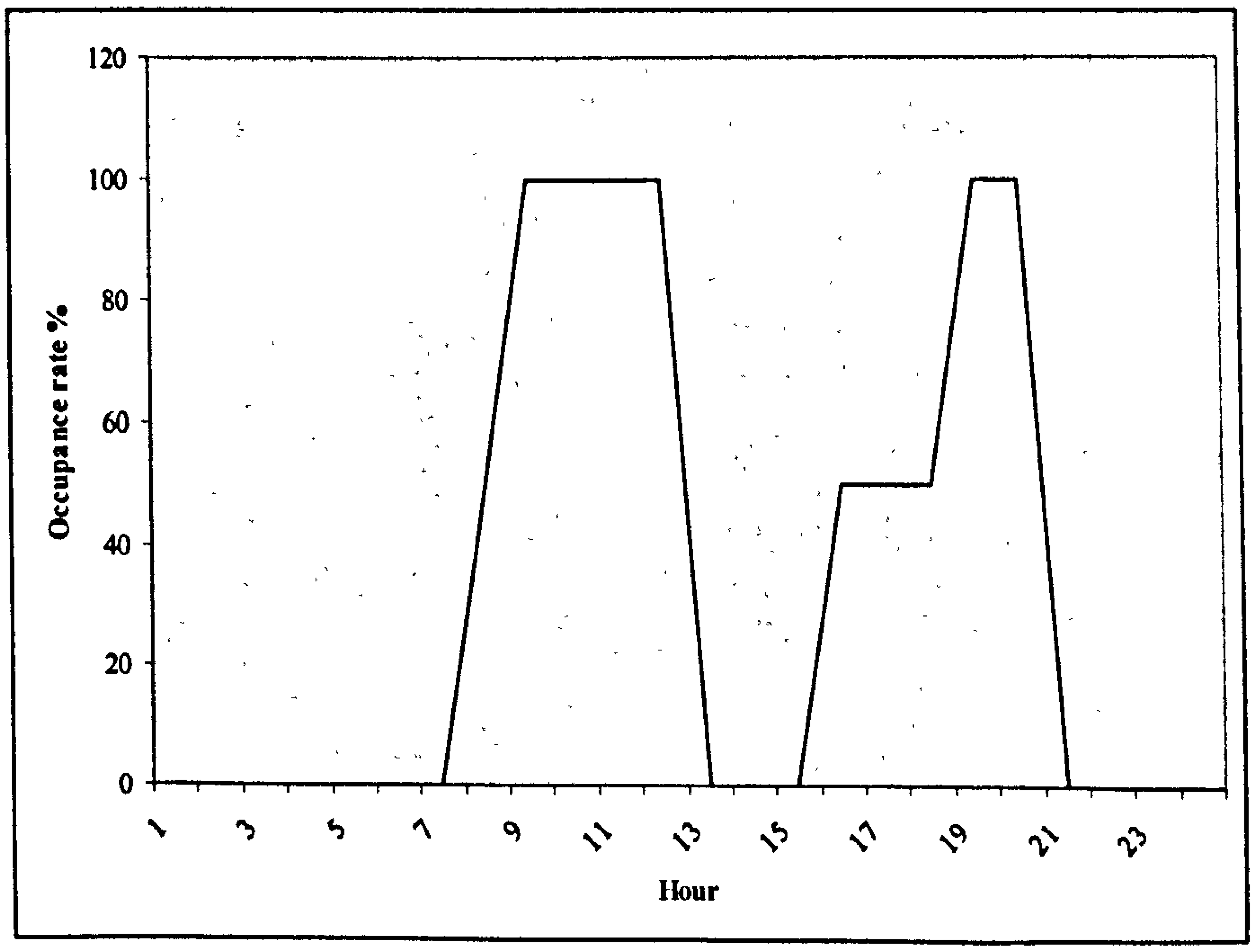


Figure 92: The association area daily occupancy profile

8.2.5.2 Cooling profile

Different cooling profiles are suggested for the different zones. The following sections illustrate these profiles in detail.

8.2.5.2.1 Cells cooling

Inmates are to be in the cells from 21:00 until 06:00 and from 14:00 until 16:30 on a daily basis. The cells cooling profile reflects the inmate occupancy profiles (Figure 91).

8.2.5.2.2 Association area cooling

The cooling profile of the association area follows the inmate occupancy profiles (Figure 92). The system is totally turned off between 20:00 and 08:00, and between the hours 12:30 and 16:00. It is switched on (full power) from 08:00 until 12:30 and between the hours 16:00 and 20:00.

8.2.5.3 Artificial lighting profile

The zones of which the artificial lighting profile is under investigation, are the cells and the association area.

8.2.5.3.1 Cells lighting profile

The lights are turned on in the cells for only two and a half hours on average per day. This is between 05:00 and 06:00, and between 20:00 and 21:30. The limited window to wall ratio minimises the influence of seasonal variations. Figure 93 shows the cells daily lighting profile.

8.2.5.3.2 Association area lighting profile

For security reasons, the lights are never totally turned off in this zone. When not occupied (from 21:00 to 08:00 and from 12:30-17:00) the artificial lighting will function at 10% capacity. This will increase to 60% during the daytime occupation of the area (from 08:00 to 12:30 and from 17:00 to 18:30). The zone will be 100% (artificially) lighted from 18:30 to 21:00 (Figure 94).

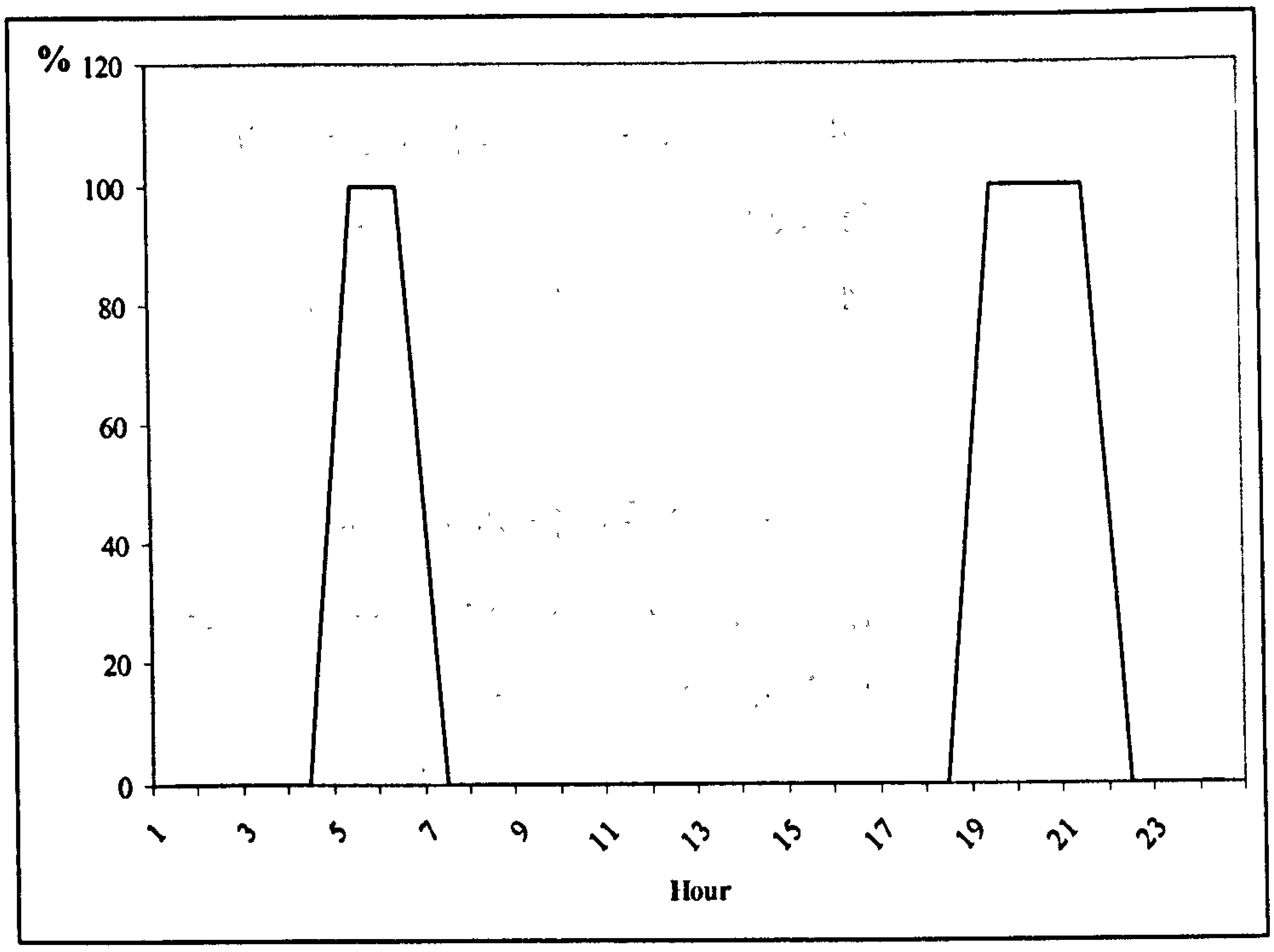


Figure 93: The cells area daily lighting profile

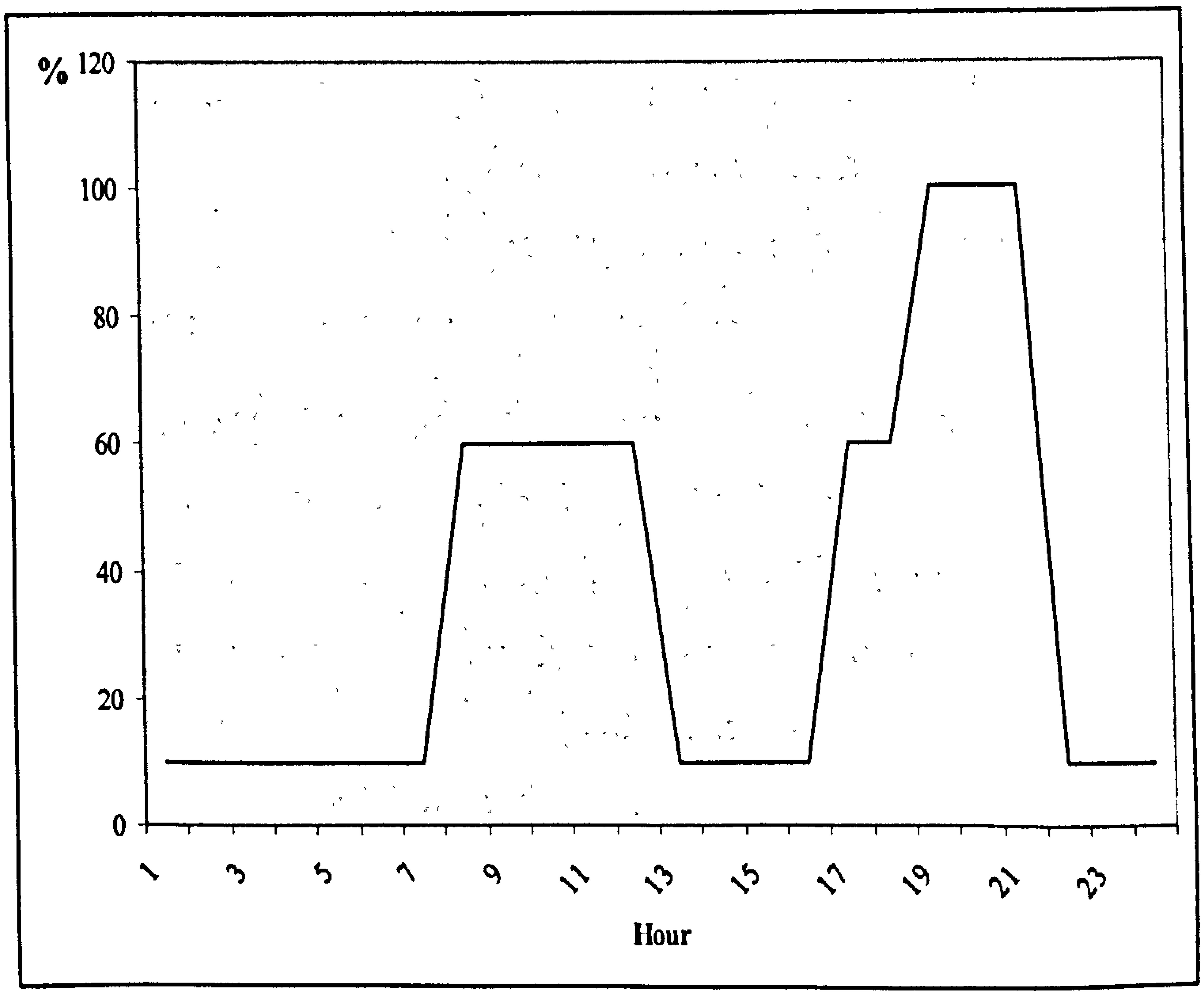


Figure 94: The association area daily lighting profile

8.3 Evaluation of the simulation model output

This section aims to illustrate and critically analyse the results of the simulation of the different scenarios. However, it is essential beforehand to understand the energy performance of the base case in order to identify the impact of the different scenarios on the building energy performance.

8.3.1 The base case thermal/energy performance

This section presents the simulated thermal behaviour of the base case. The annual loads of the building and the cells area are presented. As the total peak load in the peak month determines the chillers' loads, it is important to investigate the hourly thermal behaviour of the building. Such analysis can also help in understanding the relationship between occupancy and activities of inmates in different parts of the prison.

Additionally, to examine the sensitivity of the cooling load to different architectural configurations (i.e. orientation, occupancy patterns, and elevation) more detailed analyses are obtained by investigating different selected cells.

8.3.1.1 The total loads

Figure 95 shows the total and the per square metre annual and peak cooling loads, for the whole building and for the cells area. The peak month is August (Figure 3 A-D). The building and the cells behaviour on the peak day shows the sensitivity of the cooling load to the inmates' daily programme. This is mostly evident in the variation of the peak hour, between the cells and the total building (Figure 95: E-H).

It is important, however, to distinguish the contribution of the envelope, which is the main concern of this thesis, to the total load. Table 18 presents the results of the base case simulation and shows the envelope's role in the building cooling load. The minor solar load is instantly noticed (1.3 %); this is, however, related to the limited glass area in the prison building. Hence the conduction load seems to be the main contributor to the envelope load and, consequently, to the total load.

Table 18: The role of the building envelope in the building cooling load

Load Type	Base case
Conduction gain KWH/m^2	43.15
Solar gain KWH/m^2	1.92
Total envelope heat gain KWH/m^2	45.08
Annual total cooling load KWH/m^2	143.68
Conduction load in relation to total cooling load %	30.03
Solar load in relation to total cooling load %	1.34
Envelope load in relation to total cooling load %	31.37

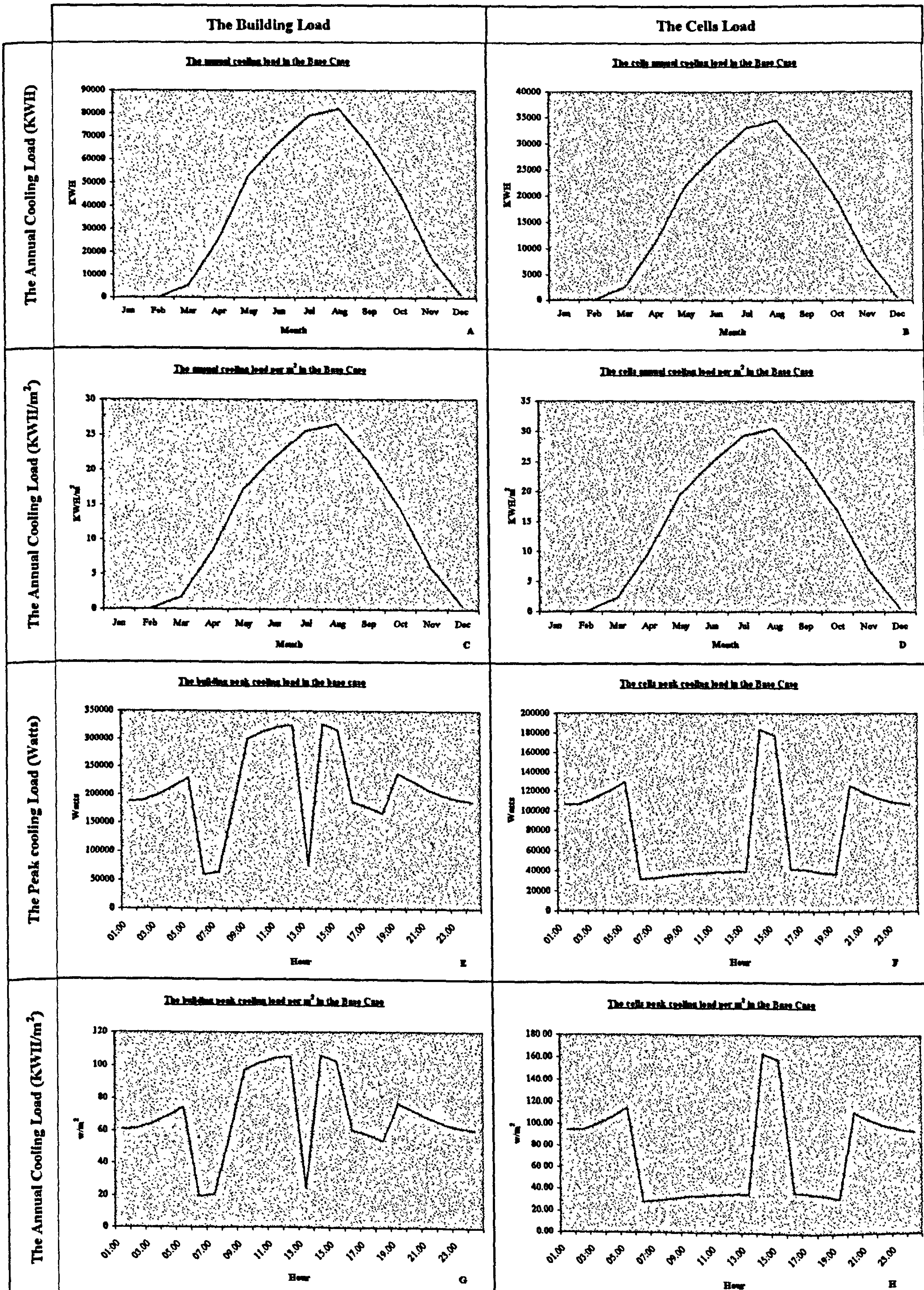


Figure 95: The total peak and annual cooling loads in the base case

The cells load comprises 42.3% of the total building load (Figure 96) while occupying 36.6% of the total built up area. It is, hence, essential to investigate the behaviour of the individual cells in different orientations of the building.

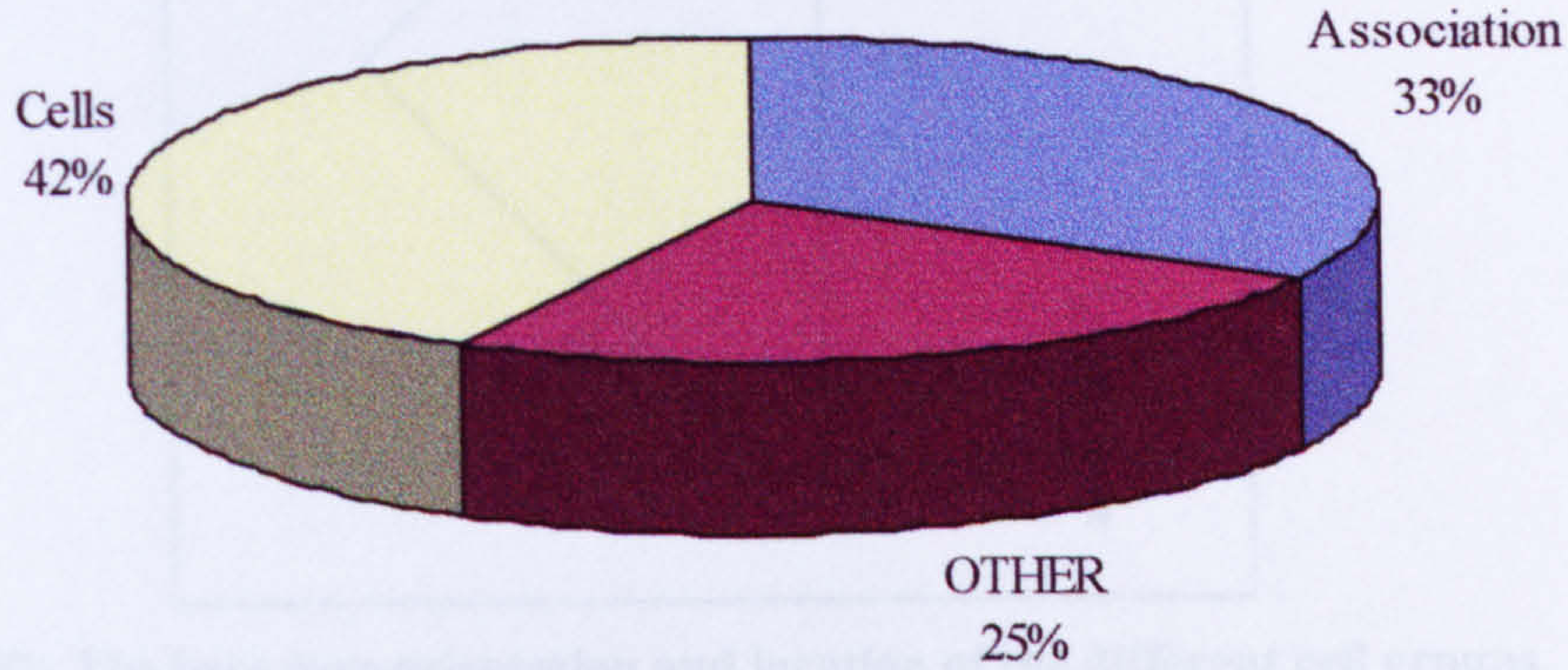


Figure 96: The contribution of different zones to the total building cooling load

8.3.1.2 The cells analysis

Detailed investigation was carried out on twelve cells to examine the impact of orientation, elevation, and occupancy rate on the cells cooling load. The cells are categorised in three groups which are:

1. **O_1**: Four cells located on the **East** orientation. Two single cells. One is located on the ground floor and the other is located on the first floor. Each has the same area, that is 10.56m^2. The other two are multi-occupancy cells designed to host four inmates in an area of 22m^2 (5.5m^2 per inmate). The two cells are located on different levels (ground and first floors).

2. **O_2**: Four cells located on the **North West** orientation. Similar to **O_1**, these are two single cells and two multi-occupant cells located on different levels.

3. **O_3**: Four cells located on the **South West** orientation. The cell patterns follow the ones in O_1 and O_2.

Figure 97 shows the location of the different cell categories in the prison building.

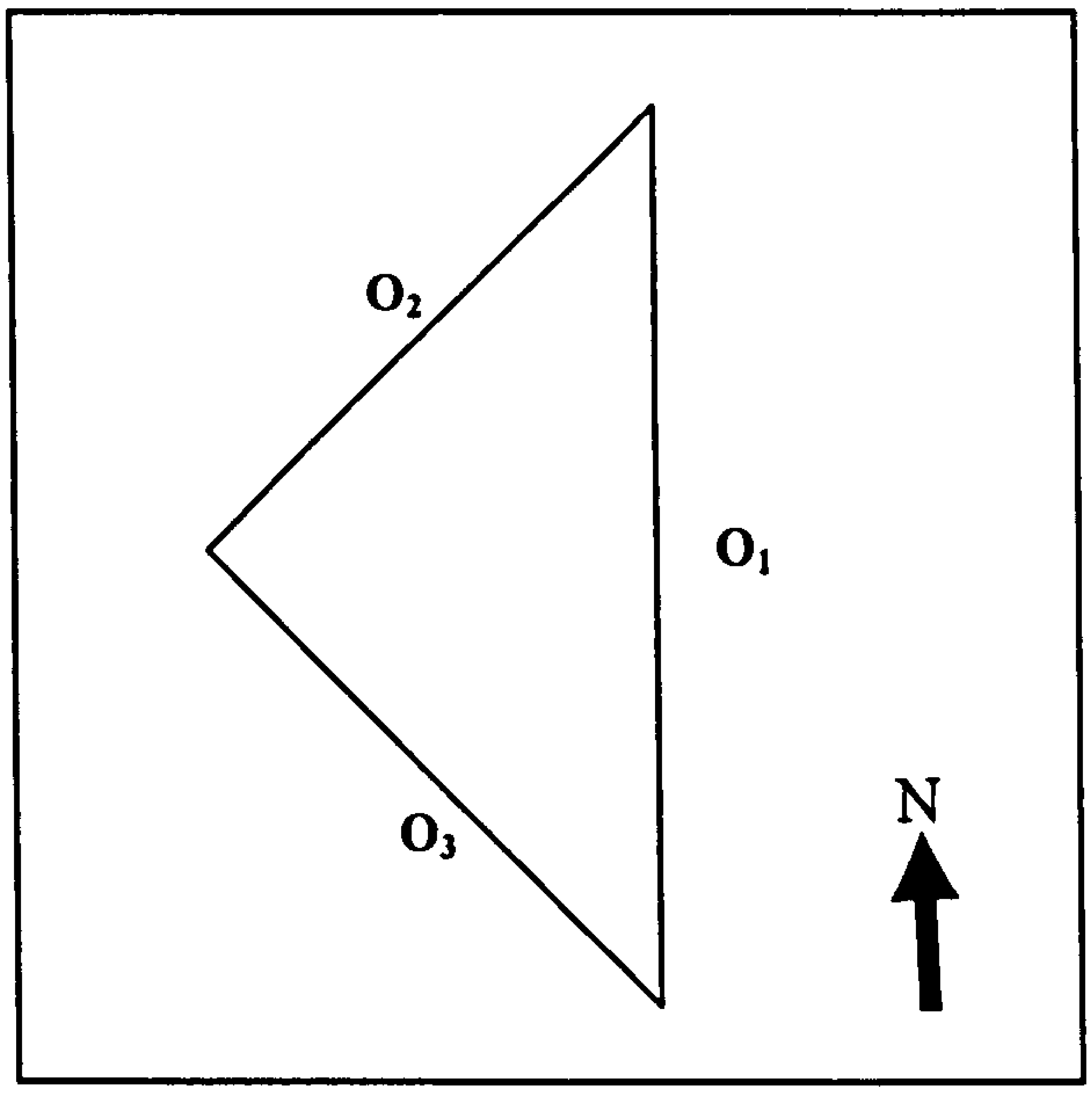


Figure 97: The base case orientation and location of the different cell groups.

8.3.1.2.1 The cells total cooling load

Figure 98 shows the annual and the peak cooling load for the selected cells. The peak month for all the cells is August. The figures show that **orientation** had a very minor impact on the total load. In the annual load (Figure 98 A-C) the cells in group O_3 (the South West orientation) scored the highest load. The group's single and multiple occupancy cells are 5.2 % higher than the cells located on O_2 (the North West orientation). However, the difference between O_3 and O_1 annual loads is very minor, only 0.1%.

On the peak day, the pattern is slightly different (Figure 98 D-F). O_1 peak cooling load is the highest among the three orientations. The difference between O_1 and O_3 is, however, a mere 0.9%. O_2 is, on the other hand, 1.8% lower than O_1. The insignificant role of orientation can be related, however, to the limited glass area, which reduced the impact of solar heat.

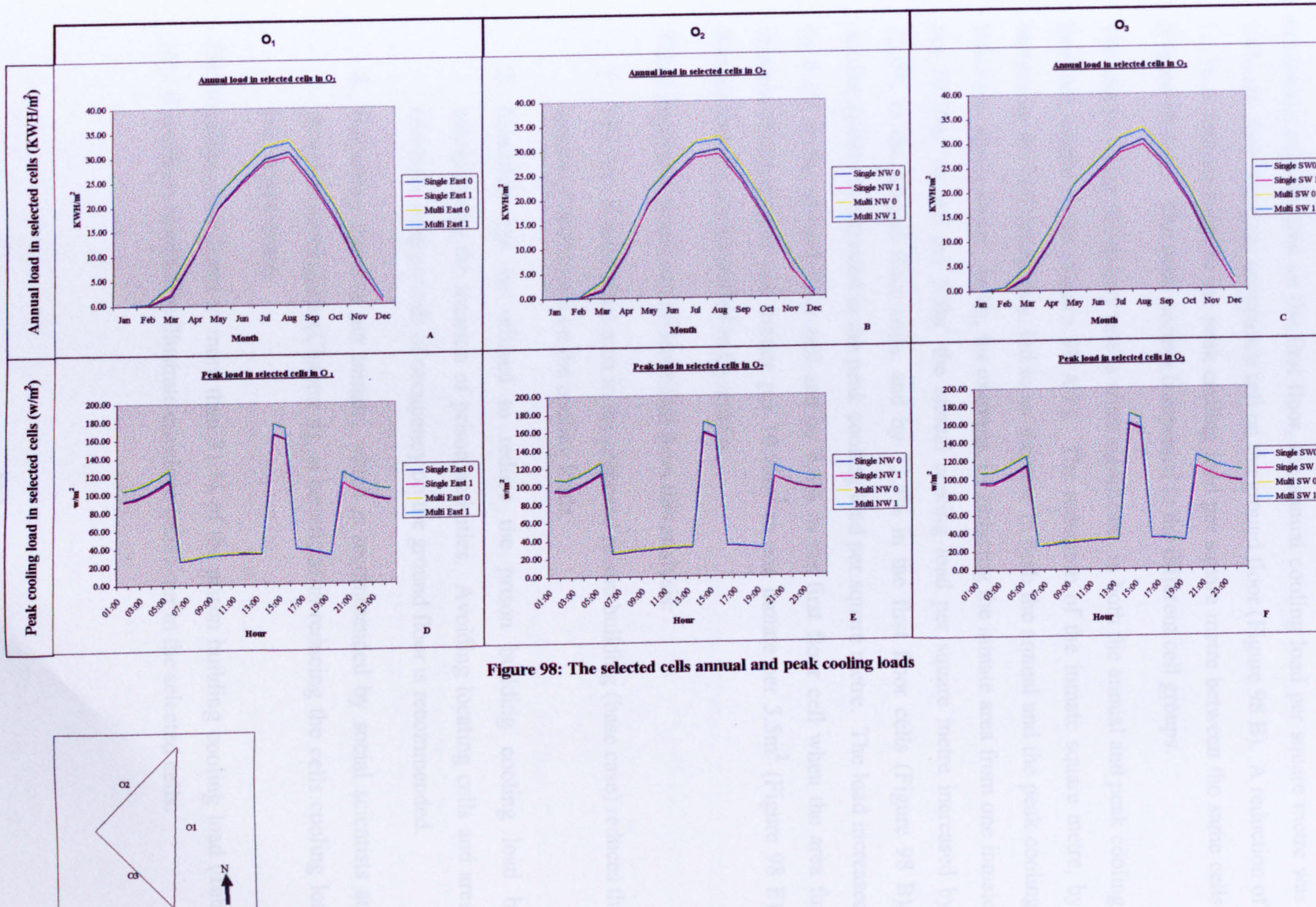


Figure 98: The selected cells annual and peak cooling loads

The impact of the cell **elevation** and **occupancy rate** are, however, more significant in both the annual and the peak loads. In O_2, for example, locating single cells on the first floor led to 2.1% reduction in the annual load per square metre (Figure 98 B) and 1.7% reduction in the peak cooling load per square metre (Figure 98 E). In the multi occupancy cells located on the first floor, the annual cooling load per square metre was 1.4% less than the same occupancy cell on the ground floor (Figure 98 B). A reduction of 1.2 % is also recorded in the peak cooling load per square metre between the same cells (Figure 98 B, E). The same pattern is repeated in the different cell groups.

The impact of the occupancy rate is more significant, in both the annual and peak cooling load per square metre (Figure 98 A-F). The reduction of the inmate square metre, by increasing the cell occupancy, led to an increase in both the annual and the peak cooling loads per square meter. In O_2, for example, by reducing the inmate area from one inmate per 10.56m^2 to one per 5.5m^2 the annual cooling load per square metre increased by 12.9% in the ground floor cells, and by 13.5% in the first floor cells (Figure 98 B). Similar pattern is recorded in the peak cooling load per square metre. The load increased by 8.1% in the ground floor cell and by 8.6% in the first floor cell when the area for inmates changed from one inmate per 10.56m^2 to one inmate per 5.5m^2 (Figure 98 E). Similar patterns are identified in O_1 and O_3.

Three important points can be identified from this analysis:

1. The very limited glass area in the proposed prison building (base case) reduces the impact of orientation on the cooling loads.
2. Elevation can be utilised to reduce the prison building cooling load by manipulating the location of prison activities. Avoiding locating cells and areas that have long periods of occupancy on the ground floor is recommended.
3. Increasing the area per inmate, which is recommended by social scientists and prison psychologists (Chapter 4), is beneficial in reducing the cells cooling load per square metre.

The envelope contributes to more than 31 % of the prison building cooling load (Table 18). It is hence, essential to illustrate envelope behaviour in the selected cells.

8.3.1.2.2 Role of the envelope in the cooling load of the selected cells

The solar, conduction, and the envelope (solar + conduction) per square metre annual loads for the selected cells are presented in Figure 99 (A-I). The peak loads per square metre (solar, conduction, and envelope) are presented in Figure 100 (A-I). The relationships between these loads and the building total loads are presented in Table 19. The cells with the lowest and the highest cooling loads are highlighted in the table.

Table 19: The envelope loads in relation to the total building load (%)

Load type	Single cells						Multi occupancy cells					
	East 0	East 1	NW 0	NW 1	SW 0	SW 1	East 0	East 1	NW 0	NW 1	SW 0	SW 1
Annual Solar Load %	4.24	4.33	2.65	2.70	4.48	4.56	3.57	3.61	2.21	2.24	3.74	3.78
Annual Conduction Load %	36.69	35.40	32.94	31.35	37.70	36.53	31.04	29.73	27.42	25.90	31.59	30.37
Annual Envelope Load %	40.94	39.73	35.59	34.06	42.18	41.09	34.61	33.34	29.62	28.14	35.33	34.15
Peak Solar Load %	1.52	1.54	1.09	1.11	1.21	1.23	1.34	1.36	0.97	0.98	1.08	1.09
Peak Conduction Load %	21.37	20.00	20.43	18.99	20.99	19.59	19.35	18.36	18.51	17.51	18.96	17.98
Peak Envelope Load %	22.89	21.54	21.52	20.10	22.20	20.82	20.69	19.72	19.48	18.49	20.04	19.07

From the **orientation** point of view, the patterns of the envelope loads in the selected cells follow those of the total loads. The lowest loads are recorded in O_2, which is located on the North West orientation, while the highest annual loads are found in O_3, that is the South West oriented cells, and the peak load is recorded in O_1 which is East oriented. The difference between the loads in O_1 and O_3 is however, minor, less than 1% in both the annual and the peak load (Figure 99 and Figure 100).

The impact of **elevation** on the selected cells total load follows the pattern of the envelope load. The envelope thermal load of the cells that are located on the first floor is less than the same load in the cells located on the ground floor. This applies to both peak and annual cooling load (Figure 99 and Figure 100).

Interestingly, in the winter months the impact of elevation is reversed. For example the annual envelope load in O_3 shows that the cells located on the ground floor recorded less cooling load than the cells located on the first floor (Figure 100: I).

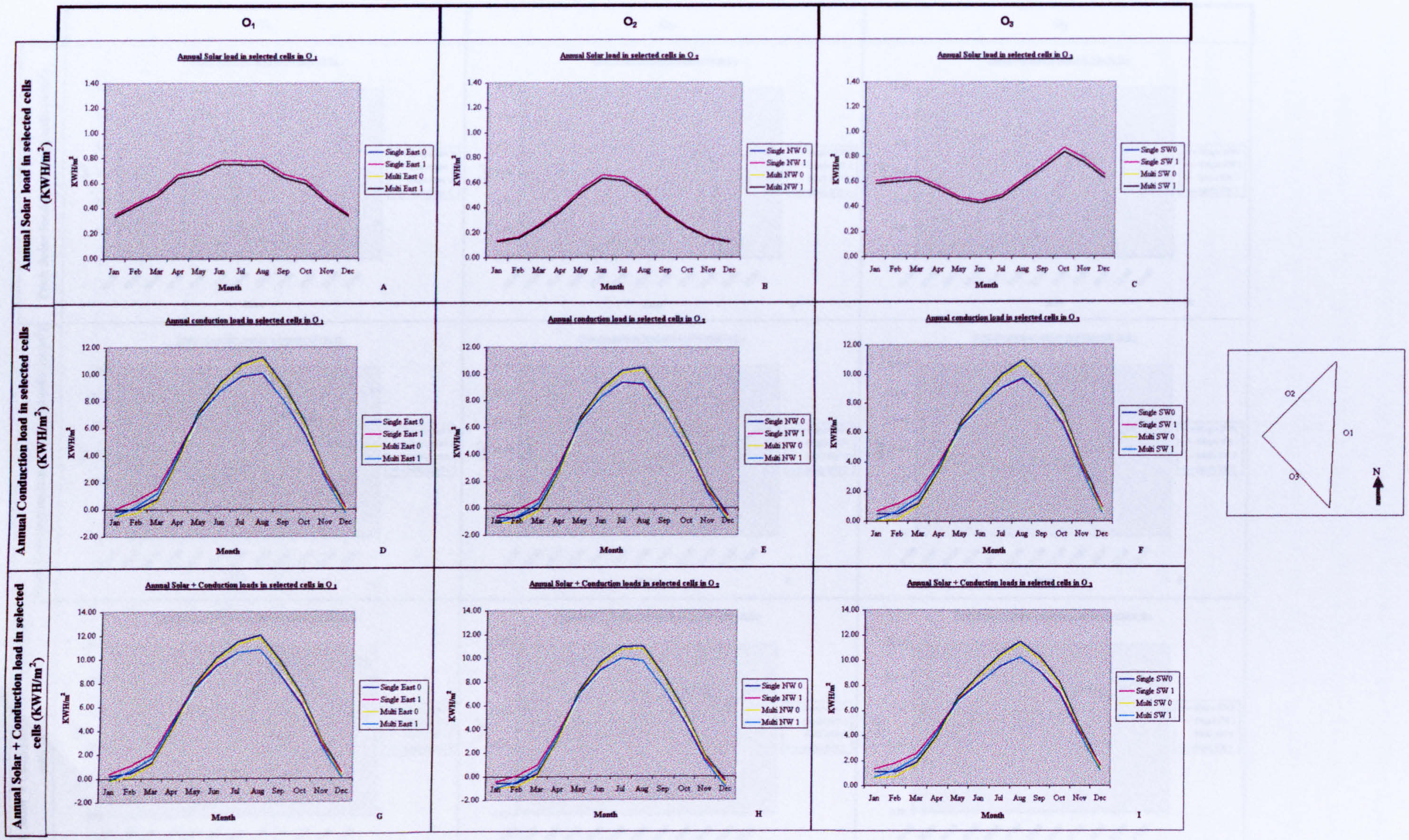


Figure 99: The selected cells annual solar and conduction loads

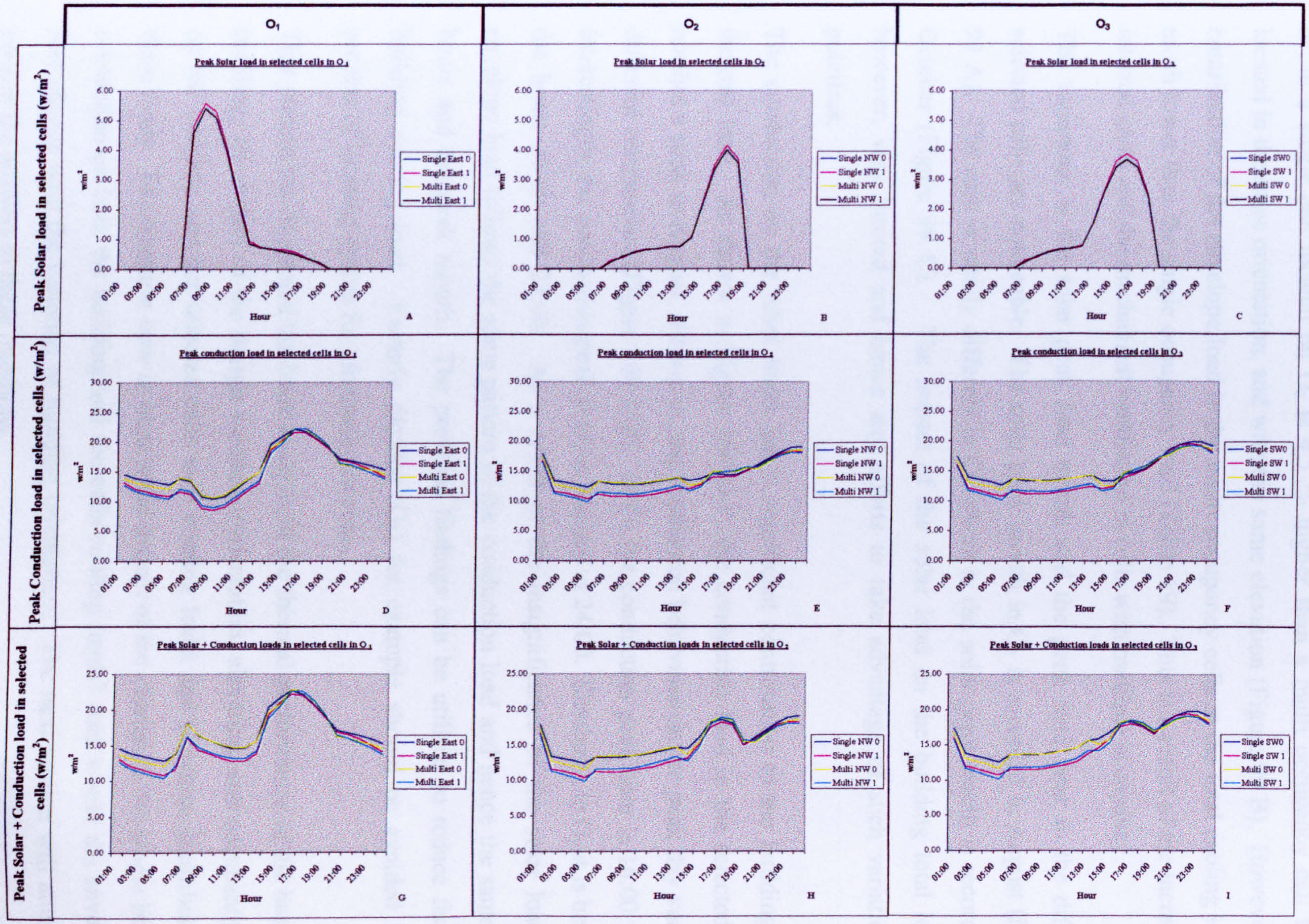


Figure 100: The selected cells peak solar and conduction loads

The impact of **area per inmate** on the envelope thermal shows a different pattern. The cells with a low area per inmate ($5.5m^2$) had a much lower envelope load than the cells with high area per inmate ($10.56\ m^2$). For example the envelope annual cooling load per m^2 in a single cell located on O_2 is 4.5 % higher than a multi occupancy cell that is located in the same orientation, and with the same elevation (Figure 99 B). However, the contribution of the envelope load in the multi occupancy cells to the total cooling load is much lower than the single occupancy load (Table 19). This is a result of the increase in internal gains and the mechanical ventilation in cells with multiple occupancy.

The variations in the solar peak load month and the peak load hour in the different selected cells are noticeable. The solar peak month in O_1 is recorded in August (Figure 99 A). The case is totally different in O_3 where is the solar peak month is recorded in October (Figure 99 C). The impact of the solar load on the building total load is however, very limited and hence any efforts to take advantage of such variations is pointless.

The conduction on the other hand, has a significant contribution to the building total thermal load. As shown in Figure 100 D-F, the conduction load in the selected cells reaches a peak in August. However, the conduction behaviour on the peak day varies in different orientations (Figure 100 D-F). In O_1 the conduction peak hour is 16:00 while, interestingly, the conduction peak in O_2 is reached at 24:00. Similarly, in O_3 it is between the hours 22:00 and 23:00. As a result of the insignificance of the solar load, the envelope load follows the same pattern of the conduction load and hence the same peak hours and the peak month. The previous findings can be utilised to reduce the total building cooling load. Easterly façades (O_1) for example should be avoided in the process of locating spaces for afternoon activities.

This section has illustrated the basic analysis of the thermal performance of the base case building, the impact of the design variables (orientation, elevation, and occupancy rate) on the building and the selected cells total cooling loads and envelope contribution to these loads. The question now is what is the impact of the change in the whole building orientation on both the building and the cells cooling loads? And would the envelope's role change with the variation of building orientation? The next section will attempt to present the answers to these questions.

8.3.2 The impact of building orientation on the building cooling loads

This section aims to examine the impact of the prison building orientation on its thermal performance. The previous section provided a general understanding of the building thermal behaviour and its sensitivity to certain architectural variables. The minor impact of solar load is noticeable, due to the limited window size. Hence the emphasis is placed on the fabric thermal load.

The different orientation scenarios are presented in section 8.2.2 and illustrated in Figure 87. Analyses are made for both types of cells with different orientations, as well as for the whole buildings. The cells are selected from different levels and with different sizes. The combinations of cells are similar to the ones used to investigate thermal performance in the base case (O_1, O_2, and O_3). The description of the different categories is given in 8.6.1.2. Figure 101 shows the location of the selected cells in the different orientation scenarios.

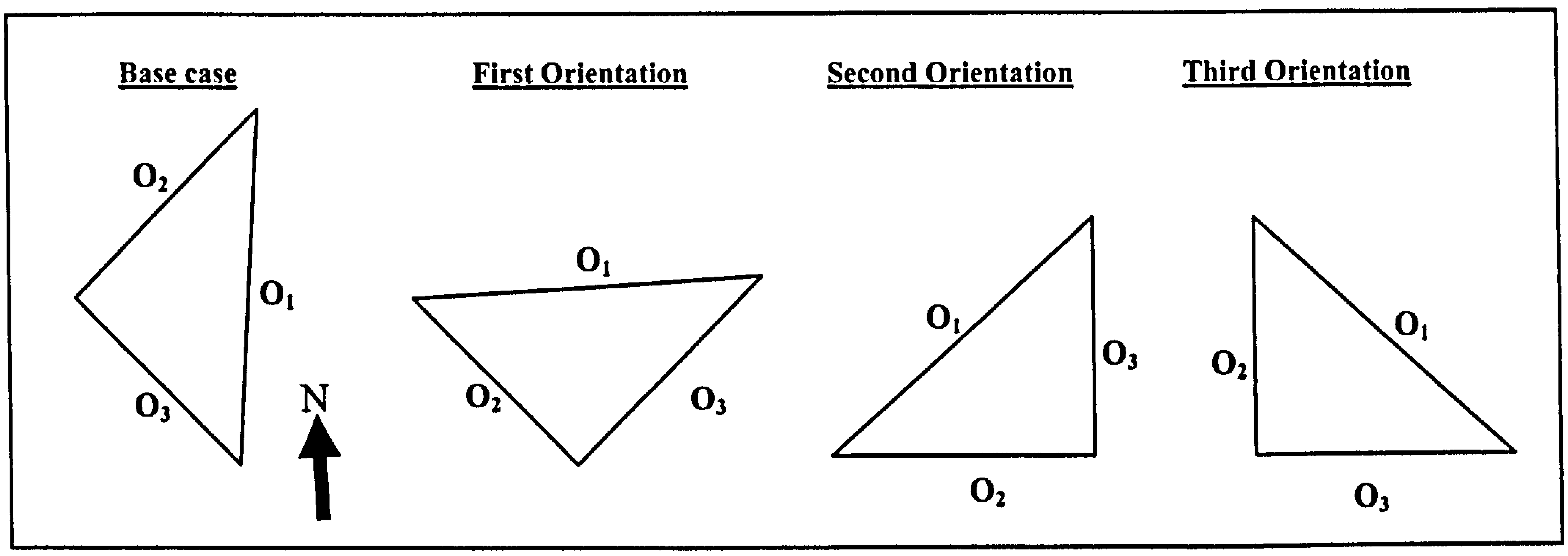


Figure 101: The selected cells location on the different orientations

8.3.2.1 The impact of orientation on the total loads

Figure 102 shows the impact of orientation on the total and the annual and peak cooling loads per square metre in the prison building. It is very clear that this impact is not significant. The highest reduction in the building annual total cooling load per square metre is recorded in the first orientation, with only 1.25% reduction from the base case. The impact of orientation on the peak load was even lower. The peak load in the first orientation, which is the lowest, was only 0.72% less than the base case. This is, however, a result of the triangular form of the building which reduced the building cooling loads sensitivity to any changes in orientation.

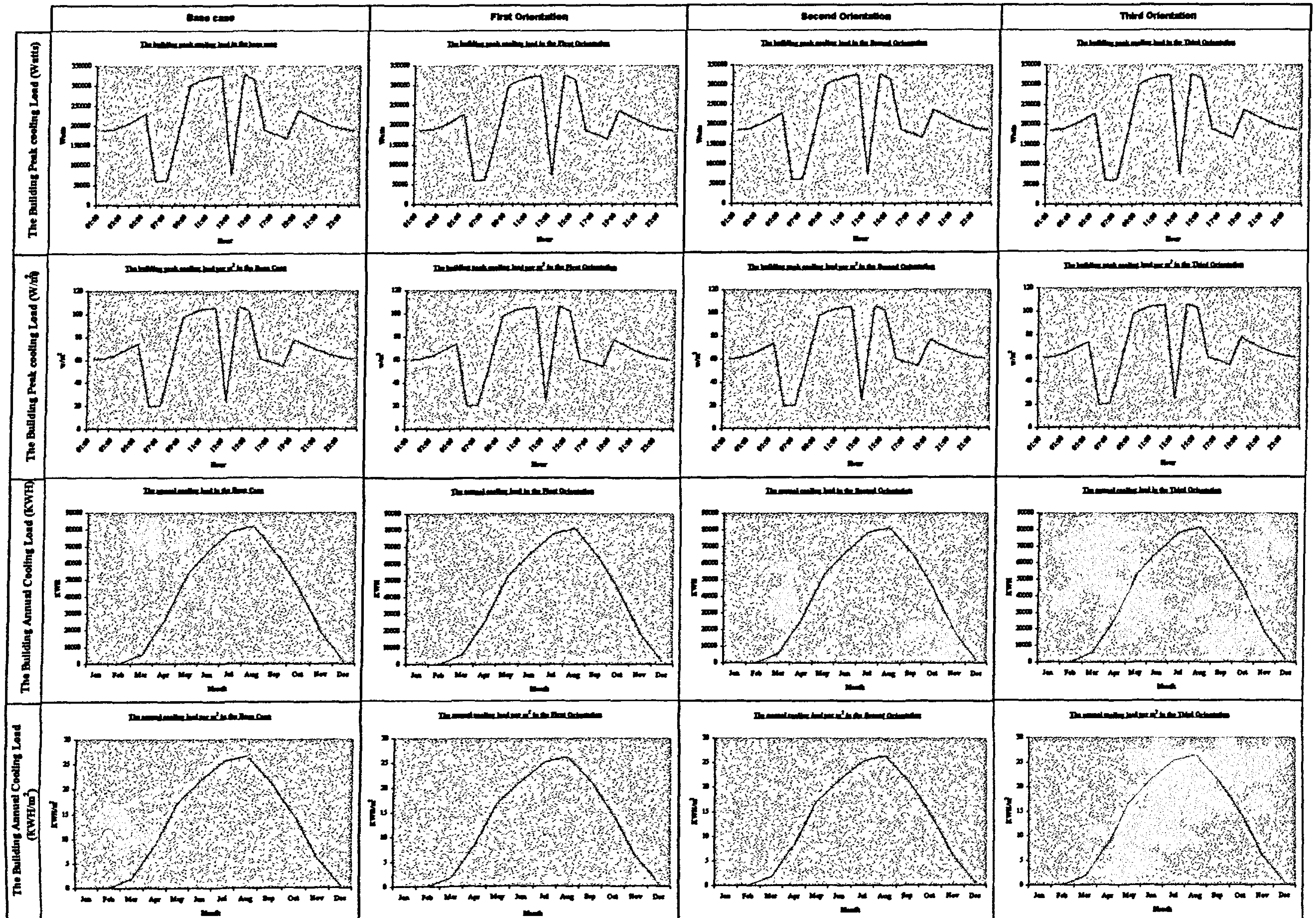


Figure 102: the impact of orientation on the building total annual and peak loads in the different scenarios

It is important, nevertheless, to examine the impact that orientation has on the building envelope. Table 20 shows that the envelope annual load per square metre in the second and the third orientations are identical (44.18 KWH/m^2), while the same type of load in the first orientation is slightly lower (43.45 KWH/m^2). The first orientation envelope therefore, has the lowest (among the other scenarios) contribution to the total annual cooling load. Figure 103 shows the annual behaviour of the solar, conduction and envelope loads per square metre in the base case and the three scenarios.

Table 20: Impact of orientation on the envelope heat gain and the building total cooling load

Load Type	Base case	First Orientation	Second Orientation	Third Orientation
Conduction gain KWH/m^2	43.15	41.84	42.44	42.44
Solar gain KWH/m^2	1.92	1.61	1.74	1.74
Total envelope heat gain KWH/m^2	45.08	43.45	44.18	44.18
Annual total cooling load KWH/m^2	143.68	141.88	142.68	142.66
Conduction load in relation to total cooling load %	30.03	29.49	29.75	29.75
Solar load in relation to total cooling load %	1.34	1.13	1.22	1.22
Envelope load in relation to total cooling load %	31.37	30.62	30.97	30.97
Relative envelope load %	100	96.39	98.02	98.01
Relative total cooling load %	100	98.75	99.30	99.29

The importance of examining the cells load is highlighted in section 8.3.1.1. A deeper investigation of the impact of orientation on the cell cooling loads is carried out in the following section.

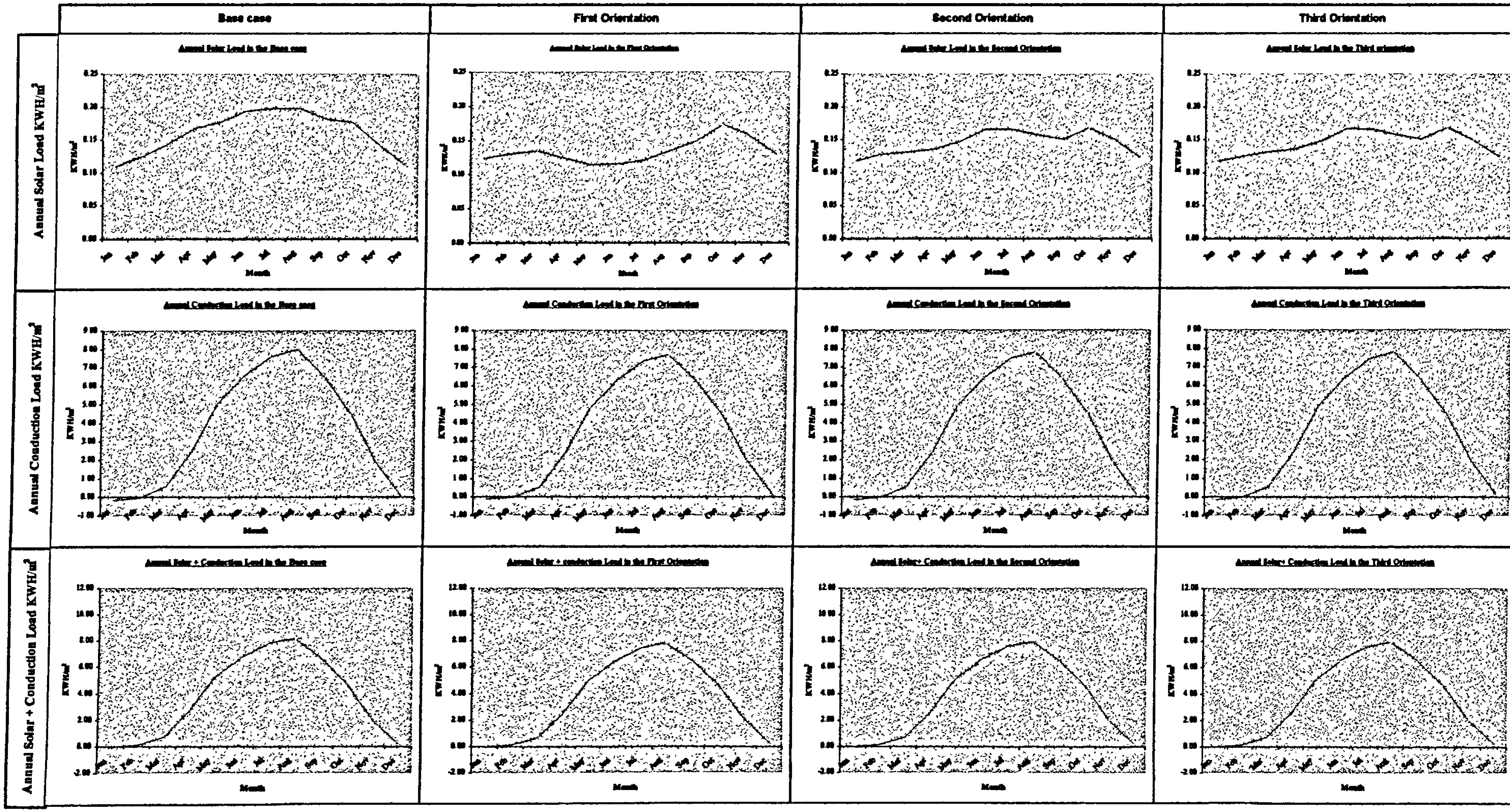


Figure 103: The impact of orientation on the building solar and conduction loads in the different scenarios

8.3.2.2 The impact of orientation on the cells cooling loads

The cells zone contributes to more than 42% of the total building cooling loads in the base case (8.3.1.1). This contribution has been constant in the different scenarios (Figure 104).

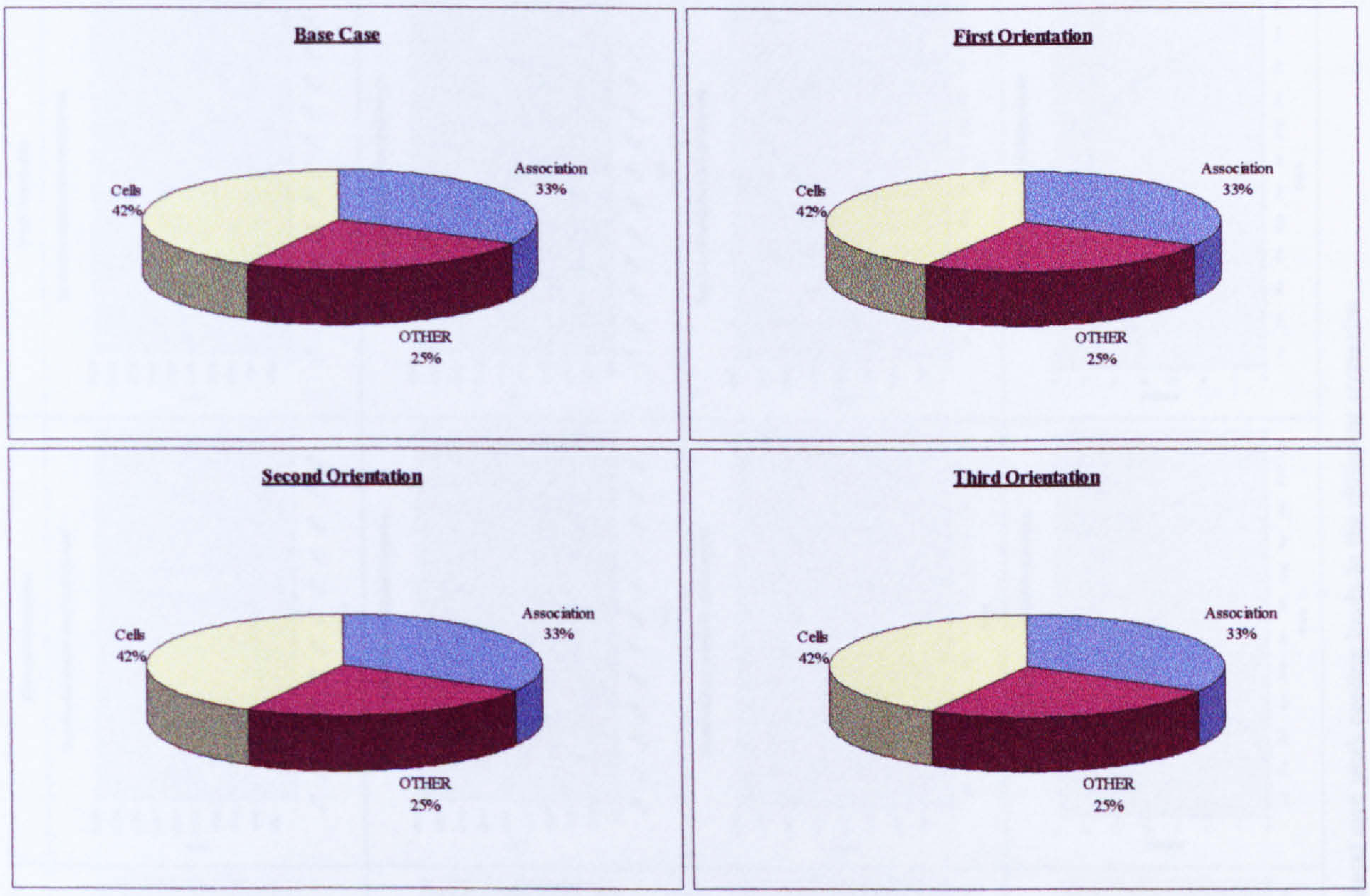


Figure 104: The cells zone contribution to the building cooling load in the different scenarios

Examining the cells annual and peak cooling load shows that orientation had only a minor impact on the cells loads (Figure 105). The highest reduction in the cells annual total cooling load per square metre is recorded in the first orientation, with 2.89 % reduction from the base case cells load. The second and third orientation cells annual loads recorded 1.54% and 1.58% reduction from the base case cells, respectively. The impact of orientation on the peak load is even less significant. The cells peak load in the first orientation, which is the lowest, is only 1.8% less than the base case cells peak load. This, however, resulted from two factors; the form of the building and the location of the cells. The first factor was presented in the previous section 8.3.2.1. Secondly, locating the cells on the different sides of the building minimised the role of orientation on the cells total cooling loads. It is, hence, important to investigate the impact of orientation on the selected cells (O_1, O_2, and O_3).

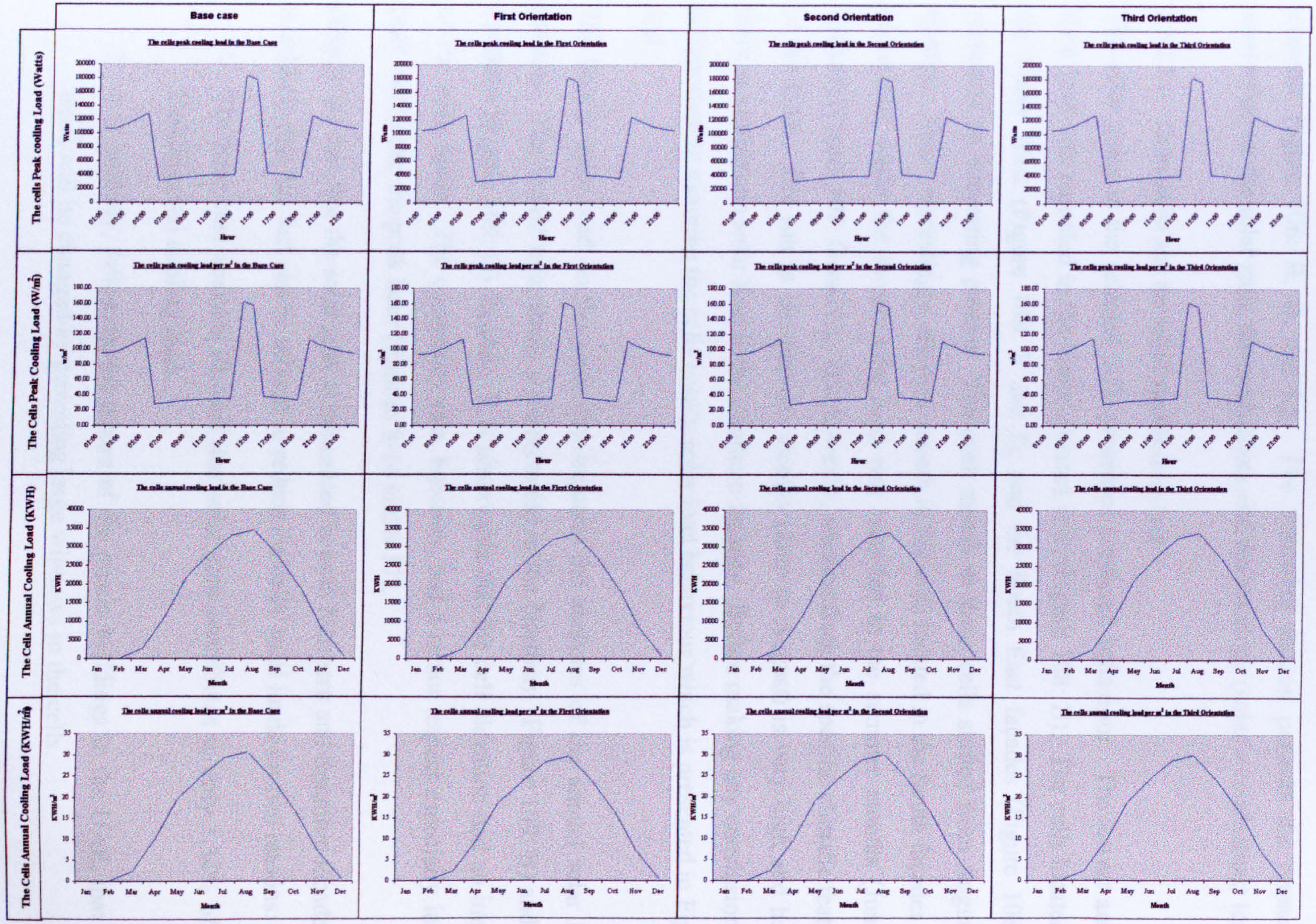


Figure 105: The impact of orientation on the cells annual and peak cooling loads in the different scenarios

8.3.2.3 The impact of orientation on the selected cells cooling loads

The selected cells annual and peak cooling loads presented a similar (in relation to the base case) sensitivity to occupancy rate, area per inmate and elevation (Figure 106, Figure 107). The minimum cooling load was recorded in the North and South situated cells (for example Figure 106: B, G, and L). The following section presents the impact of orientation on the solar gain, the conduction, and the envelope (solar + conduction) loads.

8.3.2.3.1 Orientation and the selected cells solar load

The solar gains in the selected cells presented predicted behaviour. The lowest annual solar load was recorded in the North situated cells (Figure 108: B). The cells located on the South West (Figure 108: F and I), and the South East façades (Figure 108: J) presented an interesting pattern. The peak month in these cells shifted from August to October. More interestingly, the peak month in the cells located in the South façades was November, while the lowest solar load was recorded in the summer months (June to August) (Figure 108: G and L). This however, resulted from the specific climatic features of the UAE. The sun in the summer months (June to August) is very high and hence there is a minimum solar load in the Southern façades. Before making any conclusions, it is important to examine the cells hourly solar load behaviour which is presented in Figure 109.

The hourly solar load on the peak day supports the analyses of the annual solar load patterns. The lowest solar loads were recorded in the Northern (Figure 109: B) and the Southern (Figure 109: G) façades. It is observable that the cell elevation had no impact on the solar loads. The occupancy rate, however, had a minor impact especially in the peak month and the peak hour (Figures 8-16 and 8-17).

Despite the fact that the solar gain is minimised in both Northern and Southern facades, it is unlikely that this fact can be utilised to reduce the cells' total loads for two reasons:

1. The base case analysis showed that solar gain contributes to only 1.34% of the building total cooling load.
2. It is unlikely, following the nature of the prison buildings in the UAE, that this trend will be changed by providing large windows in the cells.

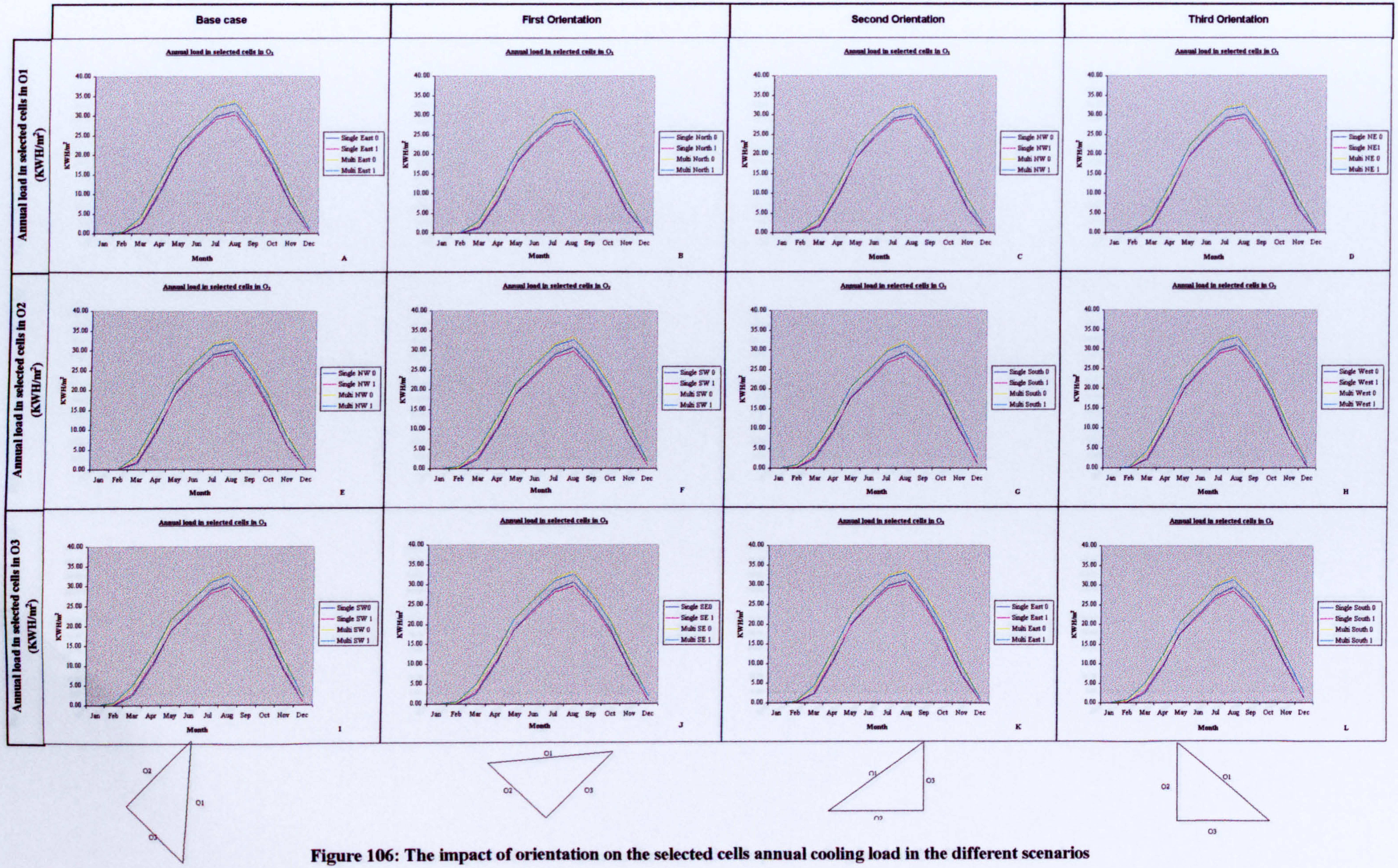


Figure 106: The impact of orientation on the selected cells annual cooling load in the different scenarios

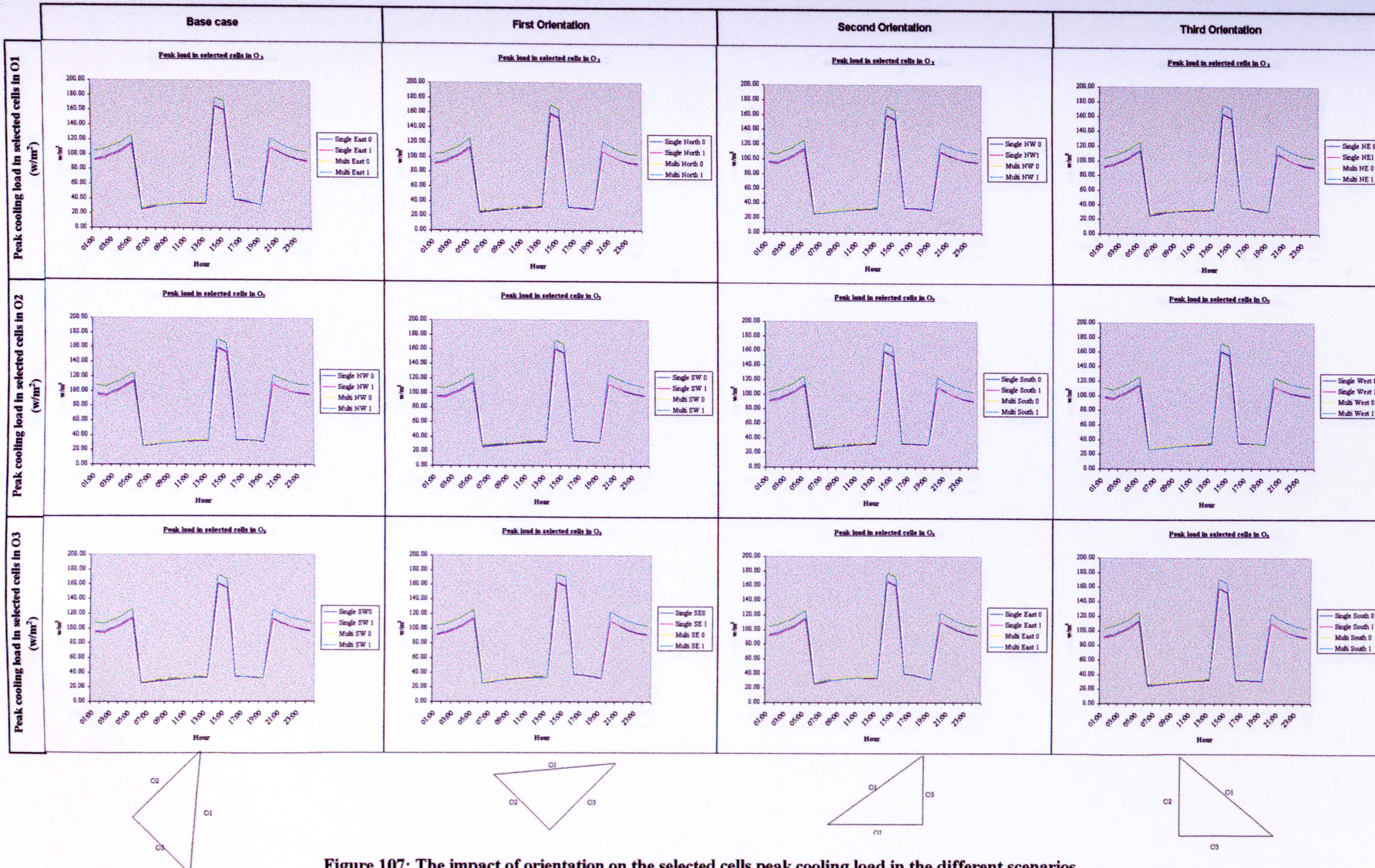


Figure 107: The impact of orientation on the selected cells peak cooling load in the different scenarios

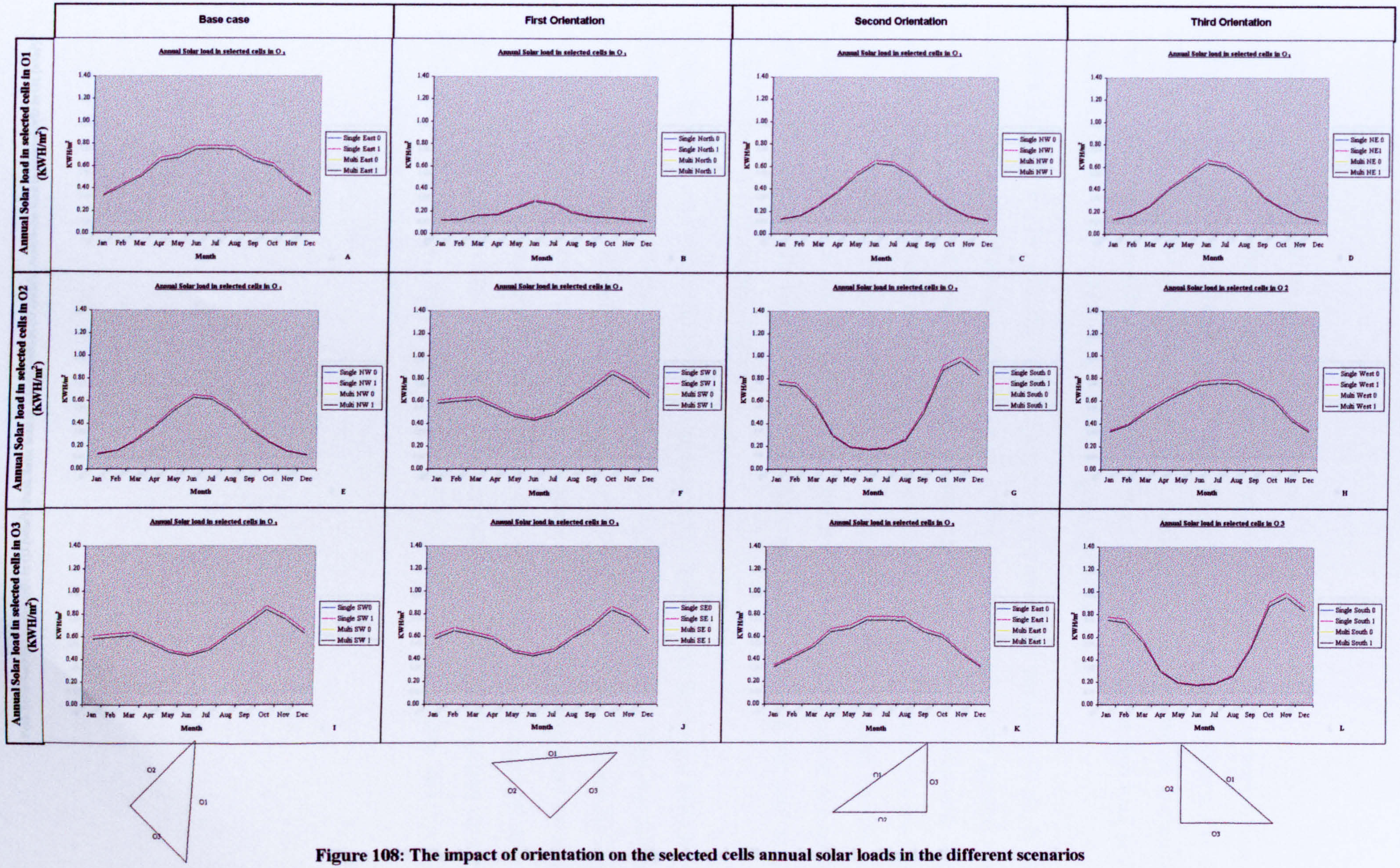


Figure 108: The impact of orientation on the selected cells annual solar loads in the different scenarios

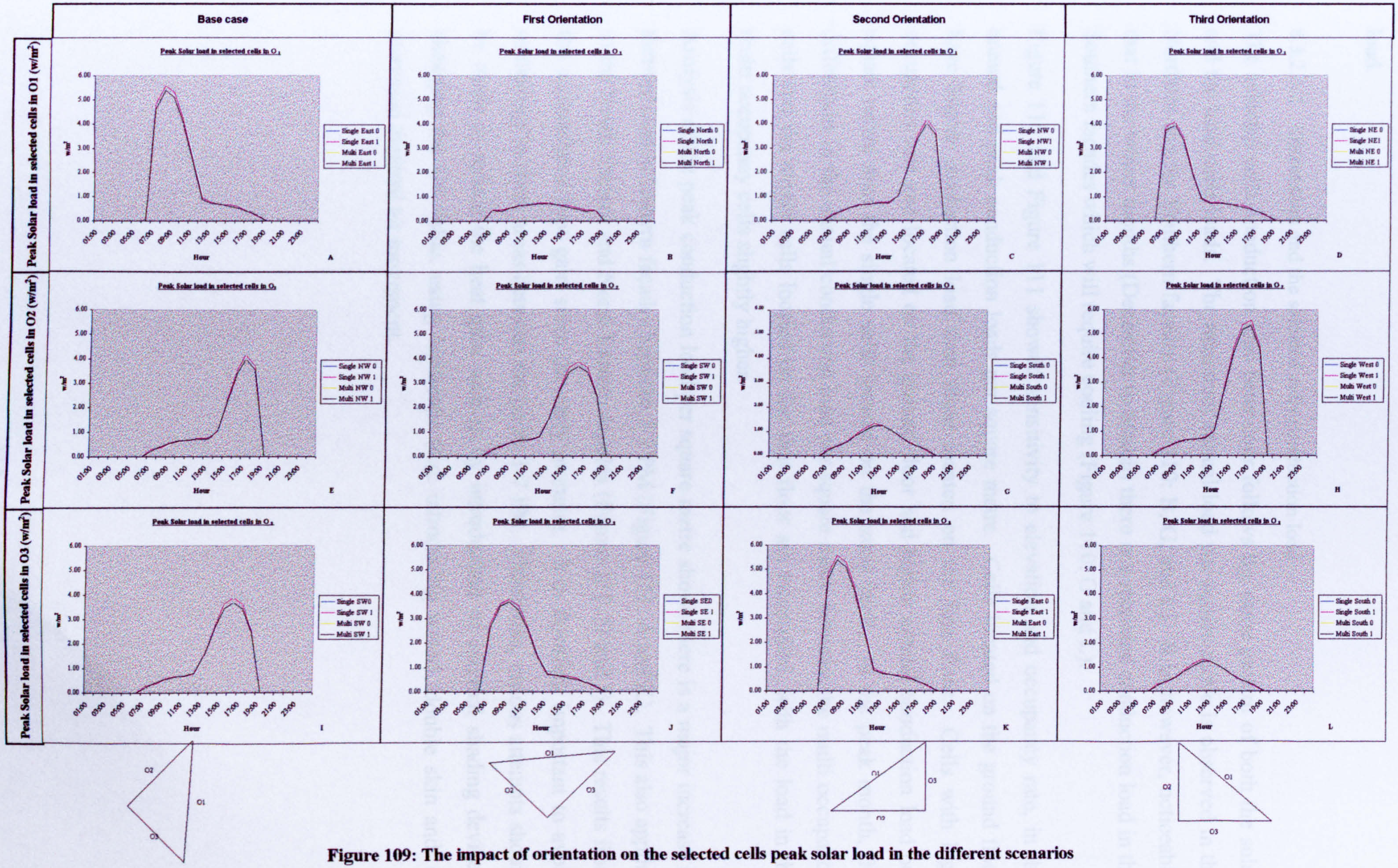


Figure 109: The impact of orientation on the selected cells peak solar load in the different scenarios

It is, hence, more important to investigate the impact of orientation on the conduction load.

8.3.2.3.2 Orientation and the selected cells conduction load

The selected cells conduction load behaviour follows the same pattern of both the solar and the total cells loads. The minimum annual load per square metre is observed in the Northern and the Southern façades (Figure 110: B, G, and L). It is, however, noticeable that in the winter months (December to March) there is a recorded conduction load in the Southern façades which will require cooling (Figure 110: G and L).

Figure 110 and Figure 111 showed sensitivity to elevation and occupancy rate, in the annual and peak conduction loads per square metre. Cells located on the ground floor have higher conduction load than those located on the first floor. Cells with high occupancy rate and located on the ground floor had higher annual conduction load per square metre than the single cells located on the same level. In the peak month, the differences in the annual conduction load per square metre between the multi occupancy cells and the single cells located on the first floor are minimised, with the load in the multi occupancy cells slightly higher.

Analysis of the peak conduction load per square metre shows there is a major increase in thermal load in Eastern façades between 3-7 PM (Figure 111: A and K). This also applies to the South Eastern and North Eastern façades (Figure 111: D and J). This results from the accumulated heat gain since the early morning. It is therefore important to avoid occupancy in these areas between the hours 3-7 PM. Otherwise, serious attempts should be made to reduce the heat gain such as by introduction of external shading devices, changing the Uo value, using landscape (e.g. introducing water), double skin and/ or increased external air movement.

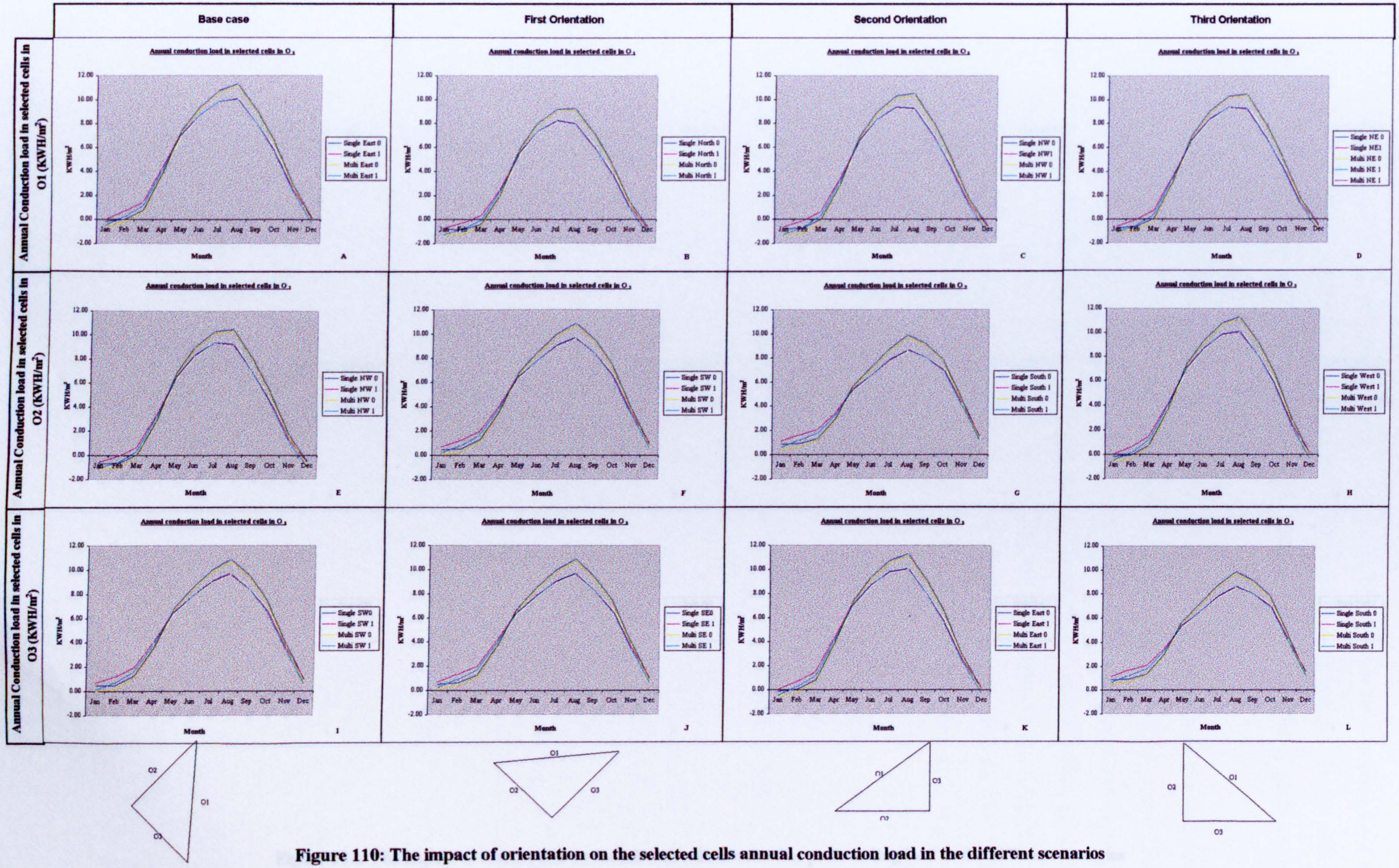


Figure 110: The impact of orientation on the selected cells annual conduction load in the different scenarios

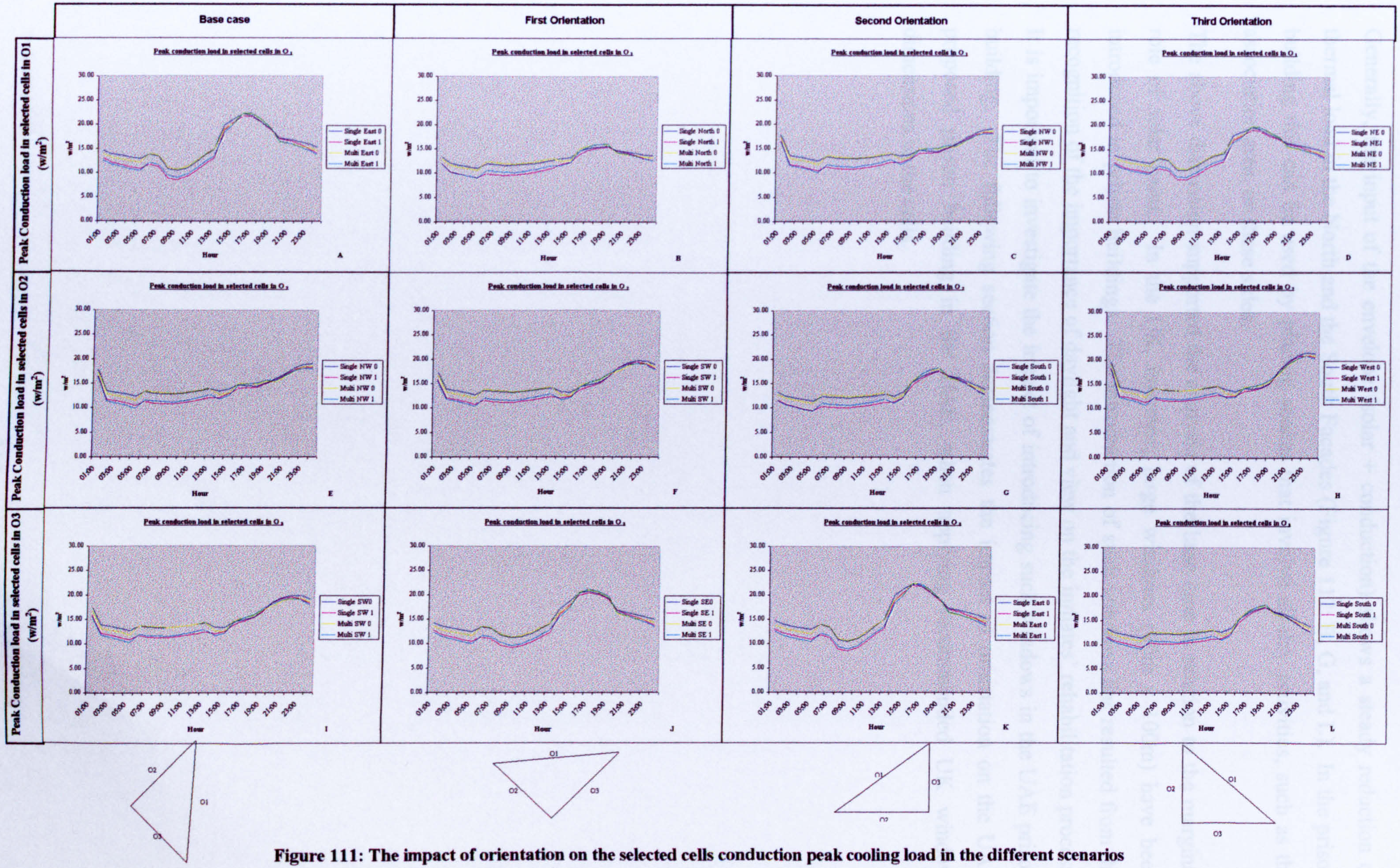


Figure 111: The impact of orientation on the selected cells conduction peak cooling load in the different scenarios

8.3.2.3.3 Impact of the orientation on the envelope load (solar + conduction)

Generally, the input of the envelope (solar + conduction) shows a steady reduction of thermal load in the North and the South Facades (Figure 112: B, G, and L). In the prison building this can be used by placing spaces that involve all-day activities, such as the association area, on these sides.

The above discussion supported the analysis of the base case in relation to the marginal role of solar gains. In the UK, however, large windows (90m x 100m) have been introduced in prison buildings. The introduction of such windows has resulted from the recognition of the importance of daylight and view on the inmates' rehabilitation process. It is important to investigate the impact of introducing such windows in the UAE prison building. The following section demonstrates the impact of orientation on the UAE proposed prison building in the UAE, when applying recommended UK window dimensions in the cells.

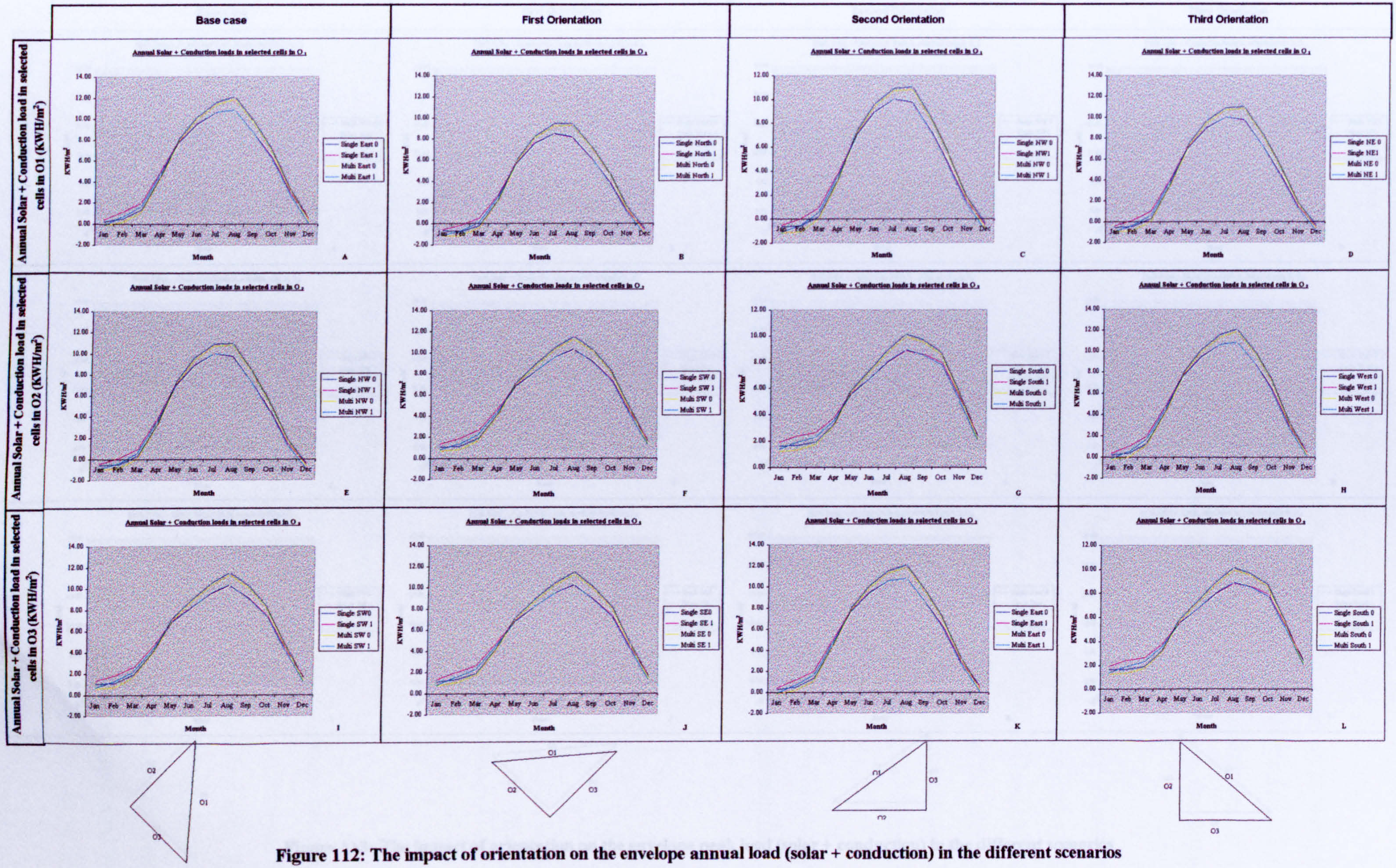


Figure 112: The impact of orientation on the envelope annual load (solar + conduction) in the different scenarios

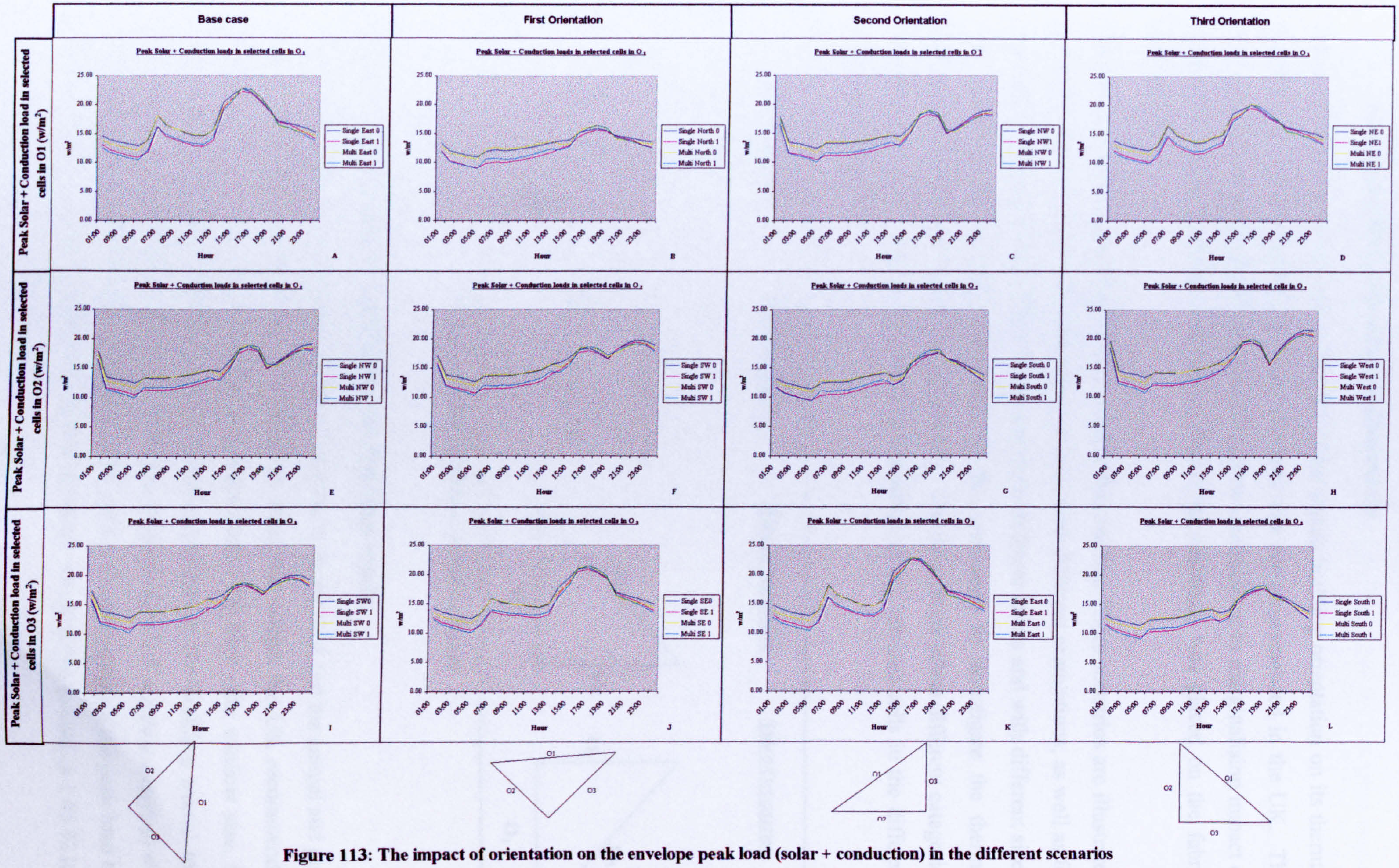


Figure 113: The impact of orientation on the envelope peak load (solar + conduction) in the different scenarios

8.3.3 The impact of orientation on the building cooling loads, when applying UK recommended prison window dimensions

This section aims to examine the impact of the prison building orientation on its thermal performance when applying the large windows that are recommended in the UK. The previous section showed that the limited window size resulted in marginalising impact of solar load on the building heat gain. Hence the emphasis was placed on the fabric thermal load.

Similar orientation scenarios are examined in this section. These scenarios are illustrated in Figure 114. Analyses are made for both cells with different orientations, as well as for the whole buildings. The cells are selected from different levels and with different sizes. The combinations of cells are similar to the ones used to investigate the thermal performance on the base case (O_1, O_2, and O_3). The description of the different categories is stated in 8.6.1.2. Figure 114 shows the location of the selected cells in the different orientation scenarios.

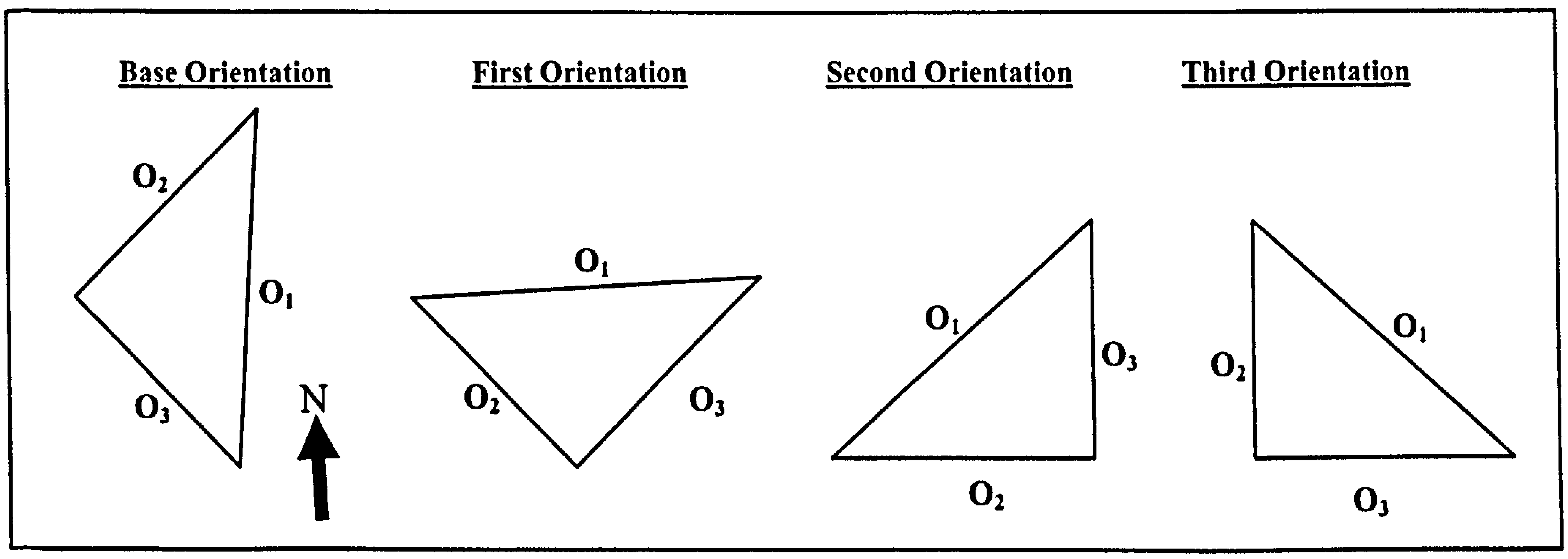


Figure 114: The orientation scenarios layout

8.3.3.1 The impact of orientation on the total loads

This section aims to present the impact of orientation on the total and the annual and peak cooling loads per square metre in a prison building that adopts the UK recommended window size. Figure 115 shows that in comparison to the base case window size, the impact of orientation is doubled. The highest reduction in the building annual total cooling load is recorded in the first orientation (similar to the UAE window analysis) with 2.5% reduction from the base orientation. The impact of orientation on the peak load has similar pattern. The peak load in the first orientation, which is the lowest, is 1.45 % less than the base orientation. That is double the impact of orientation in the base case window, 0.72%. The reduction remains, however, not significant for the same reason indicated earlier, the triangular form of the building.

The introduction of relatively large windows into the prison building façade is expected to increase the contribution of the envelope load to the building total cooling load. It is therefore important to examine the impact of orientation on the building envelope cooling load.

Table 21 shows that, similar to the base case, the envelope load in the second and the third orientations are identical (54.7 KWH/m^2), while the same load in the first orientation is slightly lower (53.1 KWH/m^2). Figure 116 shows the annual behaviour of the solar, conduction and envelope loads per square metre in the base orientation and the three scenarios.

Table 21: Impact of orientation on the envelope heat gain and the building total cooling load
(Using the UK recommended window size)

Load Type	Base Orientation	First Orientation	Second Orientation	Third Orientation
Conduction gain KWH/m^2	42.79	41.79	42.30	42.30
Solar gain KWH/m^2	13.83	11.32	12.37	12.35
Total envelope heat gain KWH/m^2	56.63	53.10	54.67	54.65
Annual total cooling load KWH/m^2	153.97	150.19	151.86	151.86
Conduction load in relation to total cooling load %	27.79	27.82	27.85	27.86
Solar load in relation to total cooling load %	8.99	7.54	8.15	8.13
Envelope load in relation to total cooling load %	36.78	35.36	36.00	35.99
Relative envelope load %	100	93.78	96.55	96.51
Relative total cooling load %	100	97.55	98.63	98.63
Relative (to base case) envelope load %	125.62	117.81	121.28	121.24
Relative (to base case) total cooling load %	107.16	104.53	105.69	105.69

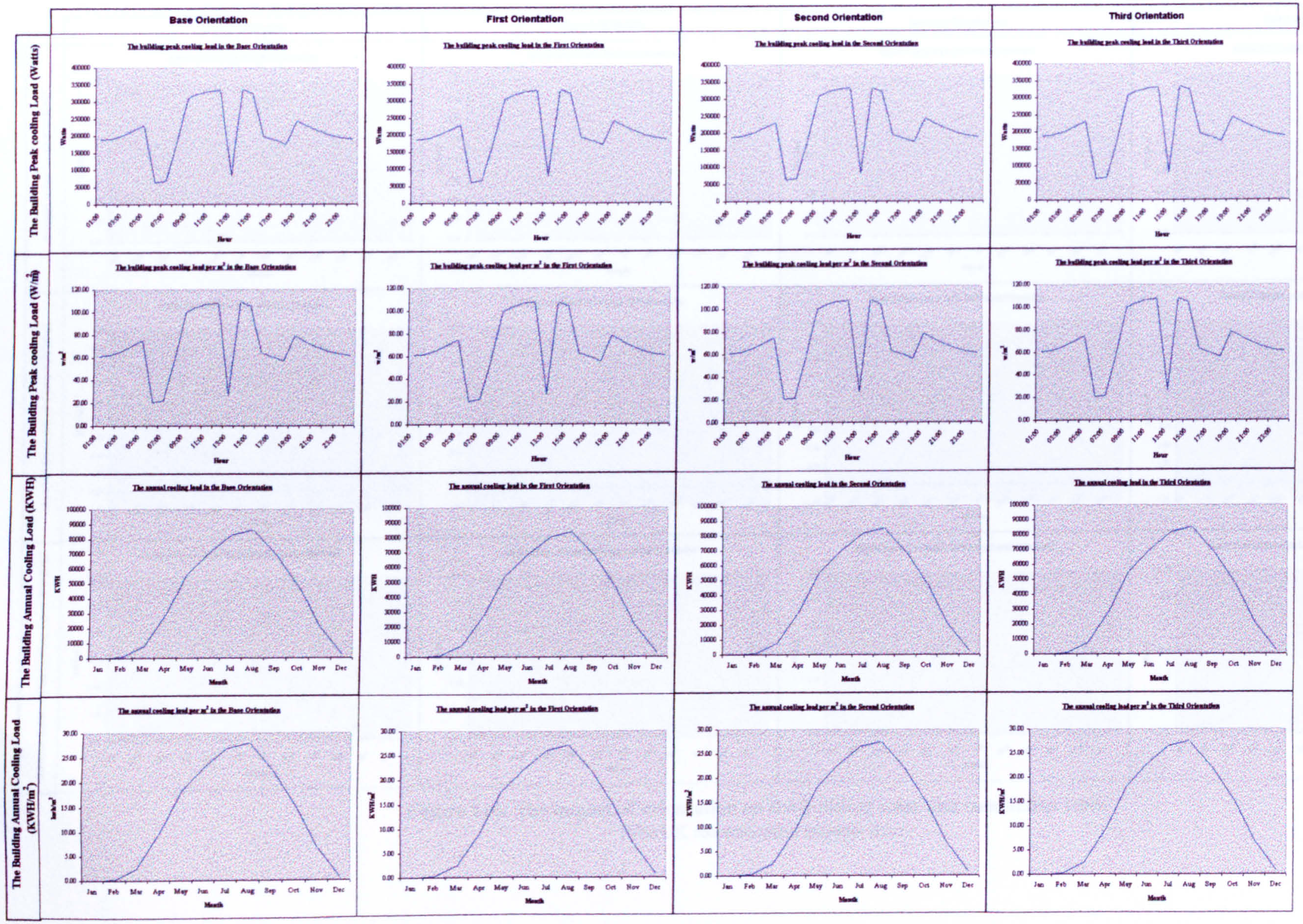


Figure 115: The impact of orientation on the building total annual and peak loads
(The UK recommended window size)

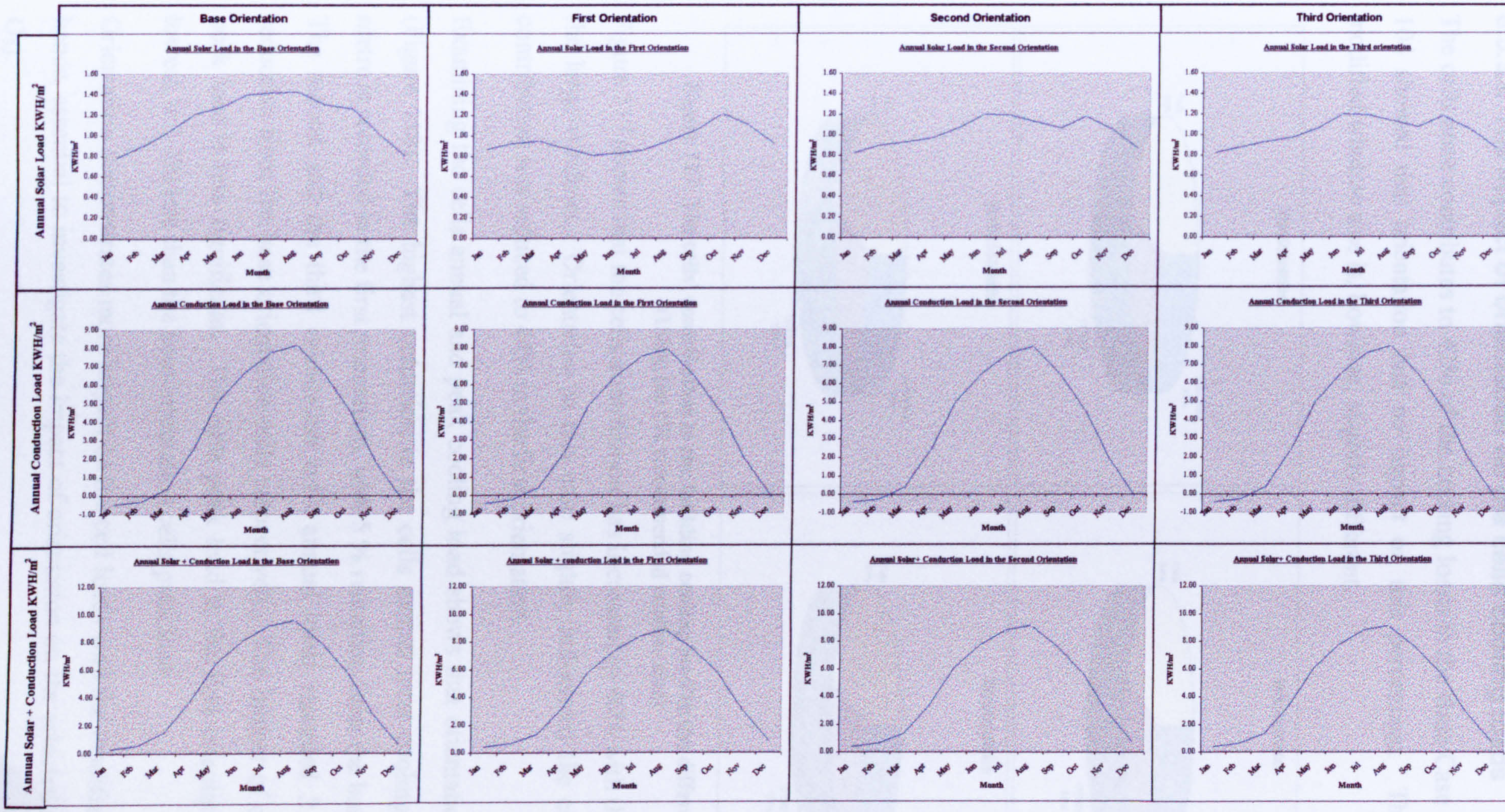


Figure 116: The impact of orientation on the building solar and conduction loads
(The UK recommended window size)

8.3.3.2 The impact of orientation on the cells cooling loads

The cells zone contributes to 42% of the cooling loads in the Base Case (8.3.1.1). Figure 104 showed that orientation had no impact on this percentage. The case with the modified window size is, however, slightly different.

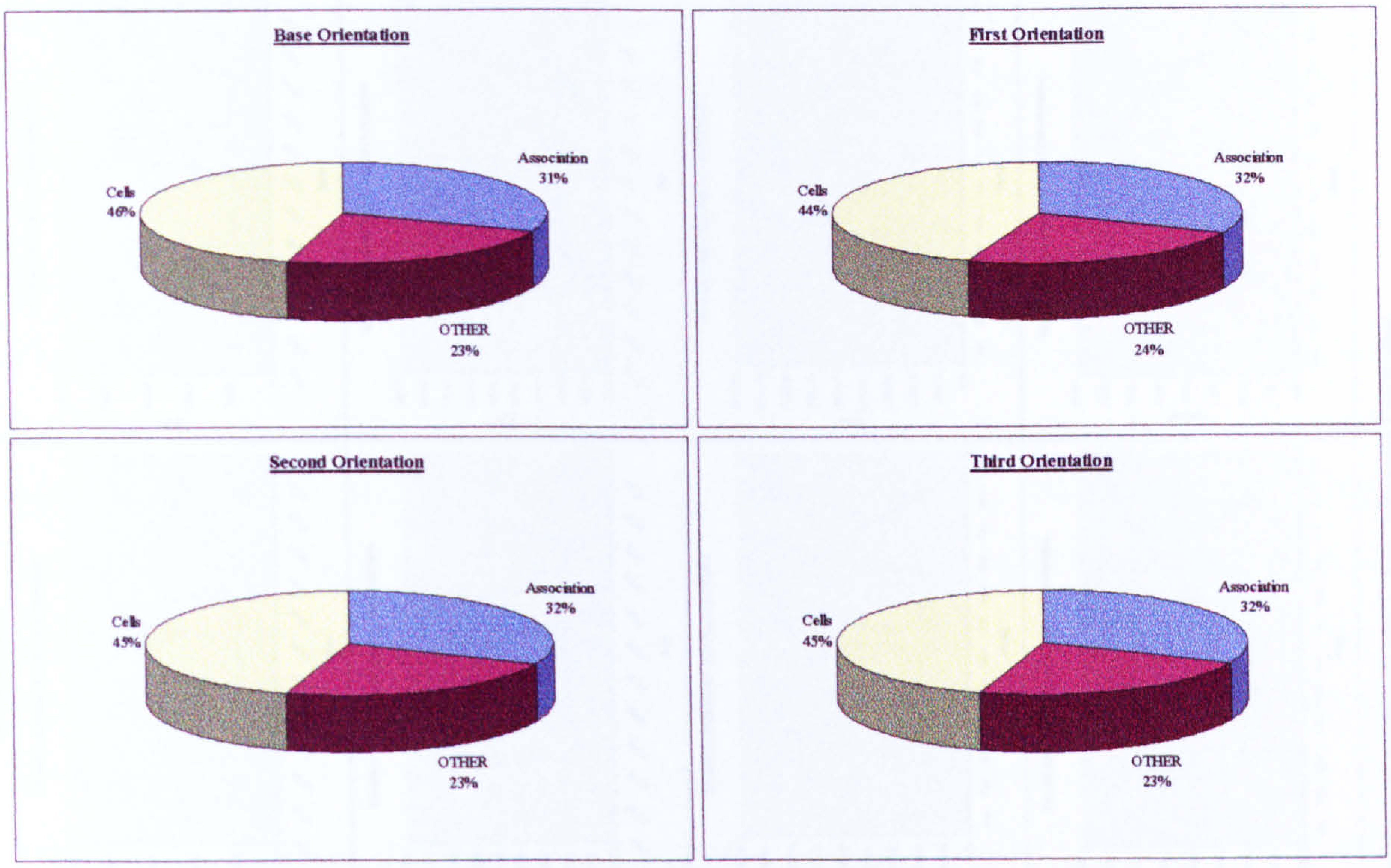


Figure 117: The cells' contribution to the building cooling load in the different scenarios
(Using the UK recommended window size)

Figure 117 shows that the cells contribution has increased to 46% with the introduction of the large windows. Orientation in this case slightly influenced the cells load, and its contribution was reduced to 44% in the first orientation.

Examining the cells annual and peak cooling load shows that orientation had an impact (Figure 118). The highest reduction in the cells annual total cooling load per square metre is recorded in the first orientation, with 5 % reduction from the base case cells load. The second and the third orientation cells annual loads recorded 2.73% and 2.74% reduction from the base orientation cells respectively. The impact of orientation on the peak load is less significant. The cells peak load in the first orientation, which is the lowest, is 3.4% less than the base orientation cells peak load.

Orientation demonstrates more impact on the cell loads with the modified windows. It is, hence, essential to investigate the impact of orientation on the selected cells (O_1, O_2, and O_3).

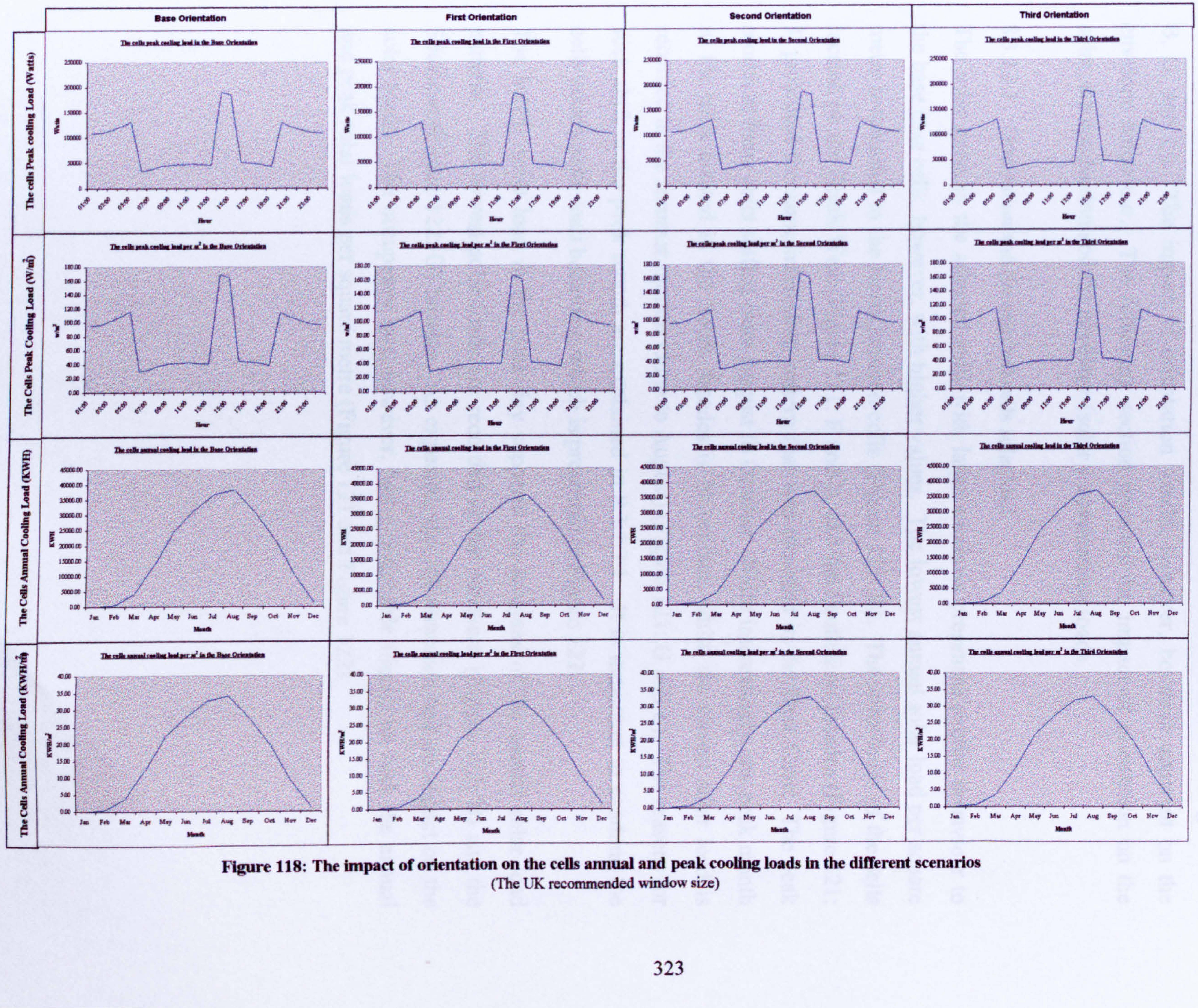


Figure 118: The impact of orientation on the cells annual and peak cooling loads in the different scenarios
(The UK recommended window size)

8.3.3.3 The impact of orientation on the selected cells loads

The selected cells annual and peak cooling loads follows the same patterns of the Base Case. Sensitivity to occupancy rate and elevation is obvious (Figure 121 and Figure 122).

The minimum cooling load is recorded in the North and South situated cells (Figure 121: B, G, and L). The impact of orientation would, however, be more apparent on the envelope behaviour. The following section presents the impact of orientation on the solar, the conduction and the envelope (solar + conduction) loads.

8.3.3.3.1 Orientation and the selected cells solar load

The solar gains in the selected cells with large windows presented similar behaviour to the base case cells, however, with higher values. The lowest annual solar load per square metre is recorded in the North situated cells (Figure 121: B). The solar loads of the cells located on the South West (Figure 121: F and I), and the South East façades (Figure 121: J) presented the same interesting pattern that was recorded in the Base Case. The peak month in these cells shifted from August to October. More interestingly, the peak month in the cells located in the South façades is November, while the lowest solar load is recorded in the summer months (June to August) (Figure 121: G and L). The reasons for such shift in the peak month are explained in 8.3.2.3.1. It is important to examine the cells hourly solar load behaviour which is presented in Figure 122.

The hourly solar load in the peak day supports the analyses of the annual solar load patterns. The lowest solar loads are recorded in the Northern (Figure 122: B) and the Southern (Figure 122: G) façades. As expected, the cell elevation had no impact on the solar loads. The occupancy rate, however, had a noticeable impact on both the annual and peak solar loads per square metre (Figure 121 and Figure 122).

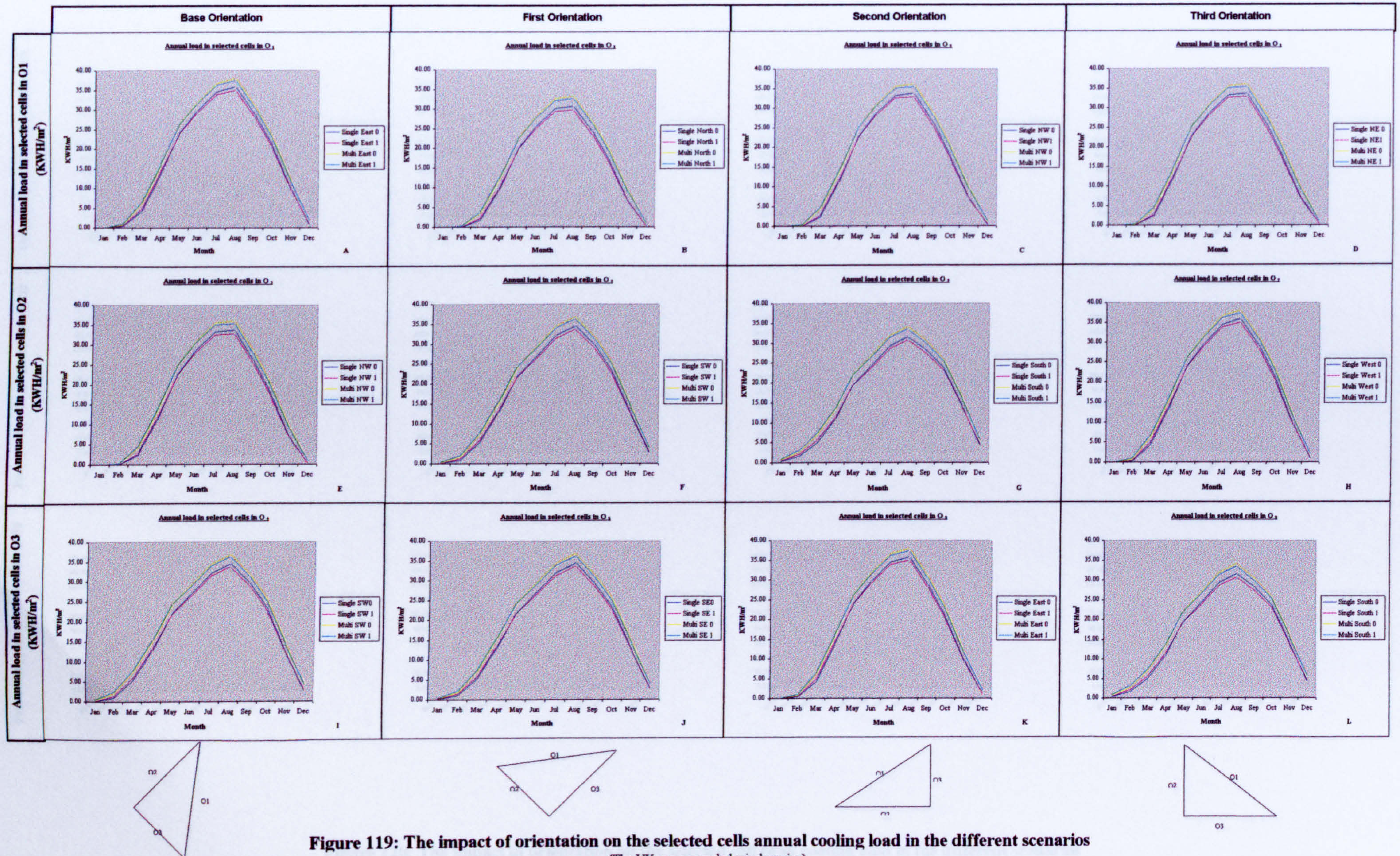


Figure 119: The impact of orientation on the selected cells annual cooling load in the different scenarios
(The UK recommended window size)

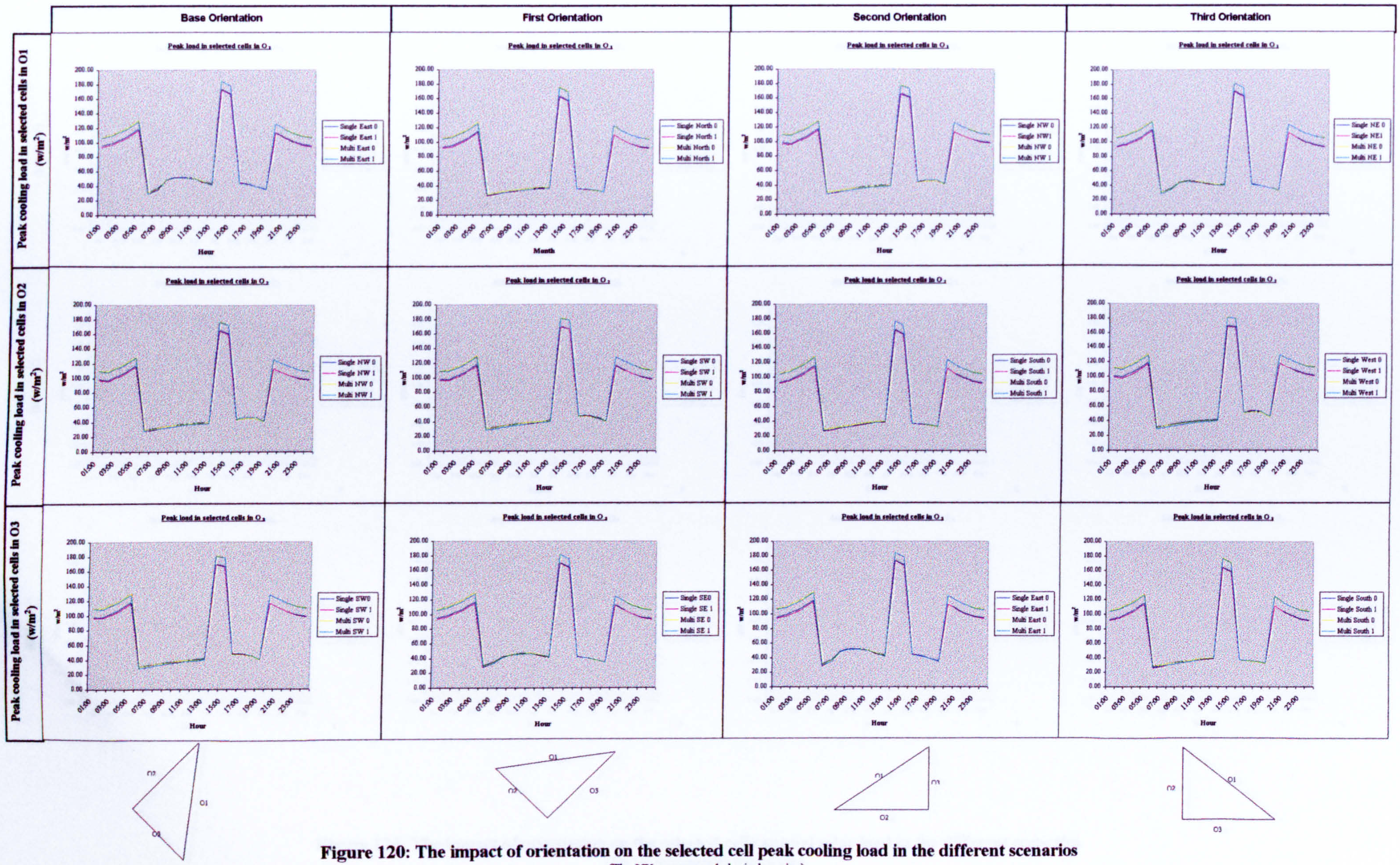


Figure 120: The impact of orientation on the selected cell peak cooling load in the different scenarios
(The UK recommended window size)

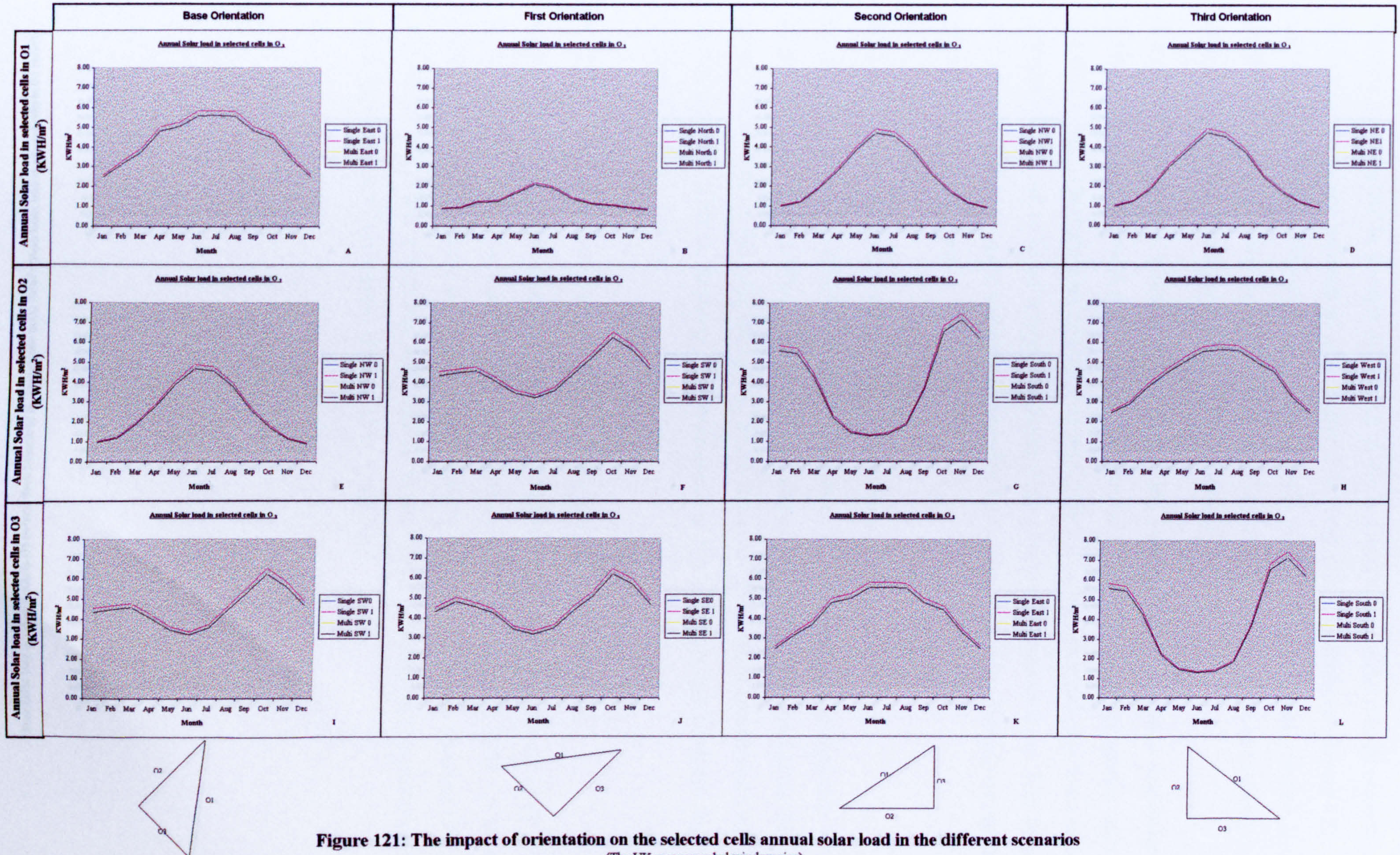


Figure 121: The impact of orientation on the selected cells annual solar load in the different scenarios

(The UK recommended window size)

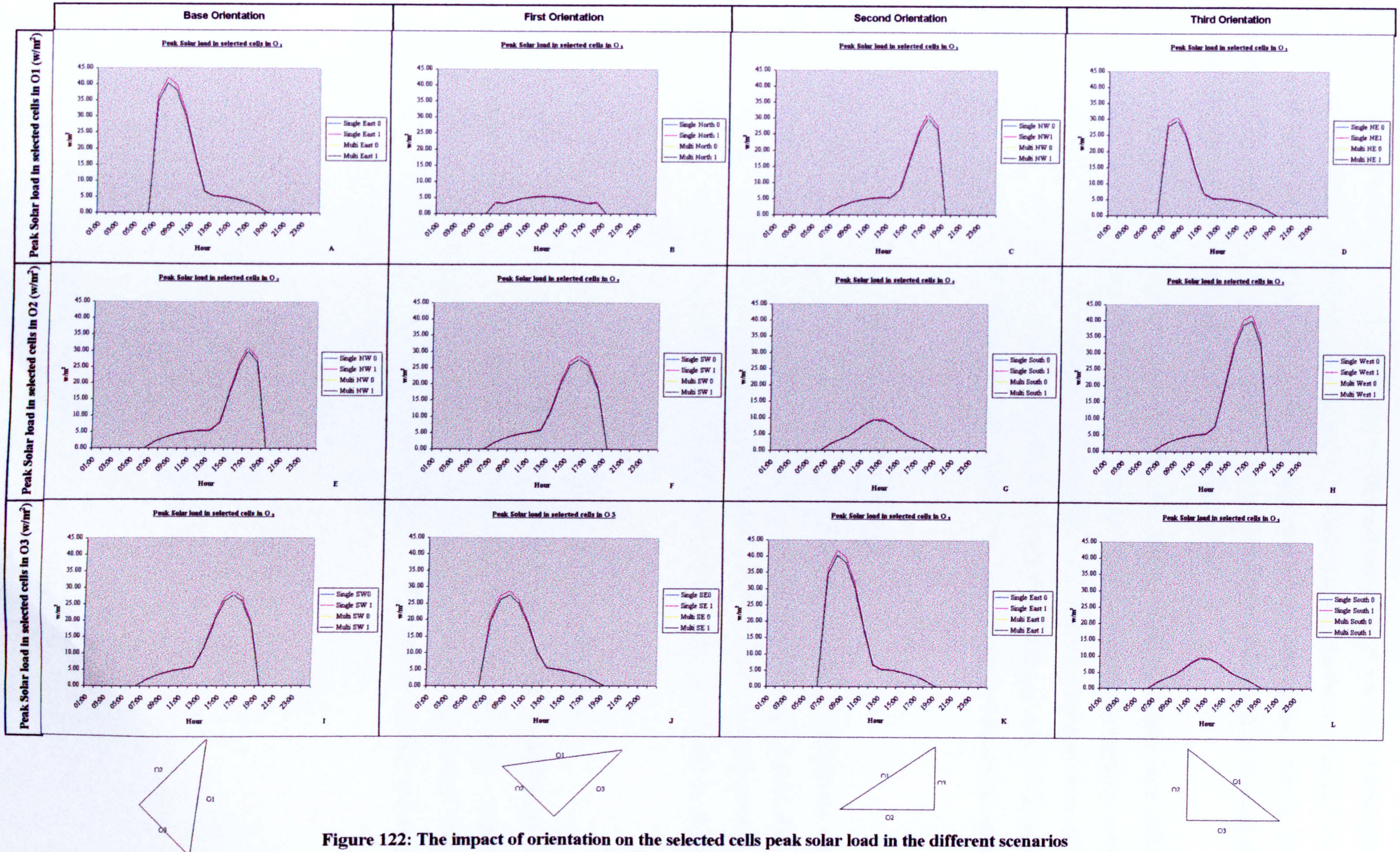


Figure 122: The impact of orientation on the selected cells peak solar load in the different scenarios
(The UK recommended window size)

Few recommendations can be extracted from the previous analysis. The change in window size resulted in a major difference in the understanding of the role of orientation. Following the major increase of solar gains, it is clear that the Northern (Figure 121: B) and Southern façades (Figure 121: G and L) show the lowest solar gains. Hence, if the decision were made to increase the window size in the prison building, then locating cells in the Northern and Southern façades would be advisable.

It is apparent that when window size increased, the impact of the occupancy rate differed from the previous case with small windows. Thermal load in the multi occupancy cells in the cool months (January and February) is negligible. The high thermal gain from casual gains/m^2 turned out to be advantageous during both winter and summer time. This means that if larger windows were to be recommended for humane reasons, multiple occupancy cells should be considered.

8.3.3.3.2 Orientation and the selected cells conduction load

On a peak day, the conduction profile throughout the day changed completely when larger windows were introduced (Figure 124). The conduction profiles on a peak day are largely dependent on the solar heat gain, which increases the internal temperature rapidly during the day. This is, however, less noticeable in the Northern and Southern façades (Figure 124: B, G, and L).

8.3.3.3.3 Orientation and the selected cells envelope load (solar + conduction)

Due to almost constant thermal load from conduction (Figure 123), an envelope with large windows would be mainly affected by solar gain profile (Figure 125). A prison building with large Southern façades would shift the peak load towards October (Figure 125: G and L), while a building with mainly Eastern façades would still experience the peak day in August (hot month) (Figure 125: A and K).

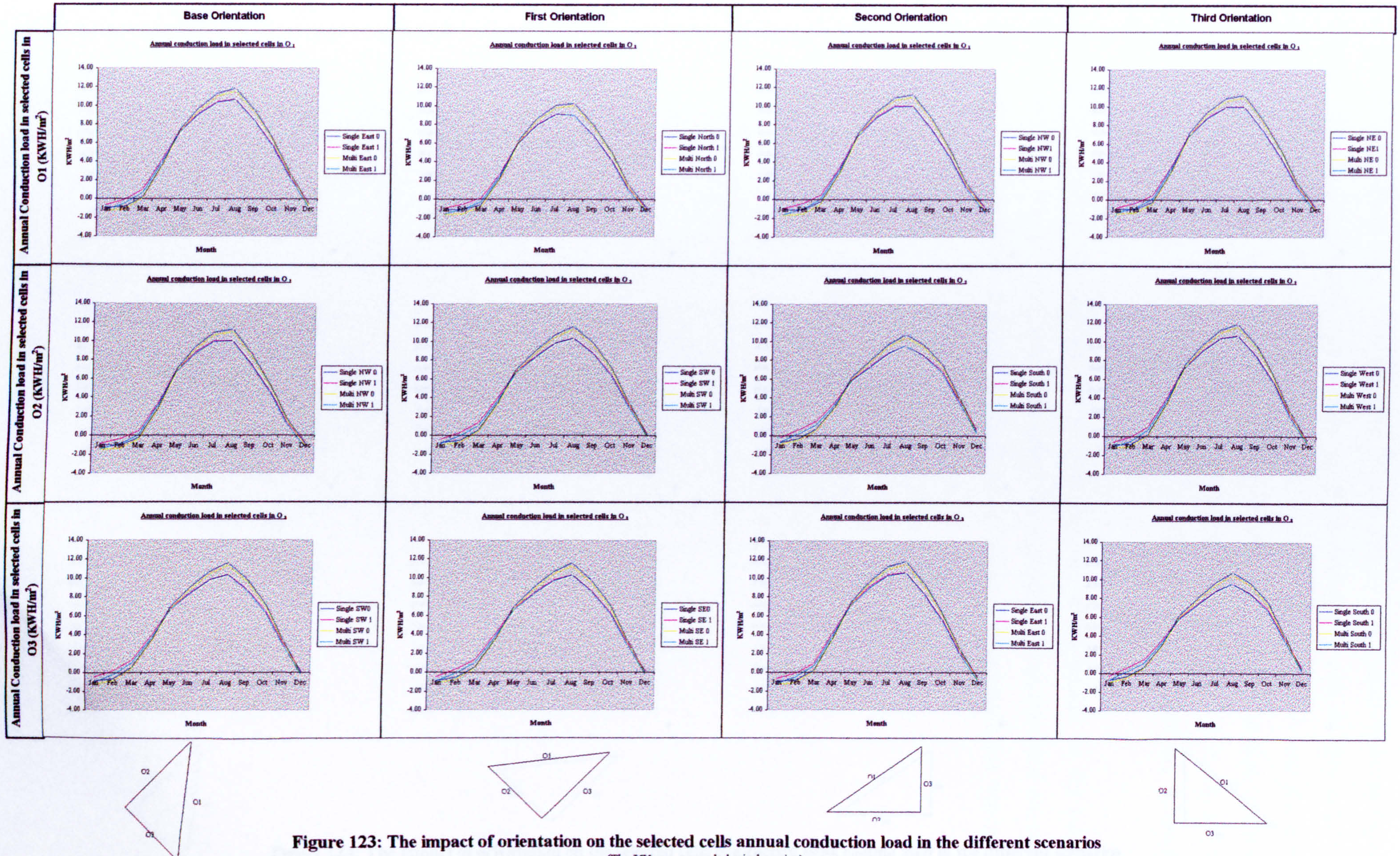


Figure 123: The impact of orientation on the selected cells annual conduction load in the different scenarios
(The UK recommended window size)

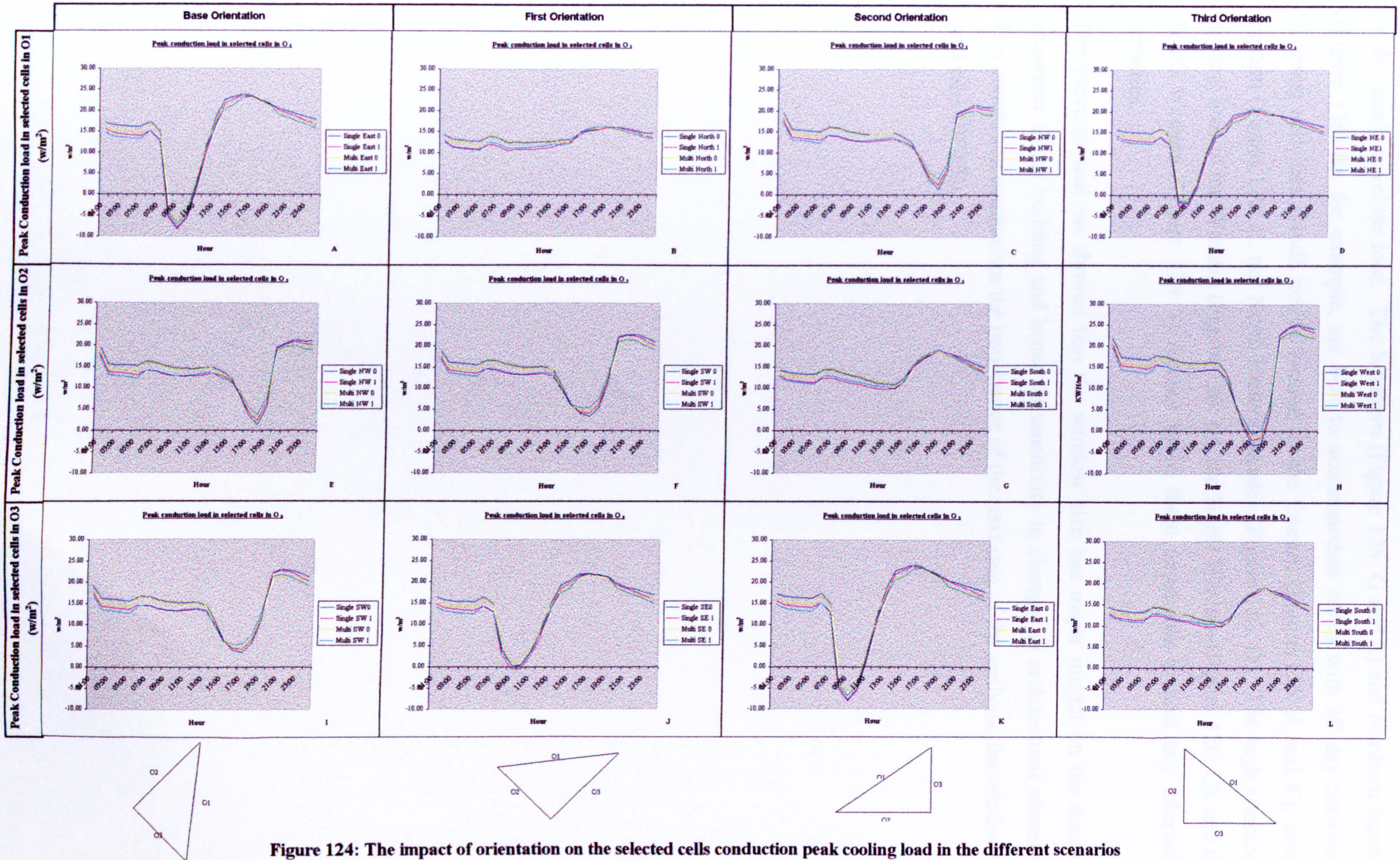


Figure 124: The impact of orientation on the selected cells conduction peak cooling load in the different scenarios

(The UK recommended window size)

It is advisable that the distribution of the prison building zones should reflect sensitivity to the hourly envelope load. The Southern (Figure 126: G and L) and Northern façades (Figure 126: B), for example, are best to accommodate zones with all day activities. Morning activities should not be located on the Eastern (Figure 126: A and K), South Eastern (Figure 126: J), nor North Eastern façades (Figure 126: D). The high afternoon thermal load of the Western (Figure 126: H), the North Western (Figure 126: C), and the South Western (Figure 126: I) façades make them unsuitable to host any afternoon activities.

The previous analysis showed that the window size has major impact on the thermal behaviour of the building and hence its sensitivity to changes in architectural elements. This conclusion emphasises the importance of the next step of the analysis, the window to wall ratio (WWR).

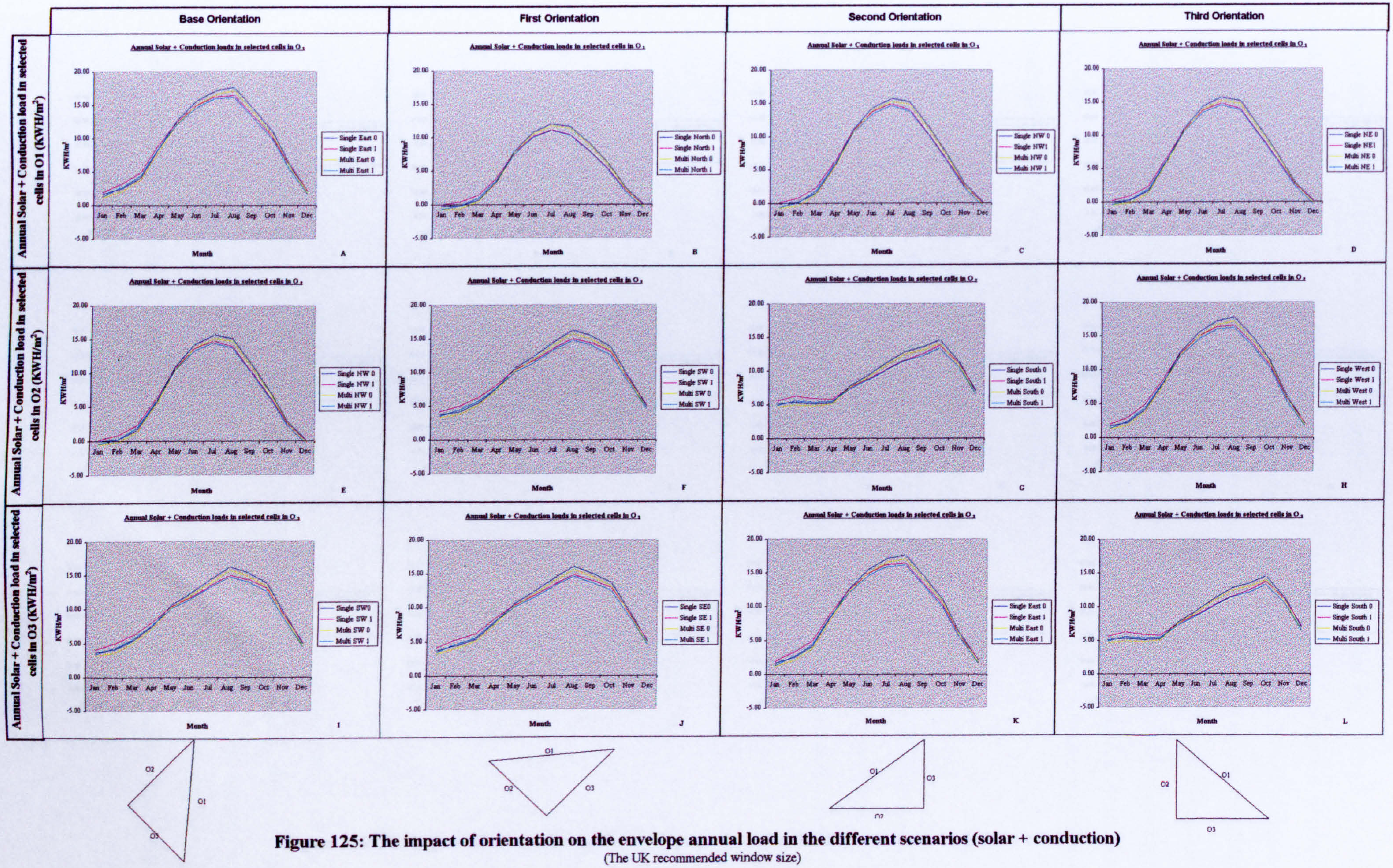


Figure 125: The impact of orientation on the envelope annual load in the different scenarios (solar + conduction)

(The UK recommended window size)

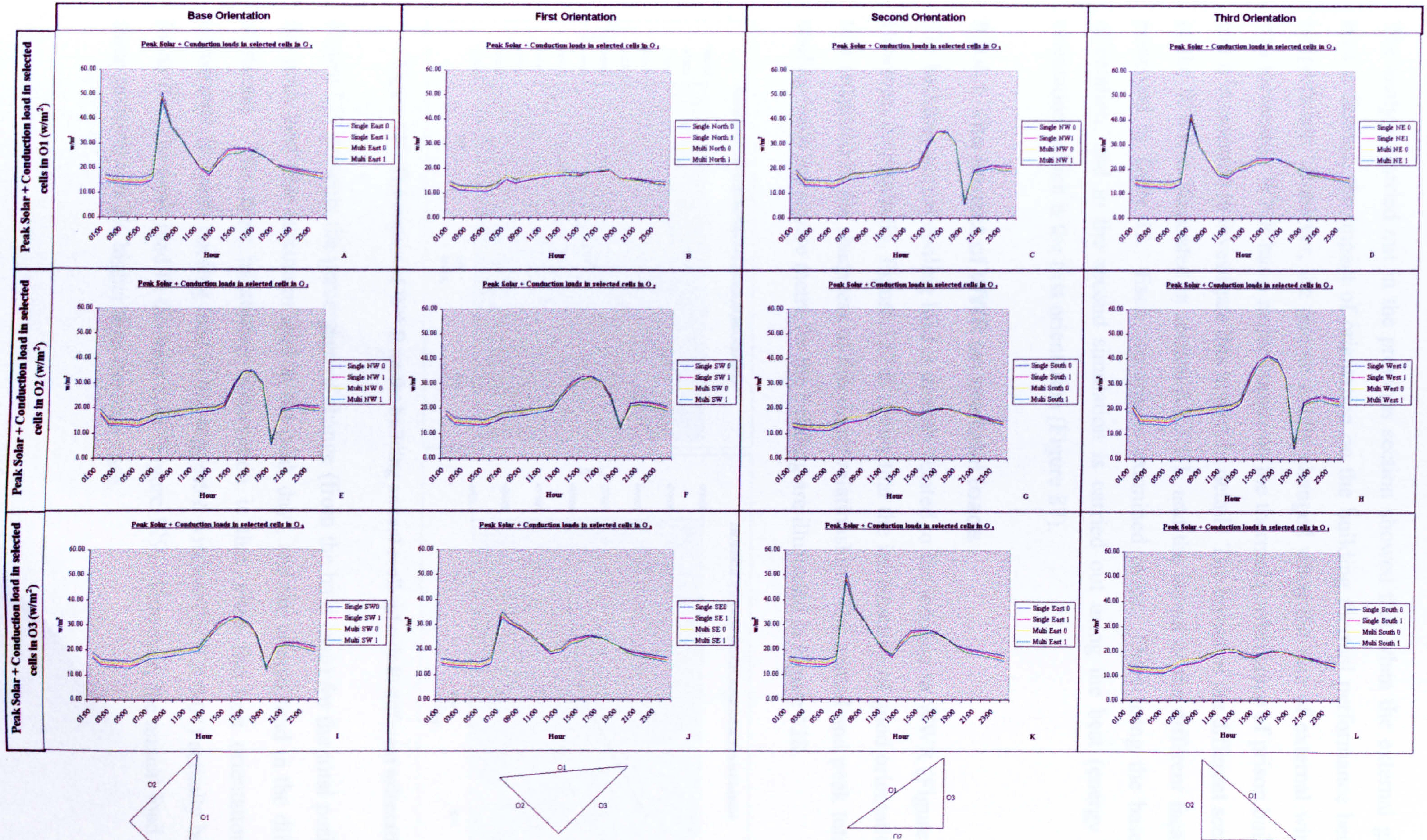


Figure 126: The impact of orientation on the envelope peak load in the different scenarios (solar + conduction)

(The UK recommended window size)

8.3.4 The impact of window to wall ratio (WWR) on the building cooling loads

The analysis carried out in the previous section showed that when the external glazing area is limited, the impact of orientation on the building thermal performance becomes insignificant. However, the picture totally changed when the size of external windows was increased. WWR has a major impact on the thermal performance of prison buildings and it is essential to investigate this impact in detail. The layout of the different scenarios of the WWR is illustrated in section 8.2.3.1.1, and the layout of the different façades is presented in Table 13. Each scenario is examined twice. Once using the base case orientation, and in the second simulation is carried out using the best (energy wise) orientation, which is the first orientation (Figure 87).

8.3.4.1 The impact of WWR on the total loads

The building annual cooling load is directly related to the increase in WWR (Figure 127). However, interestingly, Figure 127 B shows that the introduction of good orientation led to a reduction in the sharpness of this direct relationship. The annual and peak total and cooling loads per square metre for the building are illustrated in Figure 128.

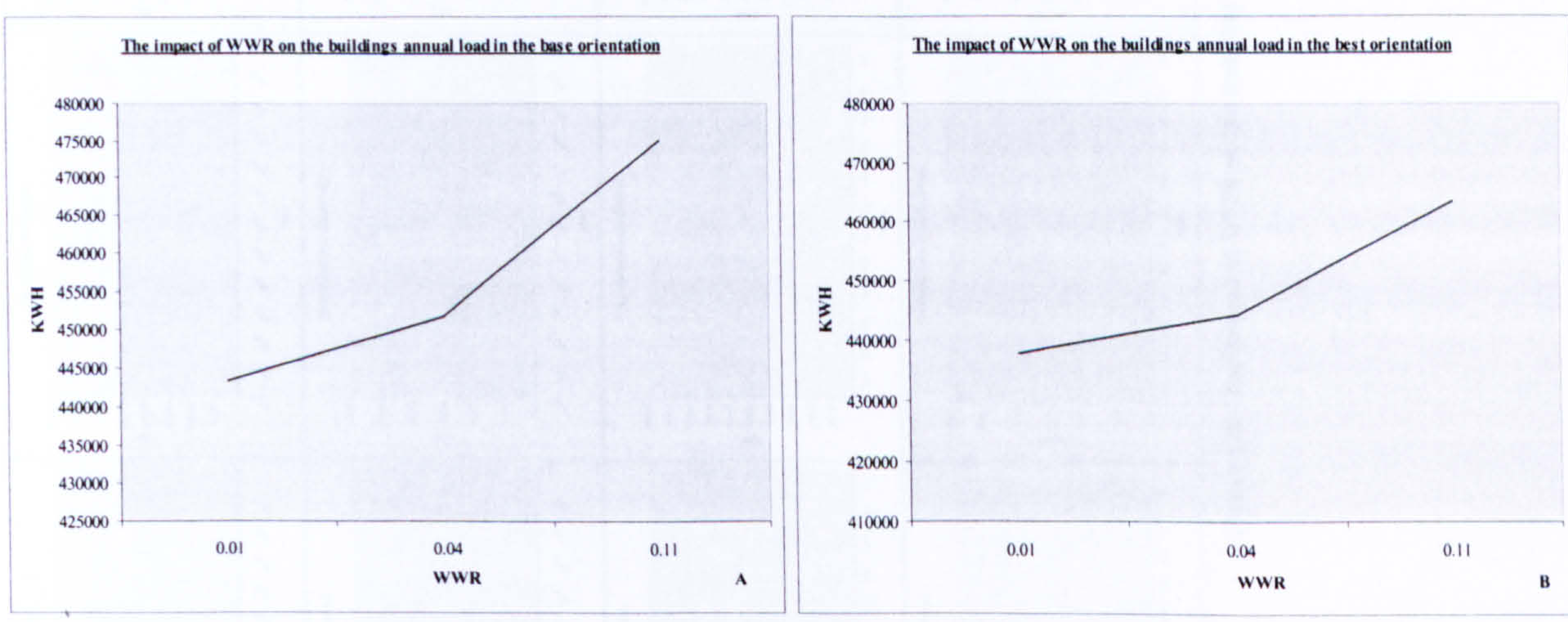


Figure 127: The impact of WWR on the building annual cooling loads in different orientations

Figure 129 presents the percentage of change (from the base case) for the total peak day, the peak load (the maximum load in the peak day), and the annual load in the different scenarios. The most interesting observation is that when the best orientation was introduced, the peak cooling load in the suggested window (WWR 0.04) actually became lower than the peak load in the base case (Figure 129). However, the annual load in the same scenario is 0.2% higher than the base case.

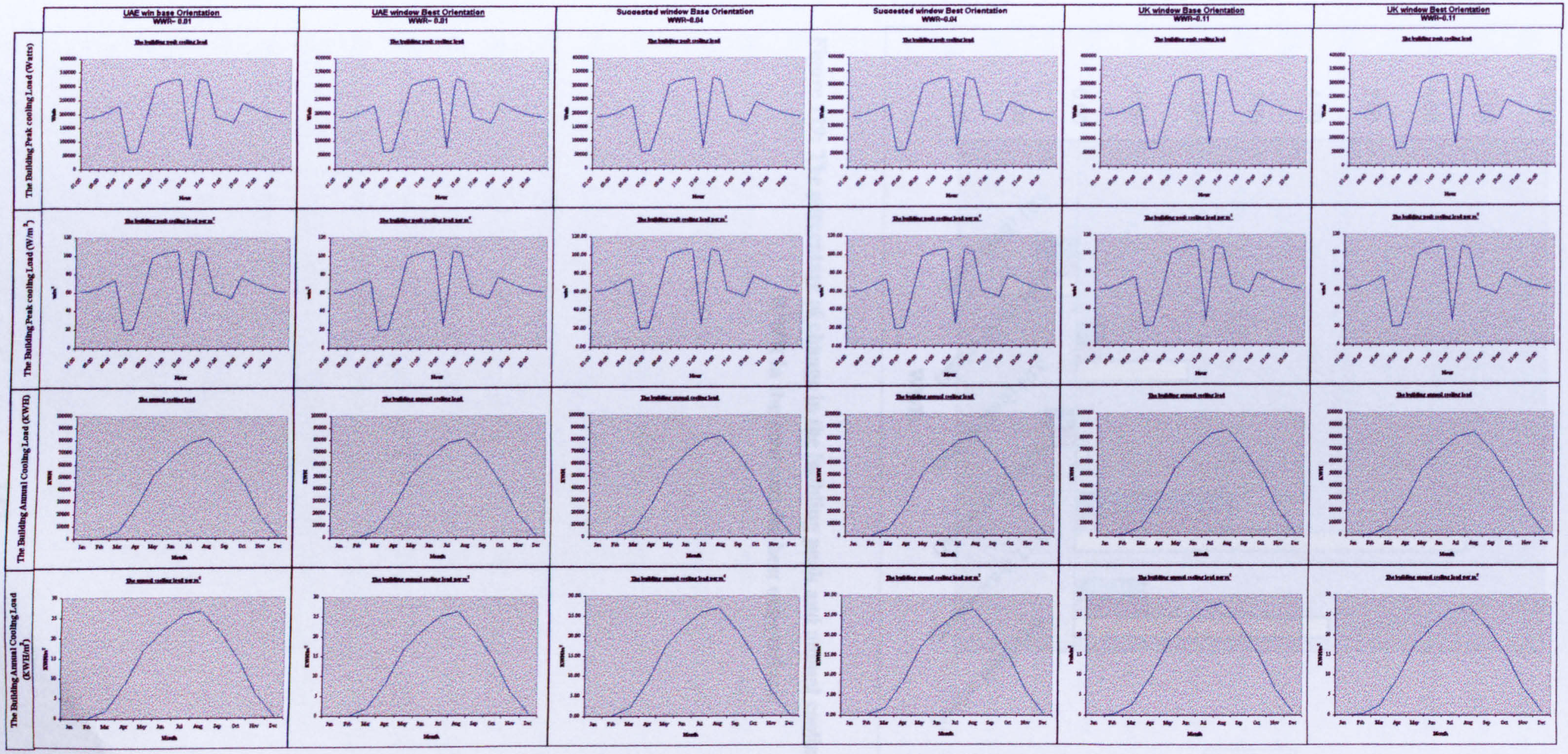


Figure 128: The impact of WWR on the building cooling loads in the different scenarios

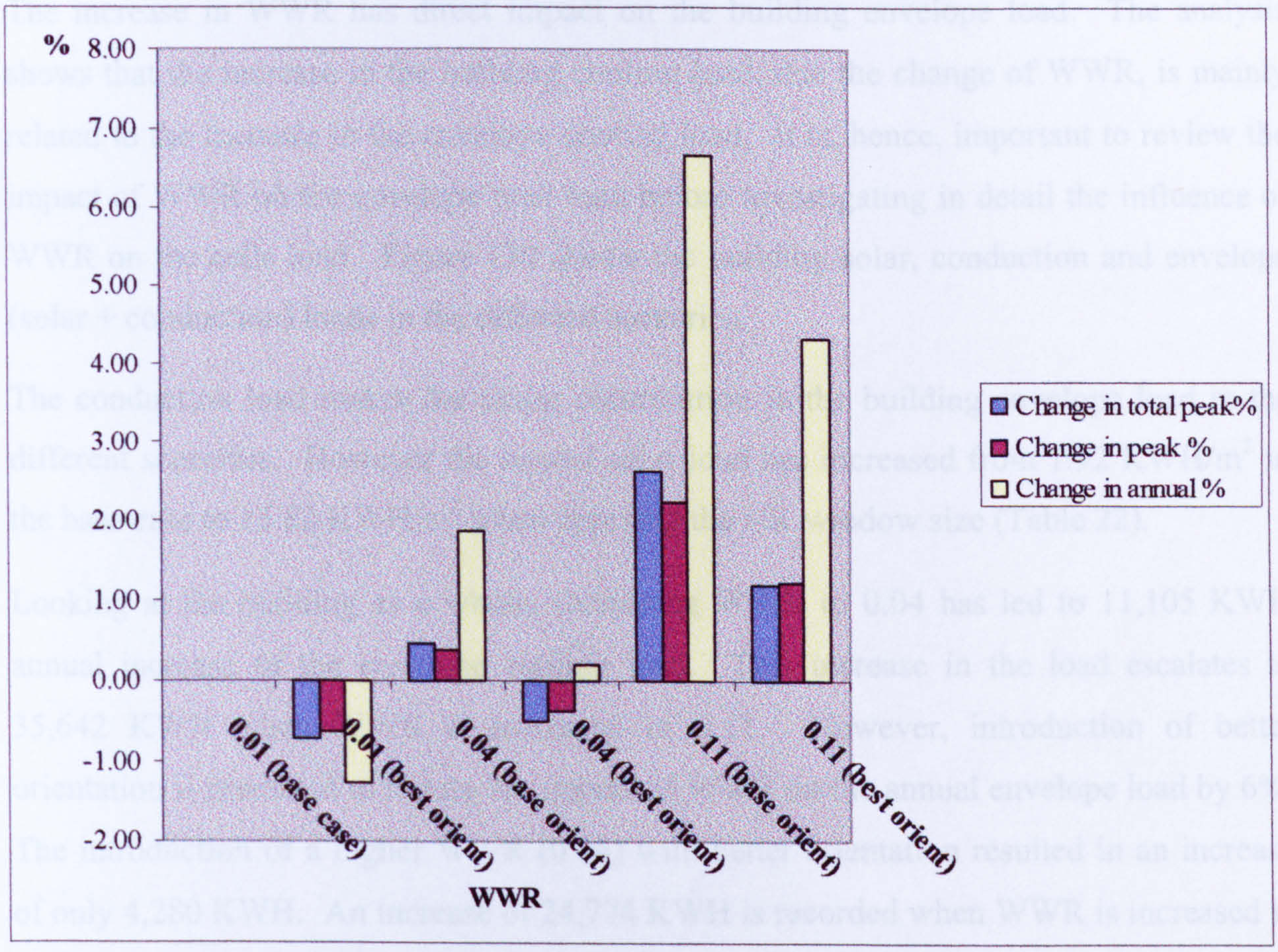


Figure 129: The percentage of change in the building peak and annual cooling loads with different WWR in the base and the best orientations

The increase in WWR has direct impact on the building envelope load. The analysis shows that the increase in the building cooling load, due the change of WWR, is mainly related to the increase in the envelope cooling load. It is, hence, important to review the impact of WWR on the envelope total load before investigating in detail the influence of WWR on the cells load. Figure 130 shows the building solar, conduction and envelope (solar + conduction) loads in the different scenarios.

The conduction load makes the major contribution to the building envelope load in the different scenarios. However the annual solar load has increased from 1.92 KWH/m^2 in the base case to 13.82 KWH/m^2 when applying the UK window size (Table 22).

Looking at the building as a whole, increasing WWR to 0.04 has led to 11,105 KWH annual increase of the envelope cooling load. This increase in the load escalates to 35,642 KWH when WWR is increased to 0.11. However, introduction of better orientation is predicted to reduce the impact of WWR on the annual envelope load by 6%. The introduction of a higher WWR (0.04) with better orientation resulted in an increase of only 4,280 KWH. An increase of 24,774 KWH is recorded when WWR is increased to 0.11 in the best orientation scenario.

In summary, the analysis of the three scenarios shows that WWR has a large impact on the overall cooling load in the UAE environment. The analysis also shows that the overall cooling load was more sensitive to orientation with higher WWR.

Despite the sharp increase in solar gain in the second scenario (WWR=0.04), the overall cooling load change is only 0.2%. Such insignificant increase might support an increase in the window area, to improve the cell environment. A large increase in WWR (i.e. as recommended by the UK Home Office, WWR=0.11) will result in a major increase of 25% in the envelope contribution of the cooling load in the UAE environment. This however, will result in a total cooling load increase of 7% with the best orientation. It is interesting to note that part of the increase in the UK recommended WWR with the best orientation actually occurs in October, and not during the hottest part of the year (July-September) (Figure 130: F)

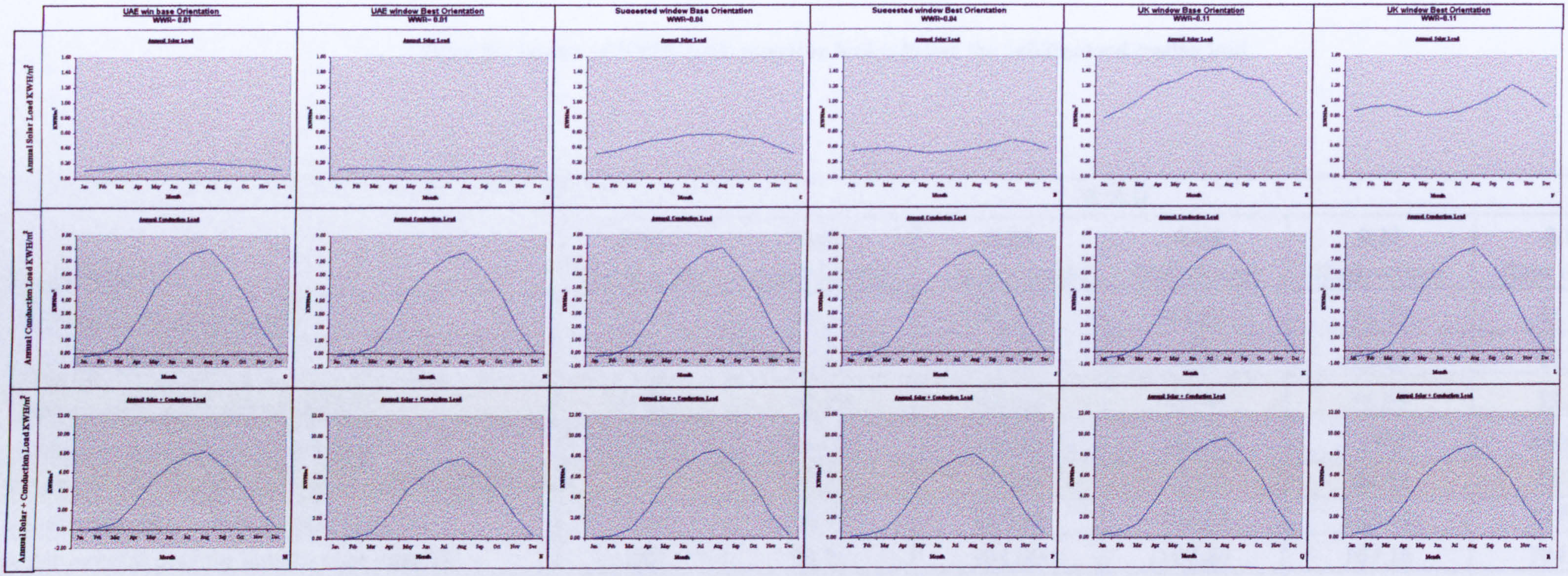


Figure 130: The impact of WWR on the building solar and conduction Loads in the different scenarios

Table 22: Impact of WWR on the envelope heat gain and the building total cooling load

Load Type	WWR					
	0.01 (base case)	**0.01** (best orient)	**0.04** (base orient)	**0.04** (best orient)	**0.11** (base orient)	**0.11** (best orient)
Conduction gain KWH/m^2	43.15	41.84	43.07	41.86	42.79	41.79
Solar gain KWH/m^2	1.92	1.61	5.60	4.61	13.83	11.32
Total envelope heat gain KWH/m^2	45.08	43.45	48.68	46.46	56.63	53.10
Annual total cooling load KWH/m^2	143.68	141.88	146.41	143.97	153.97	150.19
Envelope load in relation to total cooling load %	31.37	30.62	33.25	32.27	36.78	35.36
Relative envelope load to base case %	100	96.39	107.98	103.08	125.62	117.81
Relative total cooling load to base case %	100	98.75	101.90	100.20	107.16	104.53
Relative envelope load %	100	96.39	100	95.46	100	93.78
Relative total cooling load %	100	98.75	100	98.33	100	97.55

8.3.4.2 The impact of WWR on the overall cell area cooling loads

The overall cell area load sensitivity to changes in WWR follows the same pattern as the whole building. Figure 131 shows a direct relation between the increase in WWR and the cells annual cooling load. In a similar pattern, this increase in the cells cooling load is lessened by the introduction of a better orientation (Figure 131: B). The total, annual and peak cooling loads per square metre in the cells are presented in Figure 132.

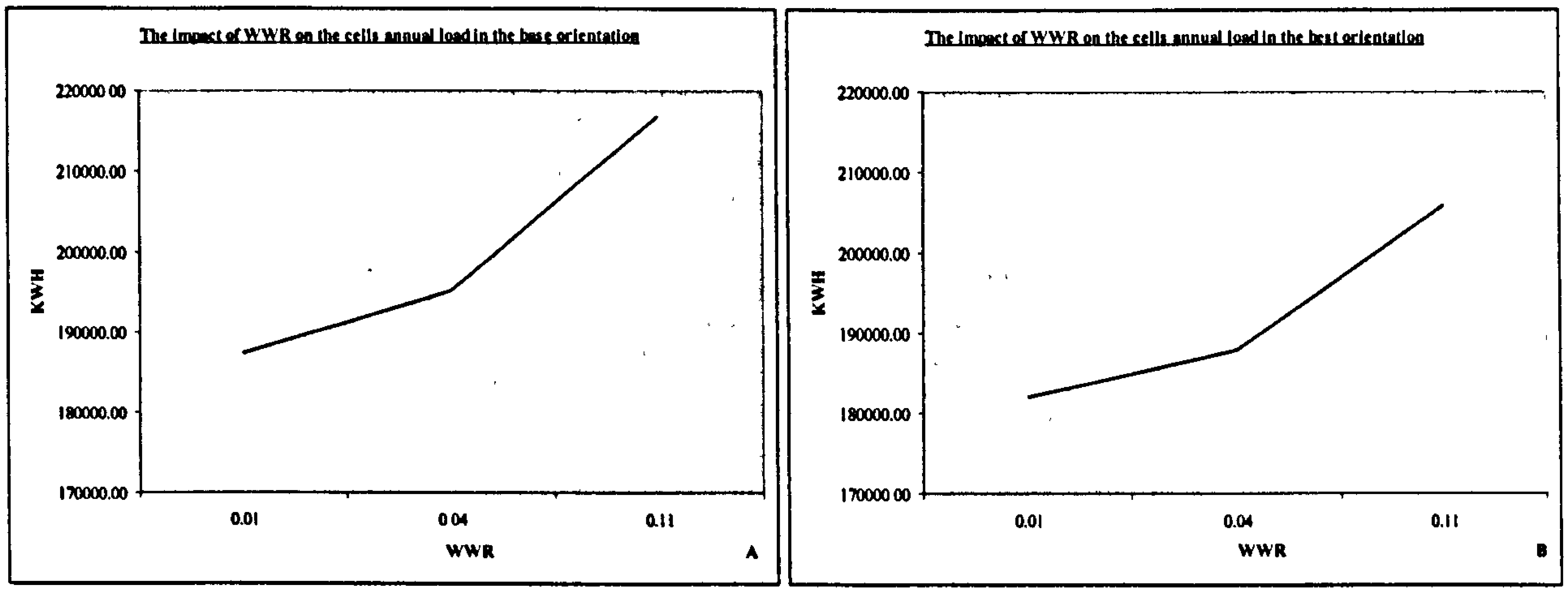


Figure 131: The impact of orientation on the cells annual cooling loads in different orientations

Figure 133 shows the percentage of the change (from the base case) in peak day, peak load and the annual load in the cells zone in the different scenarios. Interestingly, the cells peak cooling load with the suggested window (WWR 0.04) in the best orientation is lower than the same load in the base case. The suggested window annual load is slightly higher than the base case (0.27 %). This insignificant increase in the cooling load can be ignored when compared to the advantages of introducing reasonable window size to prison buildings.

As the cells are located on the peripheral of the building form, they become slightly more sensitive to change of the façade configuration. While the overall increase in total cooling load is about 7% for the whole building, the ratio becomes just above 8% for the cell area. It is however important to also investigate the WWR impact on the different types of cells.

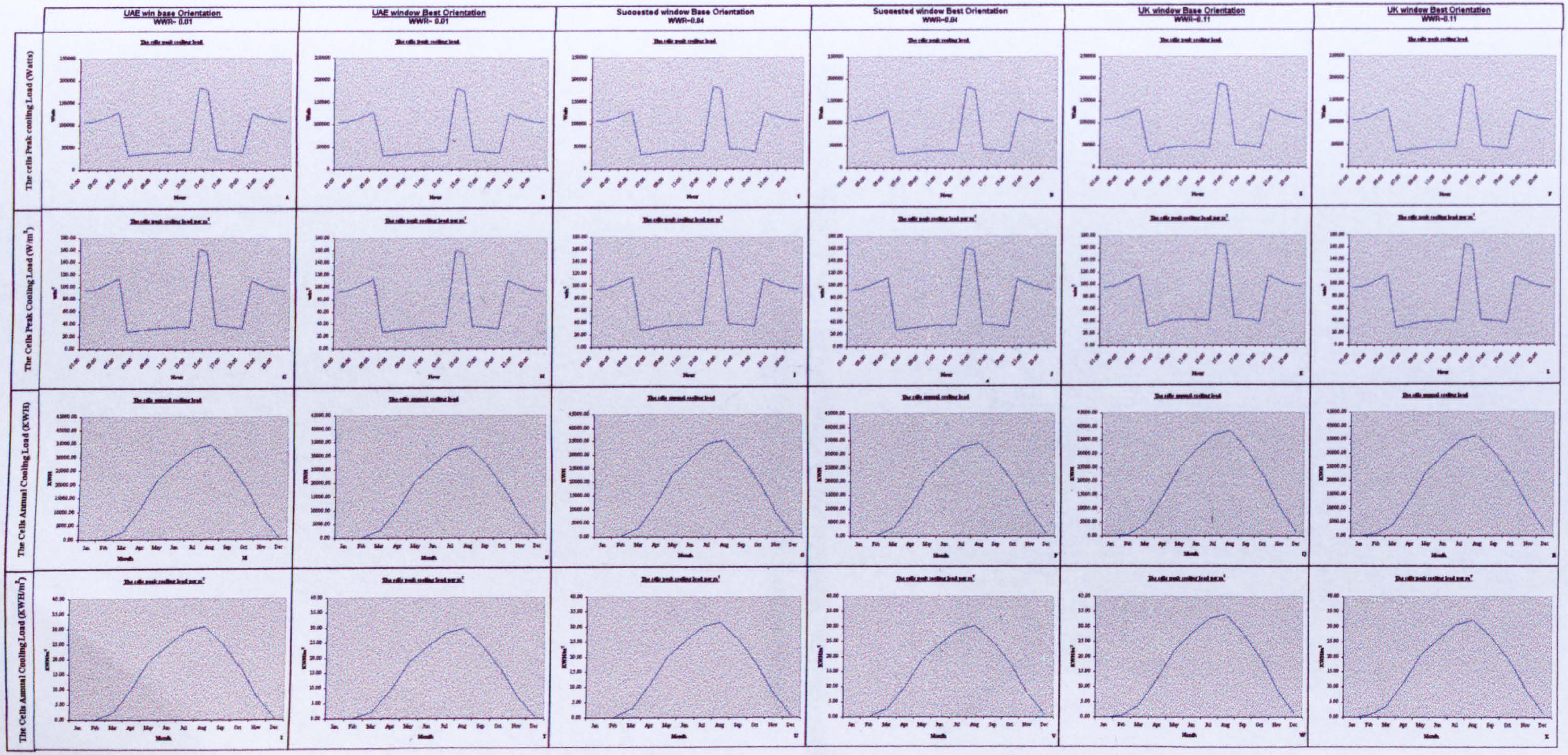


Figure 132: The impact of WWR on the cells cooling loads in the different orientations

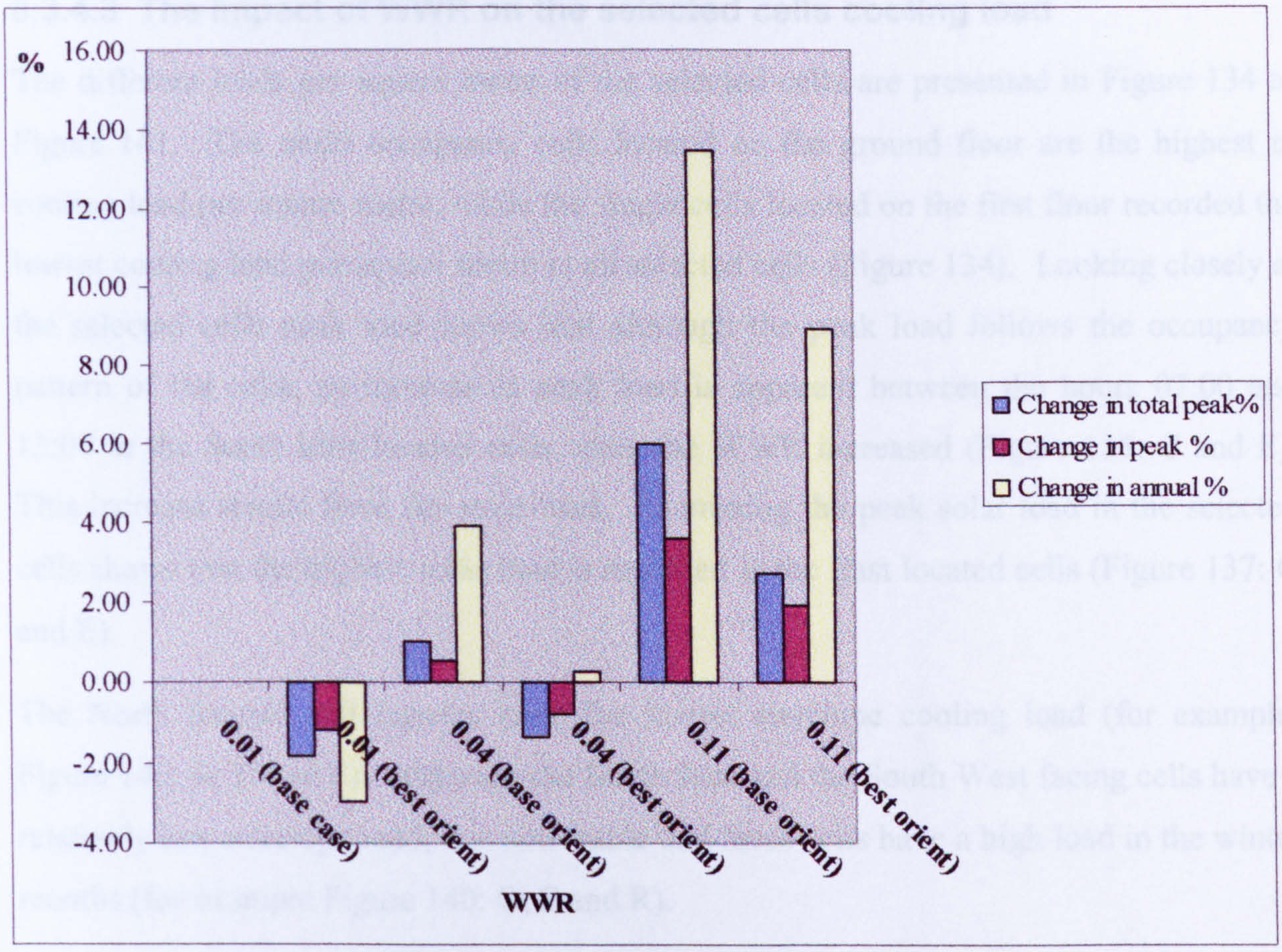


Figure 133: The percentage of the change in the cells peak and total cooling loads with different WWR in the base case and best orientation

8.3.4.3 The impact of WWR on the selected cells cooling load

The different loads per square metre of the selected cells are presented in Figure 134 to Figure 141. The multi occupancy cells located on the ground floor are the highest in cooling load per square metre, while the single cells located on the first floor recorded the lowest cooling load per square metre in all selected cells (Figure 134). Looking closely at the selected cells peak load shows that although the peak load follows the occupancy pattern of the cells, an increase in peak load is apparent between the hours 07:00 and 13:00 in the South East located cells when the WWR increased (Figure 135: C and E). This increase results from the solar load. Examining the peak solar load in the selected cells shows that the highest solar load is recorded in the East located cells (Figure 137: C and E).

The North located cell façades have the lowest envelope cooling load (for example: Figure 140: B, D and F). Although the South East and the South West facing cells have a relatively low envelope load, it is noticeable that these cells have a high load in the winter months (for example Figure 140: O, P and R).

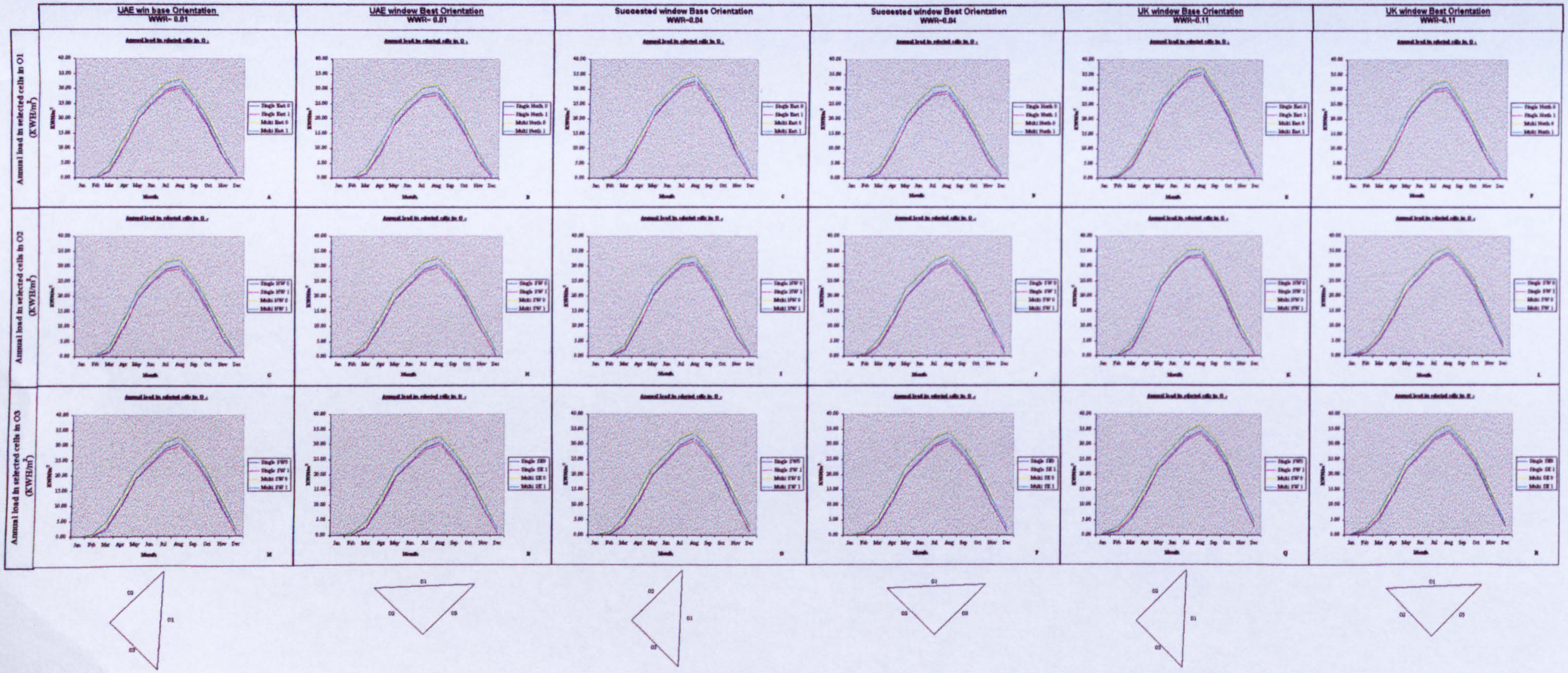


Figure 134: The impact of WWR on the annual cooling load in the selected cells in the different orientations

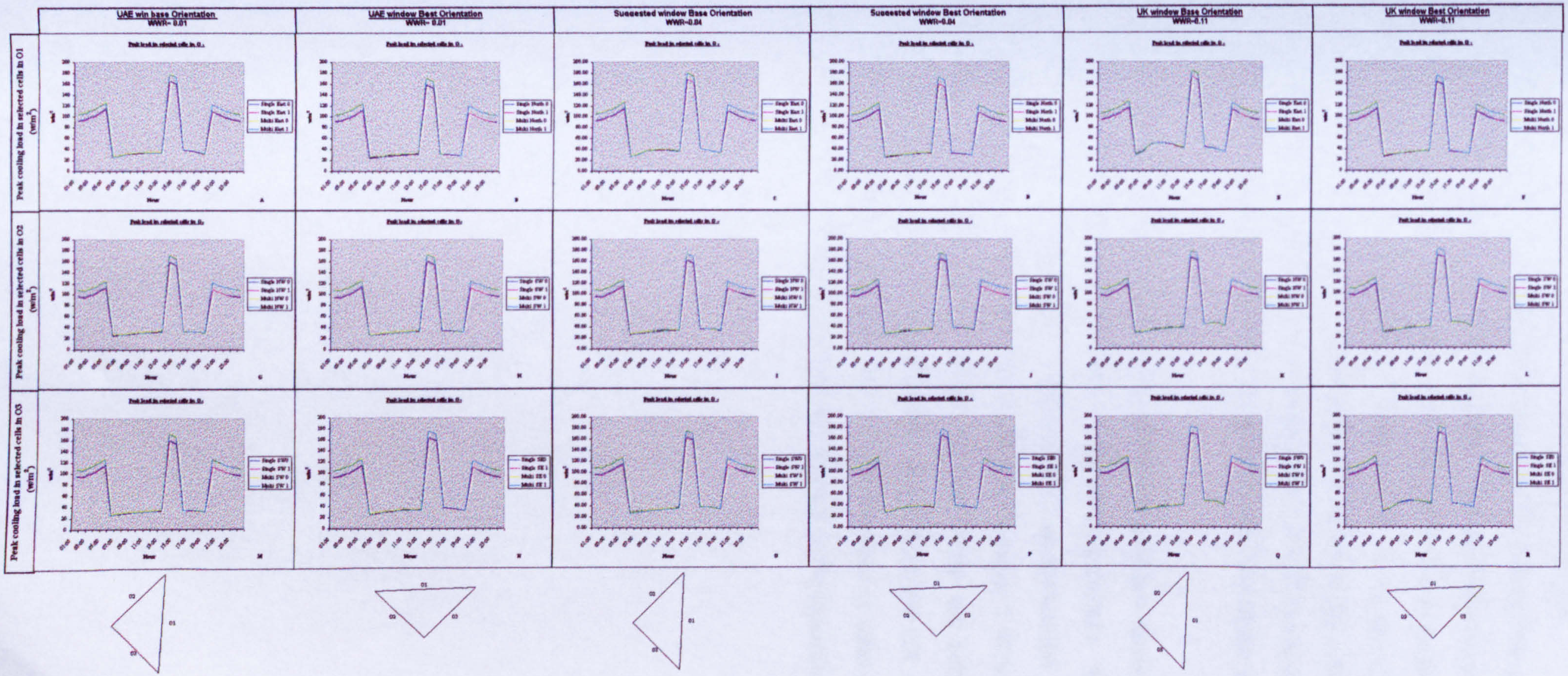


Figure 135: The impact of WWR on the selected cells peak cooling load in the different orientations

8.3.4.3.1 WWR and the selected cells solar cooling load

The previous discussion of the impact of WWR on the overall annual and peak cooling load is reflected in the selected cells. The analysis shows no major differences between the single and multiple cells. A slight difference is recorded in the base scenarios when larger windows are introduced (Figure 136: E, K, and Q). The analysis of single cells also stressed the previous argument, that the increase in the annual solar cooling load per square metre using the UK recommended WWR (with the best scenario) occurs during the winter months, while remaining relatively low in the summer months (Figure 136: F, L and R).

The testing of the increase in the peak solar gain per square metre in the selected cells can also be important for the design of the cooling system. There is a slight increase in the overall daily cooling load with the UK recommended WWR in the O_1 orientation. Despite such increase, the maximum load remains 5 W/m^2. It is also important to note that such increase occurs during the time when the cells are vacant (Figure 137: F). Similarly, analysis of O_3 orientation shows that the UK recommended WWR with the best orientation is efficient. Most of the increase in total cooling load occurs between 7 AM and 1 PM, while the inmates are located in the association area.

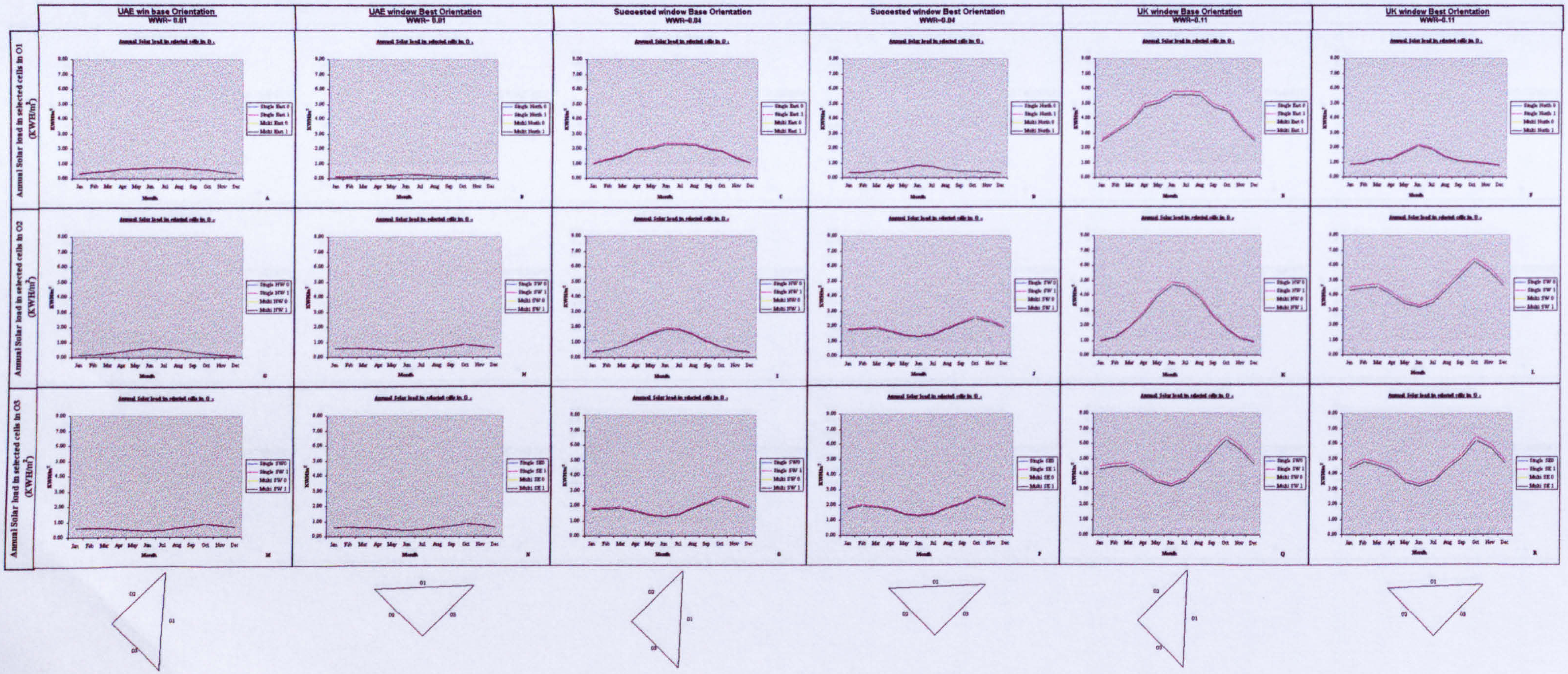


Figure 136: The impact of WWR on the selected cells annual solar load in the different orientations

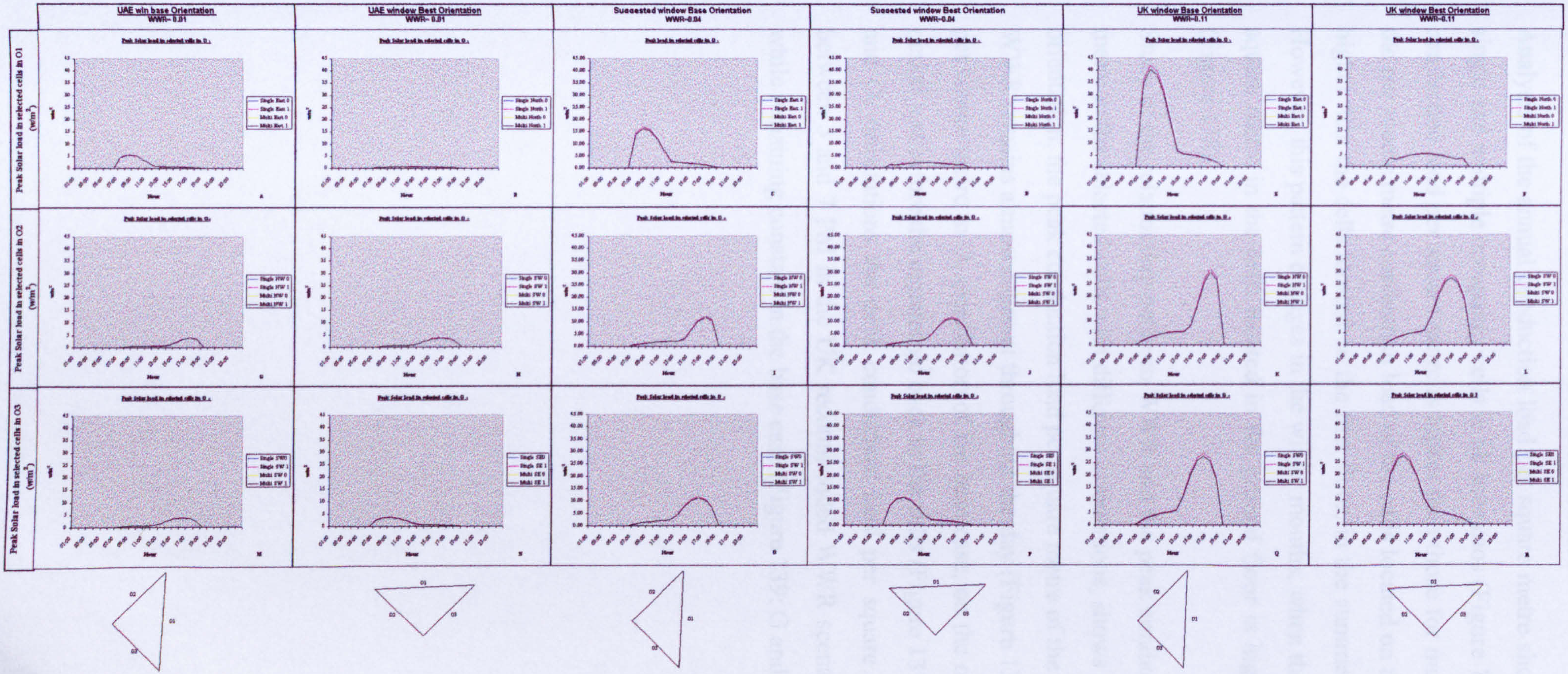


Figure 137: The impact of WWR on the selected cells peak solar load in the different orientations

8.3.4.3.2 WWR and the selected cells conduction load

Analysis of the annual conduction load per square metre shows a difference between the single and multiple occupancy cells in all scenarios (Figure 138). The single cells annual conduction load per square metre is higher than those for multiple occupancy. However, the per square metre conduction load of the cells located on the ground floor is noticeably higher than the cells located on the first floor, in the summer months (June- September). However, this pattern changes in the winter months, when the conduction annual load per square metre in the cells located in the ground floor is higher than the first floor cells (Figure 138).

Study of the relationship between WWR and the peak conduction cooling load per square metre in the selected cells with different orientations, shows interesting results. In the O_1 orientation, the peak conduction load per square metre of the cells with UK recommended WWR remains almost constant throughout the day (Figure 139: F). Peak conduction load per square metre in O_1 orientation of the base case, on the other hand, is higher in every period just before the inmates go back to the cells (Figure 139: A). On the contrary, in O_2 and O_3 orientations the peak conduction load per square metre dropped dramatically between 3 and 7 PM in the UK recommended WWR scenarios (Figure 139: K and Q), while remaining constant in the base case (Figure 139: G and M).

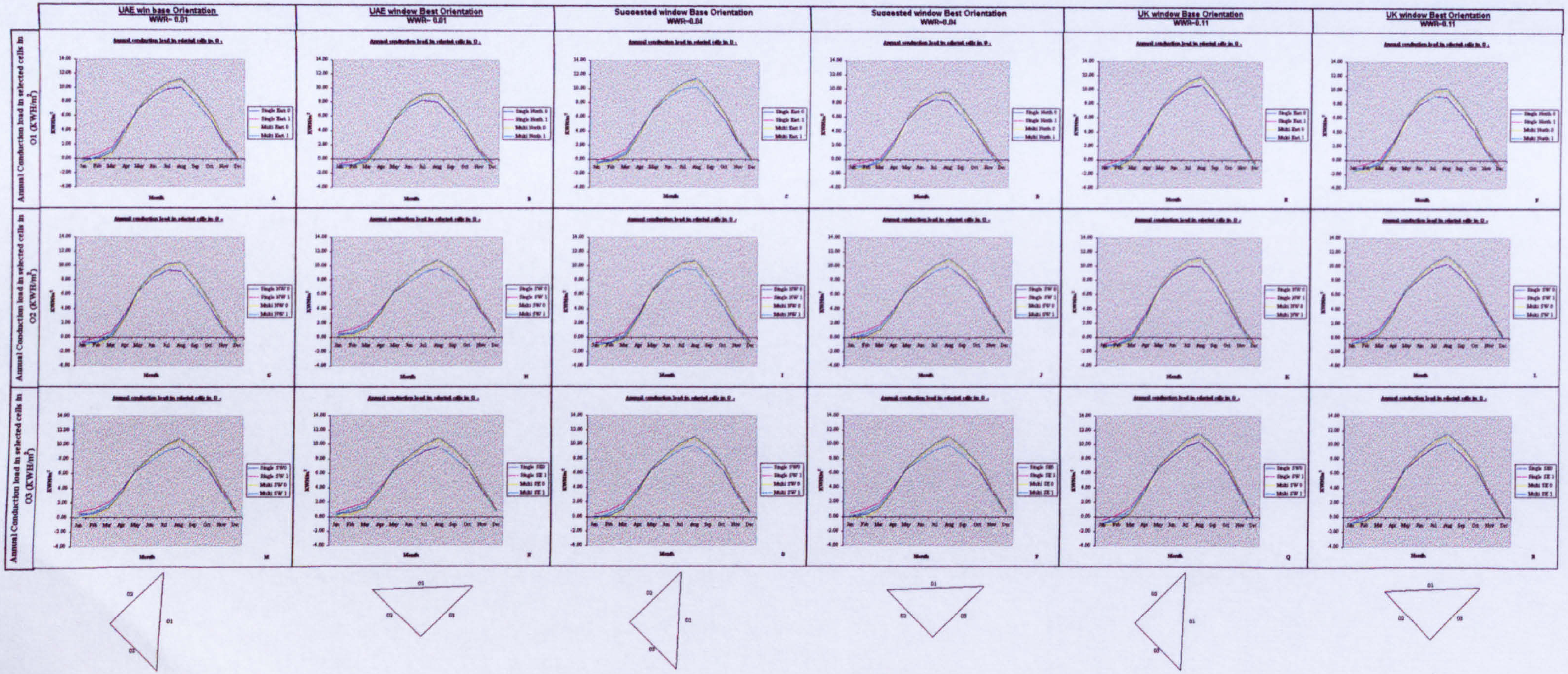


Figure 138: The impact of WWR on the selected cells annual conduction load in the different orientations

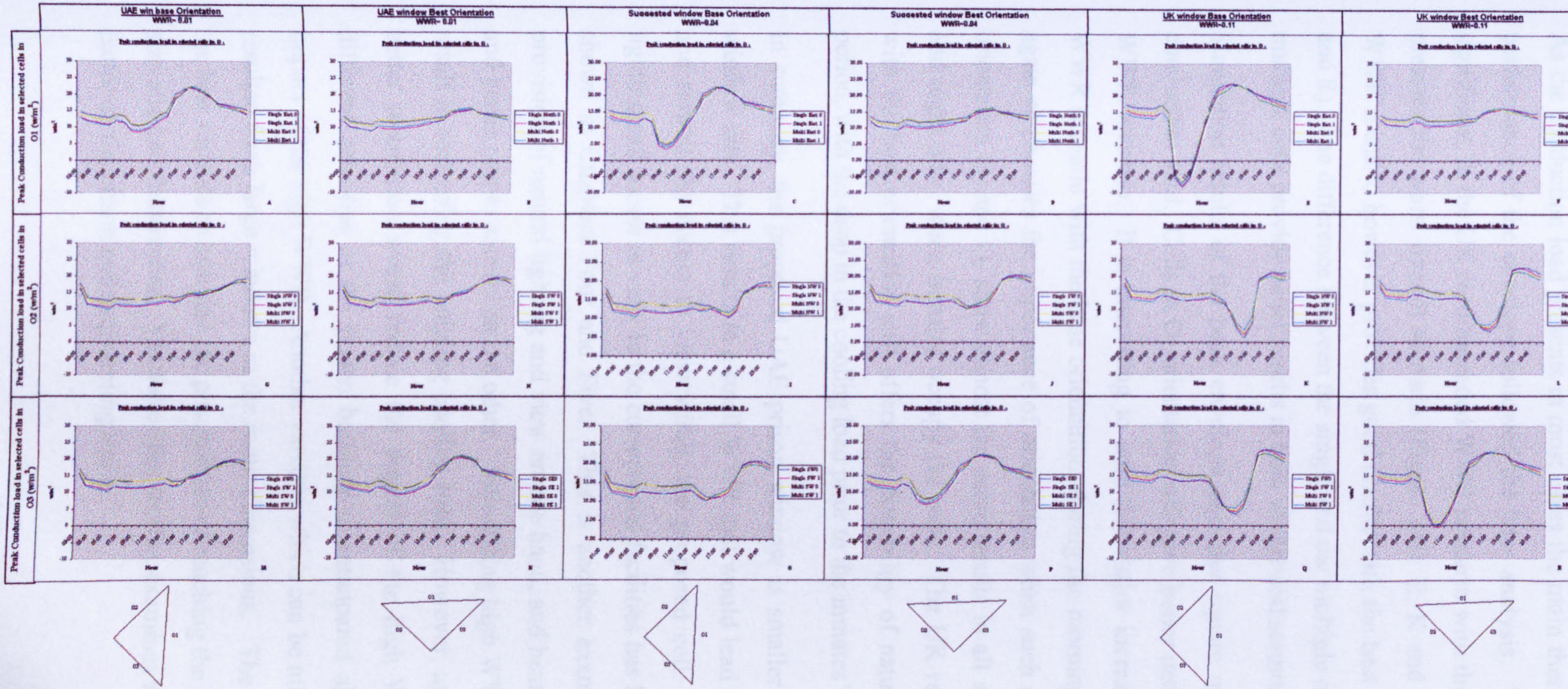


Figure 139: The impact of WWR on the selected cells peak conduction load in the different orientations

8.3.4.3.3 WWR and the selected cells envelope load (solar + conduction)

As the conduction load presents in most cases the main thermal load, the overall thermal performance of the envelope followed the later analysis. The solar load was however significant, in the UK recommended WWR scenario with the base orientation. The latter presents the worst overall scenario (Figure 140: E, K and Q). The UK recommended WWR scenario however provides good results with the best orientation (Figure 140: F, L and R). The difference between the single and the multiple occupancy cells remains. The multiple cells provide better results in both winter and summer months, in all orientations.

Simulation results of the peak envelope gain per square metre follows analysis of the conduction load. Cells in O_1 orientation still give better results in the UK recommended WWR scenario. It is interesting to note that major increase in the UK recommended WWR scenario with the base orientation, during the morning time (Figure 141: E). This again emphasises the importance of orientation when such scenario is applied. Cells in orientation O_2 and O_3 show almost the same results in all scenarios during the morning and night time, when inmates occupy the cells. The UK recommended WWR scenario with the best orientation still offers the possibility of natural cooling during the night period, with the drop in the cooling load prior to the inmates' return to the cells.

In summary, the proposed UAE prison window is smaller than the UK recommended window size. This results in a small WWR that would lead to low natural lighting levels and restrict the access to view within the proposed cell. The importance of natural lighting and access to view in the correctional facilities has been strongly emphasised, as shown in Chapters Four and Five. This is another example of the tension between provision of natural lighting and view on one hand, and heat gain through large windows and hence cost to society on the other. Introducing high WWR into prison buildings will result in increasing the building cooling load. However, appropriate measures, such as better orientation would reduce the impact of the high WWR. The location of the different activities in the prison building is anticipated also to reduce the expensive impact of the high WWR. Another variable which can be utilised to change the high load resulted from large windows in the room dimensions. The fenestration factor, hence, is the best variable to examine the possibilities of reaching the ideal combination of window size and cell dimensions. The following section examines the impact of the fenestration factor on the prison building cooling loads.

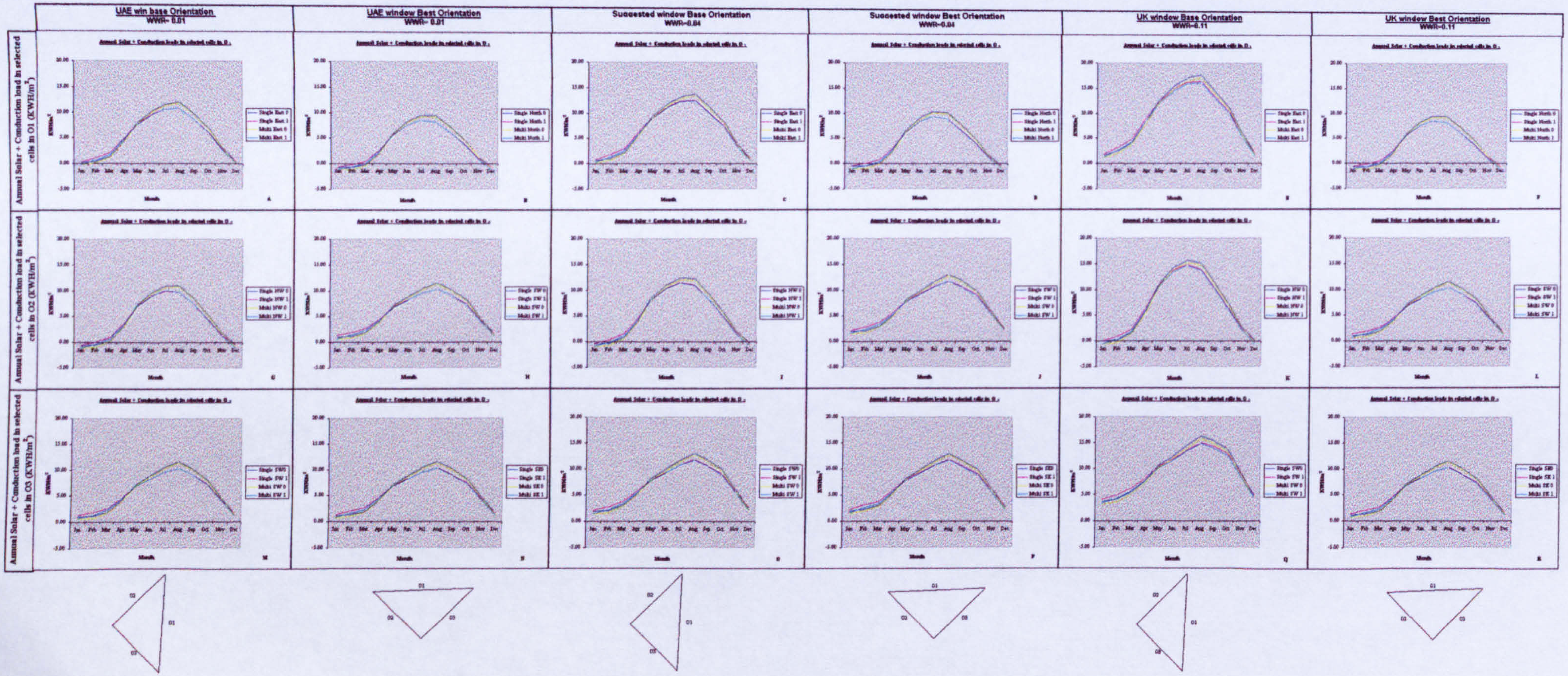


Figure 140: The impact of WWR on the selected cells annual envelope load in the different orientations

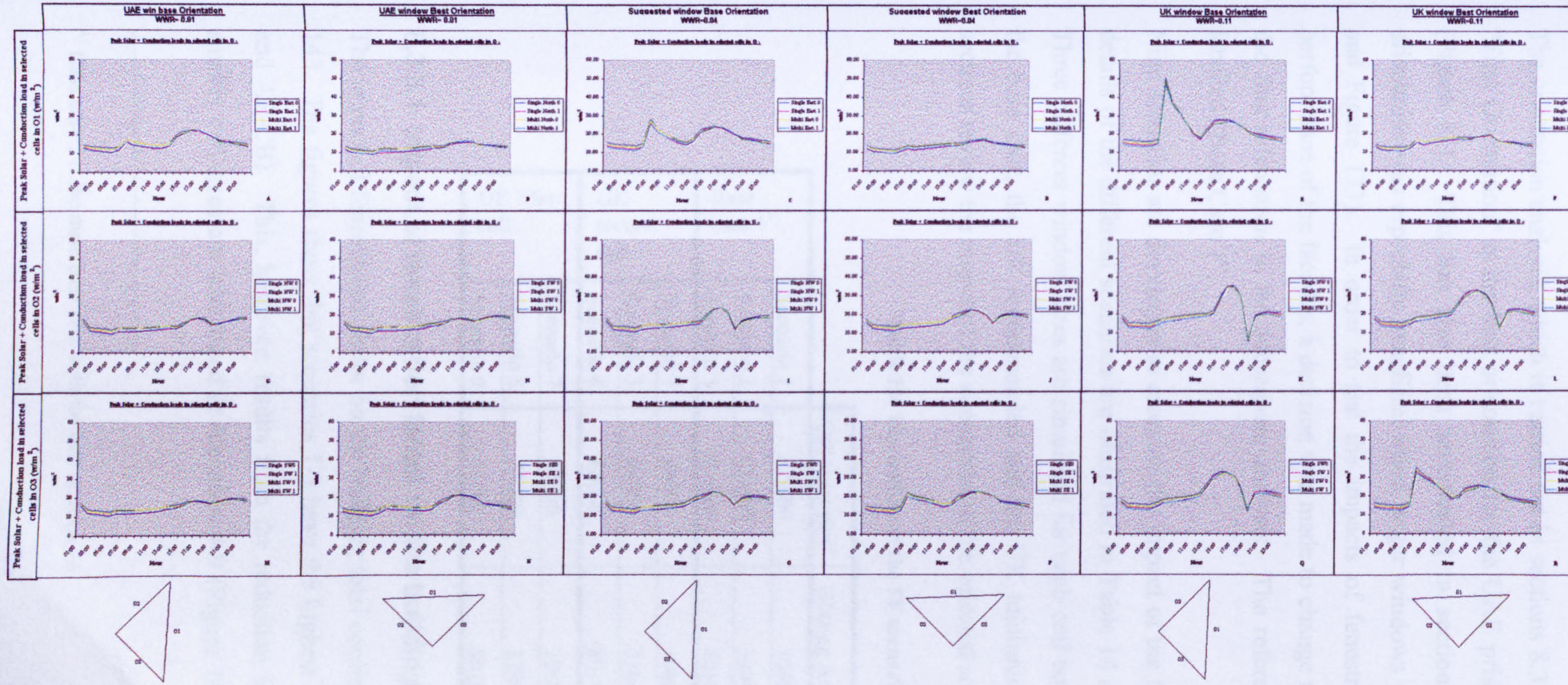


Figure 141: The impact of WWR on the selected cells peak envelope load in the different orientations

8.3.5 Impact of fenestration factor

The orientation analysis, which is carried out in sections 8.3.2 and 8.3.3, showed that the "First Orientation" is the best orientation for the UAE prison building in energy terms (Figure 87). This has also been accentuated in section 8.3.4. Applying the first orientation was especially beneficial when larger windows were introduced (Figure 129 and Figure 133). In order to test the impacts of fenestration factor on the thermal performance of the facades, a decision was made to change the base case orientation into the first orientation in the subsequent analysis. The reference case for the analysis is labelled "Base Case 1".

Nine scenarios are developed to examine the impact of the fenestration factor (FF). The details of the different scenarios are illustrated in Table 14 and summarised in Table 23. Three different window sizes are simulated for each cell configuration case. These are: the base case, the UK recommended and the UK minimum cell sizes. The following sections review the output of the simulation of the selected scenarios.

Table 23: The outline of the FF scenarios

		Cell Area mm^2	Glazing Area mm^2	FF
Base case 1[11]	Scenario 1	105600	1068	0.010
	Scenario 2	105600	3204	0.030
	Scenario 3	105600	8010	0.076
UK recom. cell	Scenario 4	68000	1068	0.016
	Scenario 5	68000	3204	0.047
	Scenario 6	68000	8010	0.118
UK Min. cell	Scenario 7	55000	1068	0.019
	Scenario 8	55000	3204	0.058
	Scenario 9	55000	8010	0.146

8.3.5.1 Impact of fenestration factor on the building cooling loads (FF)

The impact of fenestration factor on the building total cooling load is presented in Figure 143. The figures show that scenarios 1-3 have the highest total loads (Figure 143: A-C and AB-CB). This, however, results from the reduction in the building volume when smaller cell sizes are introduced in scenarios 4-9 (Figure 143: D-I and Figure 143: DB-

[11] Base case 1 is the main base case with the best orientation

IB). Investigating the hourly and annual loads per square metre would provide a better comparative analysis and understanding of the FF impact on the prison building load.

Figure 142 shows a very slight increase of both per square meter peak and annual thermal load with the increase in the fenestration factor in the whole prison building. This could be explained in the light of the overall impact of the roof conduction load and the ventilation load.

Figure 143 shows an increase in the total cooling load per square metre. This increase reaches 22% in the difference between the UAE base case 1 and the UK minimum cell size configuration with large windows (scenario 9).

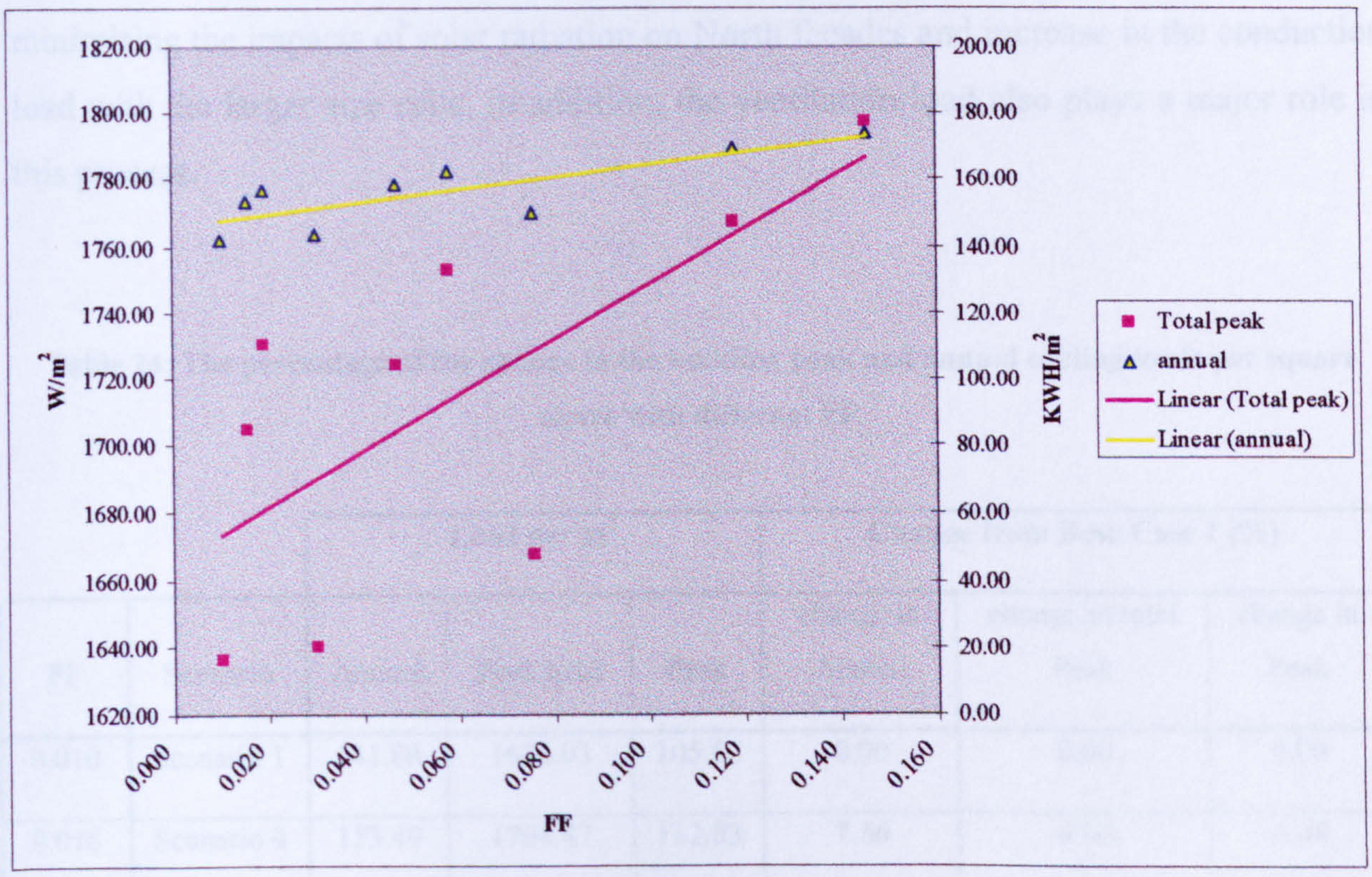


Figure 142: The impact of FF on the building peak and annual cooling load per square metre

Examining the peak and annual load per square metre shows that scenarios 1-3 have the lowest load per square meter among the nine scenarios under investigation (Figure 142 and Figure 143: AA-CA and AC-CC). Figure 144 shows the percentage of change (from the base case) in the total peak, the peak and the annual cooling loads in the different scenarios. It is clear that the cooling load per square metre (peak and annual) is inversely related to the building size. For example, the annual load per square metre in scenario 9 has increased by 18.44%. However, the cooling load is directly related to the increase in the window size. For example, the annual load in scenario 3 is 5.5 % higher than the same load in scenario 1.

More in depth analysis of Table 24 shows that the fenestration factor can have a large impact on the total thermal load in prison buildings. This can be up to 17.2% increase in the case of the UK minimum cell size with large windows (scenario 9). Similarly the annual thermal load increases by 18.4%. The difference in changes between peak (9.63%) and annual (16.25%) thermal load is much greater for more spacious cells with the same window size (Scenario 6). Changes in FF were therefore more sensitive to the cell size. This can be explained as the best orientation model put more cells on the north façade. Figure 145 shows that for scenario 8, the peak day would fall in September minimising the impacts of solar radiation on North facades and increase in the conduction load with the larger size cells. In addition, the ventilation load also plays a major role in this process.

Table 24: The percentage of the change in the building peak and annual cooling loads per square metre with different FF

		Load per m^2			Change from Base Case 1 (%)		
FF	Scenario	Annual	Peak total	Peak	change in Annual	change in total Peak	change in Peak
0.010	Scenario 1	141.88	1636.03	105.52	0.00	0.00	0.00
0.016	Scenario 4	153.49	1704.47	112.83	7.56	4.02	6.48
0.019	Scenario 7	156.79	1730.49	123.13	9.51	5.46	14.30
0.030	Scenario 2	143.97	1639.86	105.80	1.45	0.23	0.26
0.047	Scenario 5	158.34	1723.84	114.04	10.39	5.09	7.47
0.058	Scenario 8	162.42	1752.79	124.55	12.65	6.66	15.28
0.076	Scenario 3	150.19	1667.92	107.52	5.53	1.91	1.86
0.118	Scenario 6	169.41	1767.02	116.76	16.25	7.41	9.63
0.146	Scenario 9	173.95	1797.08	127.36	18.44	8.96	17.15

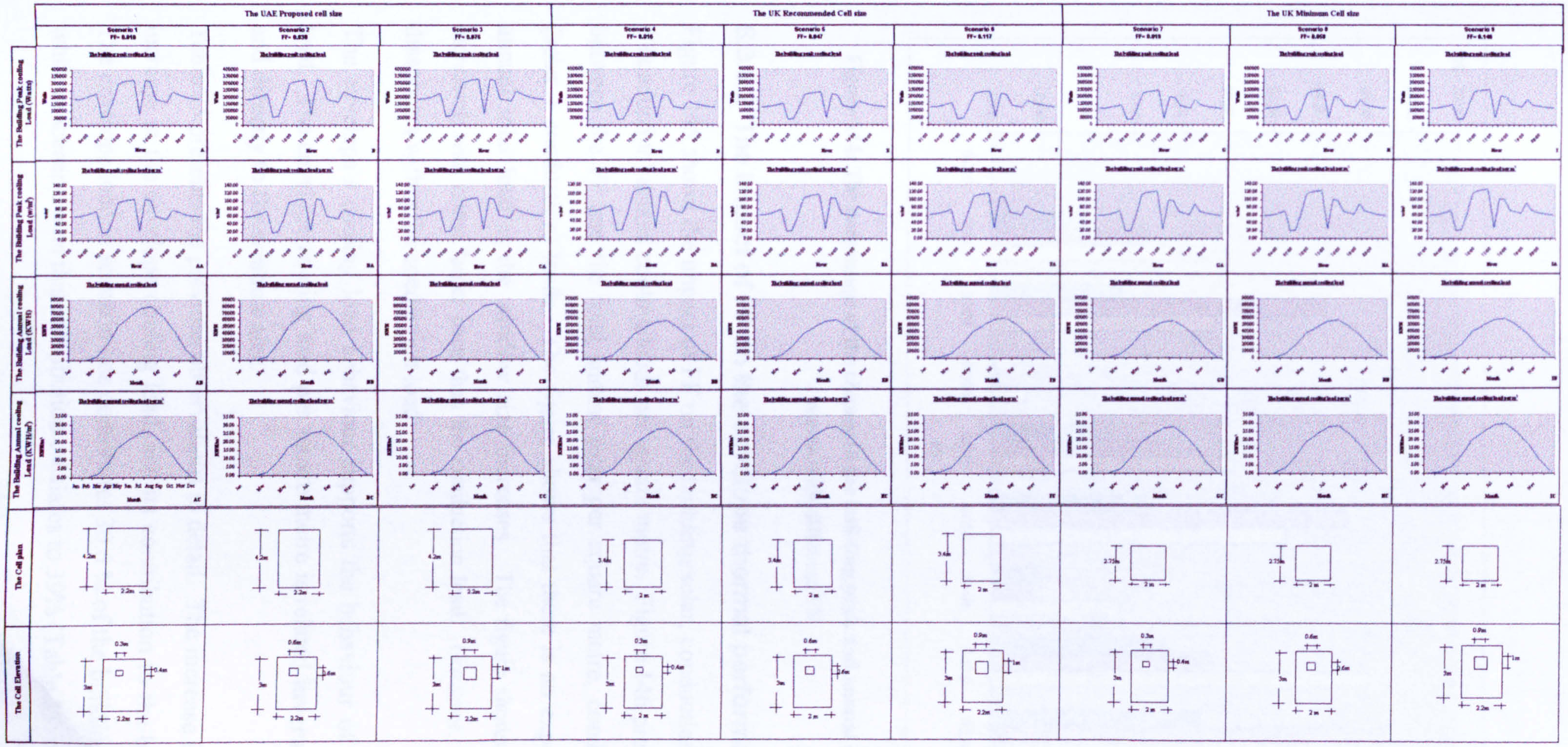


Figure 143: The impact of FF on the building cooling load in the different scenarios

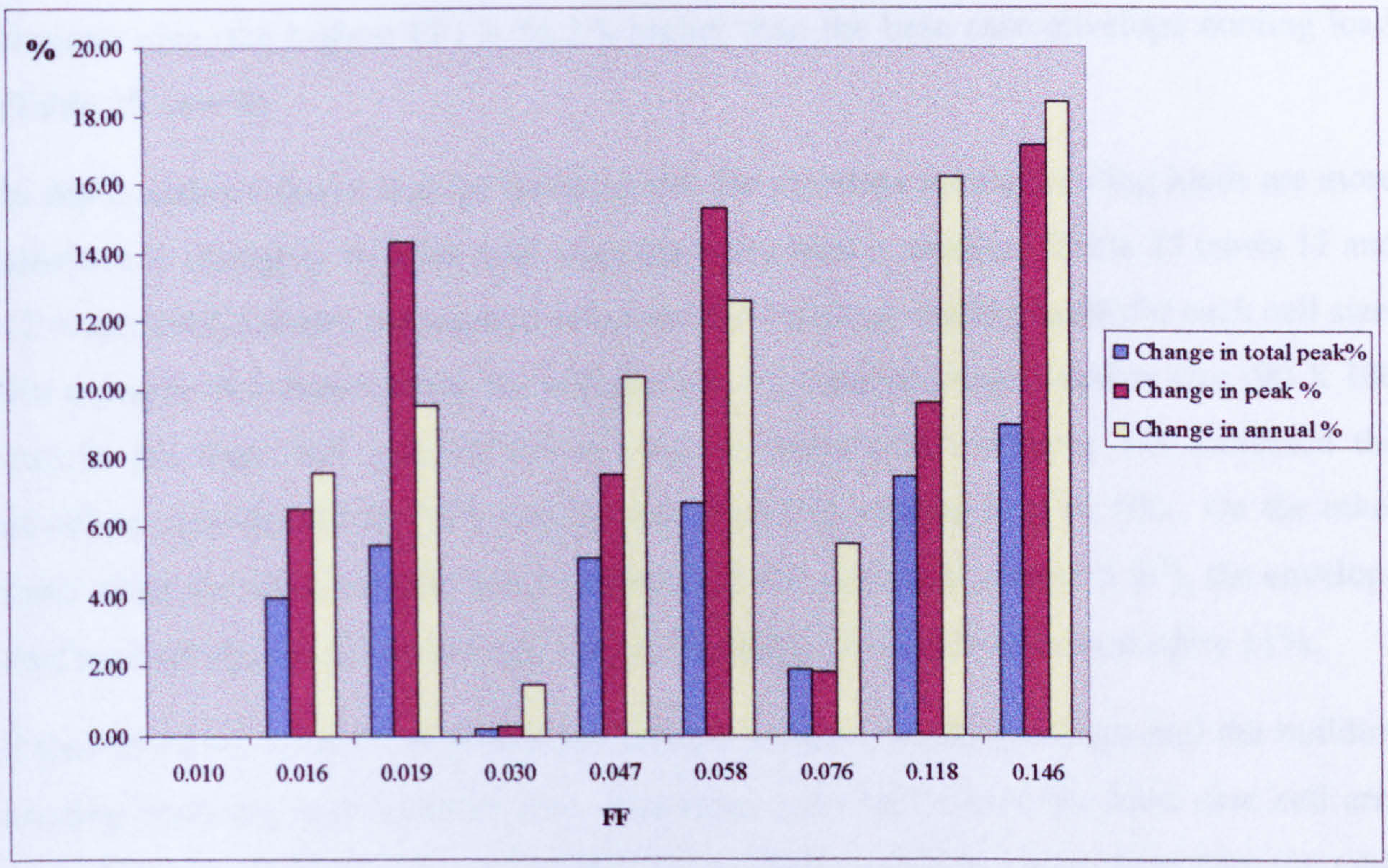


Figure 144: The percentage of the change in the building peak and annual cooling loads per square metre with different FF

8.3.5.2 The impact of FF on the envelope thermal performance

Figure 145 shows the impact of FF on the building solar, conduction and envelope (solar + conduction) annual cooling loads per square metre. Figure 146 presents the relationship between the FF and the total annual solar per square metre, conduction and envelope (solar + conduction) loads. The figure shows that there is an expected increase in the annual solar load as the window size increases. The figure shows that the solar load is increasing with rather larger pace than the conduction load. However, this increase quickly disappears within the conduction load.

The envelope's cooling load behaviour supports the behaviour of the building cooling load. The envelope cooling load per square metre is related **inversely to the room size** and **directly to the window size**.

Table 25 presents the previous observations in detail. The increase in FF leads to a direct increase in the envelope cooling load, and its contribution to the building cooling load. The envelope load in scenario one contributes 30.6 % of the building annual cooling load while in scenario nine this contribution escalates to 39% (Table 25: row 8).

Comparison analysis between the envelope cooling load in the base case and the same load in the different scenarios shows an envisaged increase. The envelope cooling load in scenario nine (the highest FF) is 56.3% higher than the base case envelope cooling load (Table 25: row 9).

In depth analysis shows that the building and the envelope annual cooling loads are more sensitive to change in window size when the room area is smaller. Table 25 (rows 11 and 12 respectively) shows the relative envelope and building cooling loads for each cell size. For example in scenario three, the introduction of relatively large window size (90 X 100 cm) in the large cell area (10.56 m^2) that is applied in scenarios 1-3 increased the envelope cooling load by 22% and the total building cooling load by 6%. On the other hand when the same window was introduced to the small cell area (5.5 m^2), the envelope cooling load increased by 36% and the total building cooling load increased by 11%.

Table 25 (rows 13 and 14) shows the relative increase of the envelope and the building cooling loads for each window size. Scenarios 1-3, which have the base case cell area with different window sizes, were taken as a reference points. It is clear from the table that the reduction of the cell size increases the cooling load per square metre. The increase in the cooling load is also related directly to the increase in the window size. For example, in scenario 4 the envelope cooling load is 14% higher than scenario 1. The same load in scenario 6 is 25 % higher than the envelope cooling load in scenario 3.

It is important before making any final conclusion to investigate the impact of the FF on the cells cooling load, which is carried out in the next section.

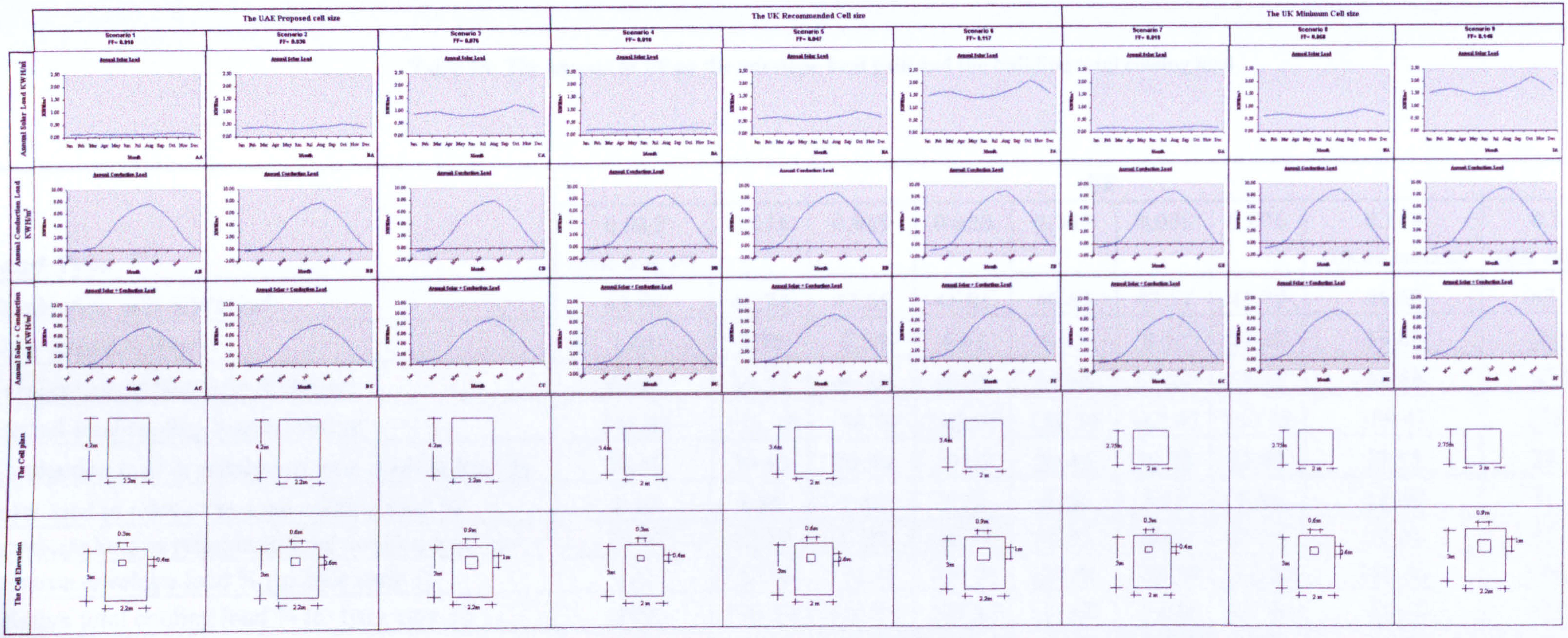


Figure 145: The impact of FF on the building solar and conduction load in the different scenarios

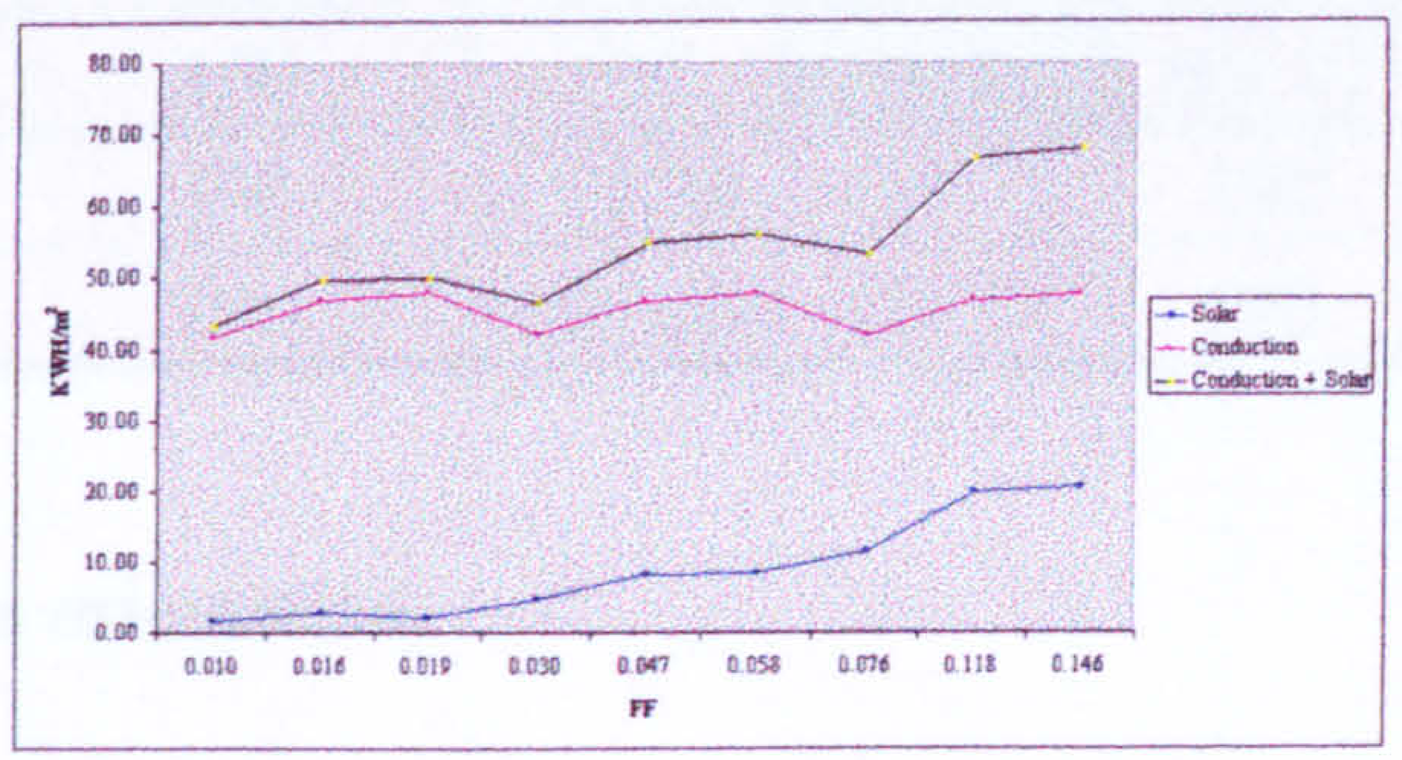


Figure 146: The impact of FF on the building solar and conduction load in the different scenarios (Summary)

Table 25: The impact of FF on the envelope heat gain and the building total cooling load

Load Type	FF								
	0.010 (base case 1*)	**0.016**	**0.019**	**0.030**	**0.047**	**0.058**	**0.076**	**0.118** (UK recom cell)	**0.146** (UK min cell)
Conduction gain KWH/m^2	41.84	46.73	47.65	41.86	46.63	47.57	41.79	46.68	47.48
Solar gain KWH/m^2	1.61	2.79	2.20	4.61	8.05	8.31	11.32	19.80	20.42
Total envelope heat gain KWH/m^2	43.45	49.53	49.86	46.46	54.68	55.87	53.10	66.48	67.90
Annual total cooling load KWH/m^2	141.88	153.49	156.79	143.97	158.34	162.42	150.19	169.41	173.95
Conduction load in relation to total cooling load %	29.49	30.45	30.39	29.07	29.45	29.28	27.82	27.55	27.30
Solar load in relation to total cooling load %	1.13	1.82	1.40	3.20	5.08	5.11	7.54	11.69	11.74
Envelope load in relation to total cooling load %	30.62	32.27	31.80	32.27	34.53	34.40	35.36	39.24	39.03
Relative envelope load % (to base case 1)	100	113.99	114.75	106.94	125.85	128.59	122.22	153.00	156.28
Relative total cooling load % (to base case 1)	100	108.18	110.51	101.47	111.60	114.48	105.86	119.40	122.60
Relative envelope load % (to each cell size)	100	100	100	106.94	110.41	112.07	122.22	134.22	136.20
Relative total cooling load % (to each cell size)	100	100	100	101.47	103.16	103.59	105.86	110.37	110.94
Relative envelope load % (to each window size)	100	113.99	114.75	100	117.69	120.25	100	125.18	127.86
Relative total cooling load % (to each window size)	100	108.18	110.51	100	109.98	105.82	100	112.80	115.82

* Base case 1 is the main base case with the best orientation.

8.3.5.3 Impact of fenestration factor on the cells cooling load

Figure 148 shows a different (than the whole building) pattern of increase of annual and peak thermal load in relation to the fenestration factor in the cell zone. While the peak load shows no major changes with the increase in the fenestration factor, annual load has a linear relationship with it.

Figure 149 shows the impact of the FF on the cells total and annual and peak cooling load per square metre. The impact of FF on the cells reflects the same pattern of the building thermal performance. The cell total annual and peak cooling load is directly related to its area (Figure 149: AA-IA and AC-IC). However, the cell annual and peak cooling load per square metre is inversely related to its area (Figure 149: AB-IB and AD-ID).

Figure 149 shows that there would be a 20% increase in per m^2 cooling requirement in the cell zone area, if the UK minimum cell configuration were adopted rather than the UAE base case with the best orientation. This direct analysis of Figure 149 can be misleading as the overall cooling load is less for the whole building and for the cells zone (Figure 149: HC and IC).

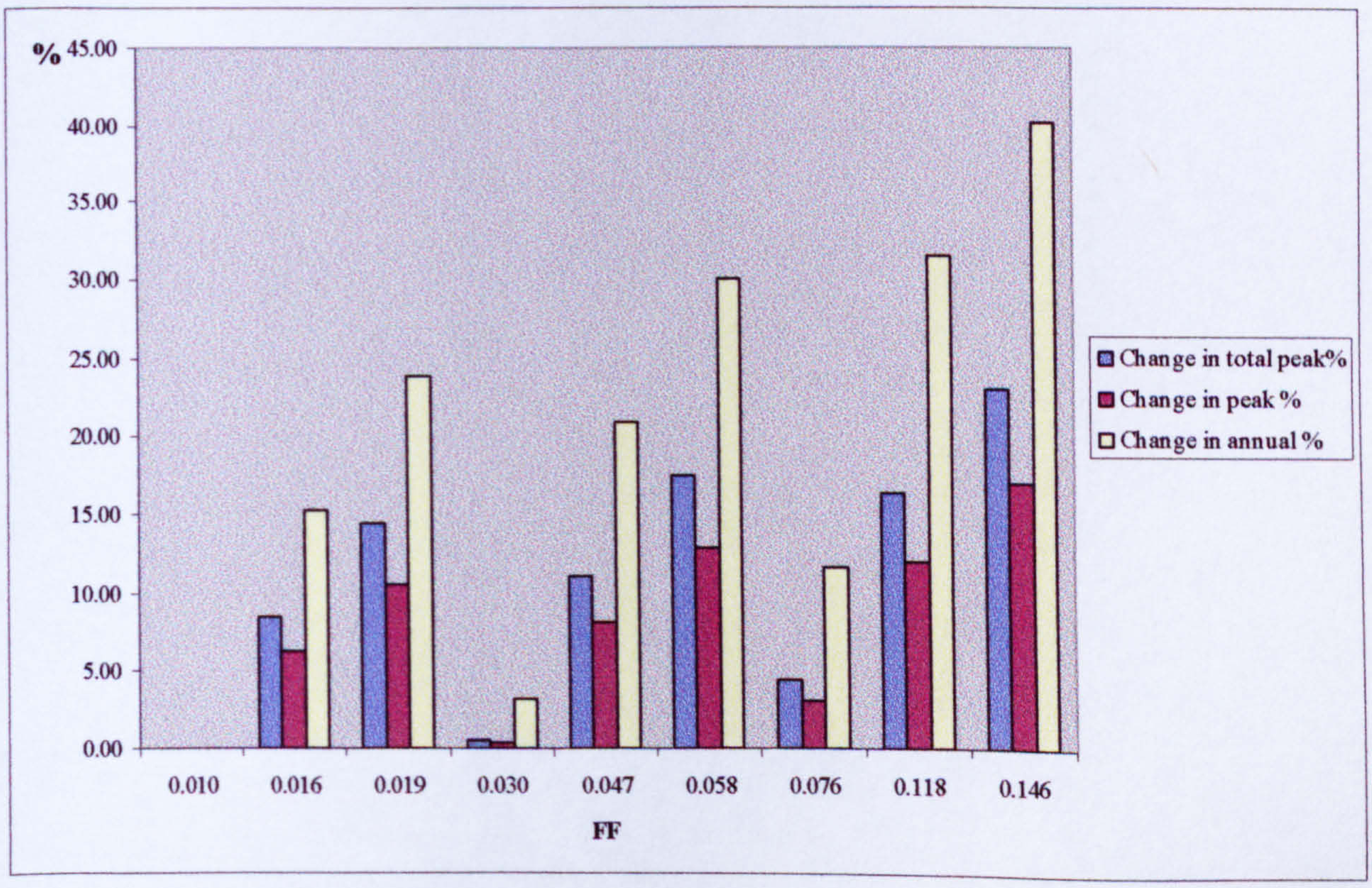


Figure 147: The percentage of the change in the cells peak and annual cooling loads per square metre with different FF

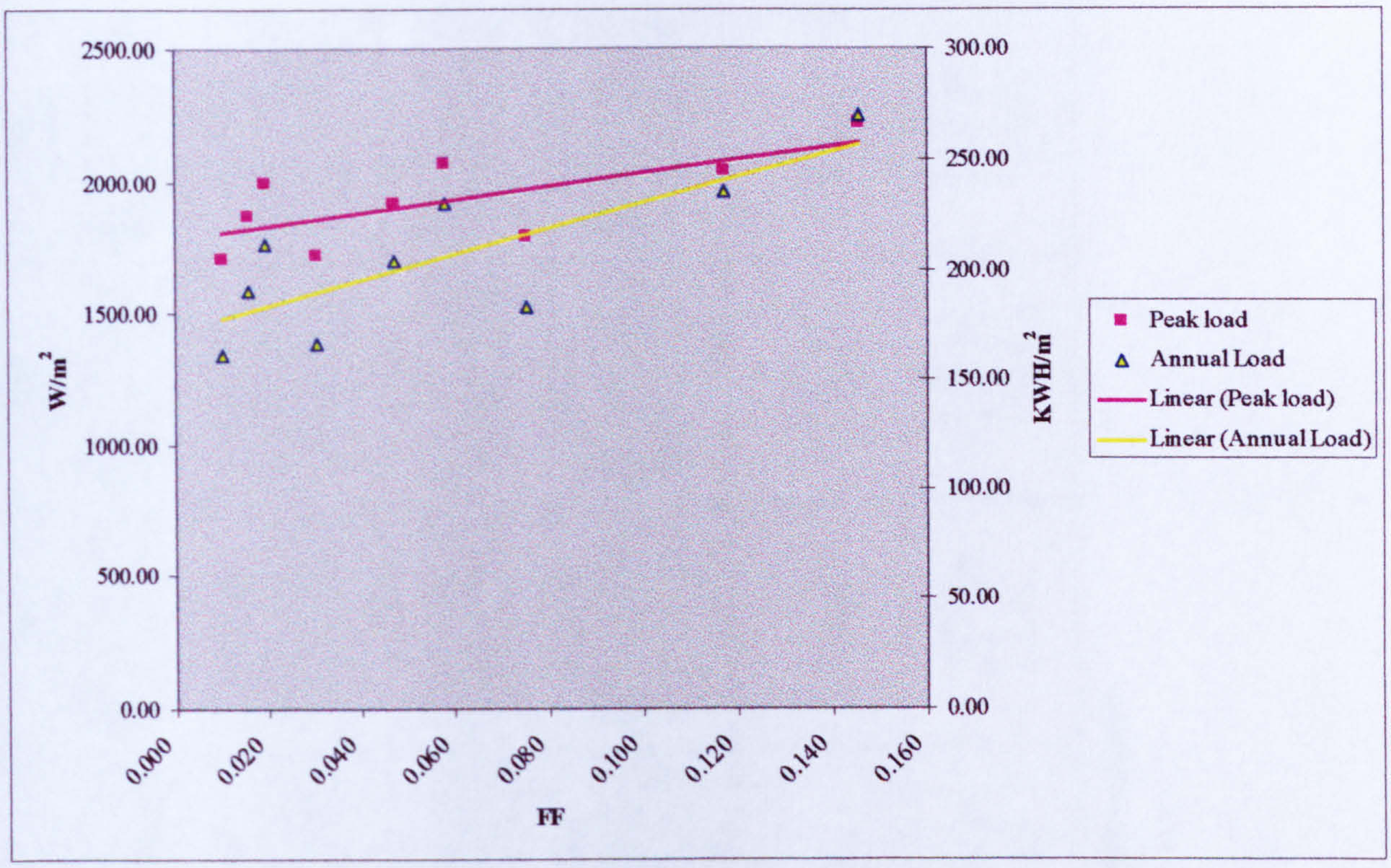


Figure 148: The impact of FF on the cells annual and peak cooling load per m²

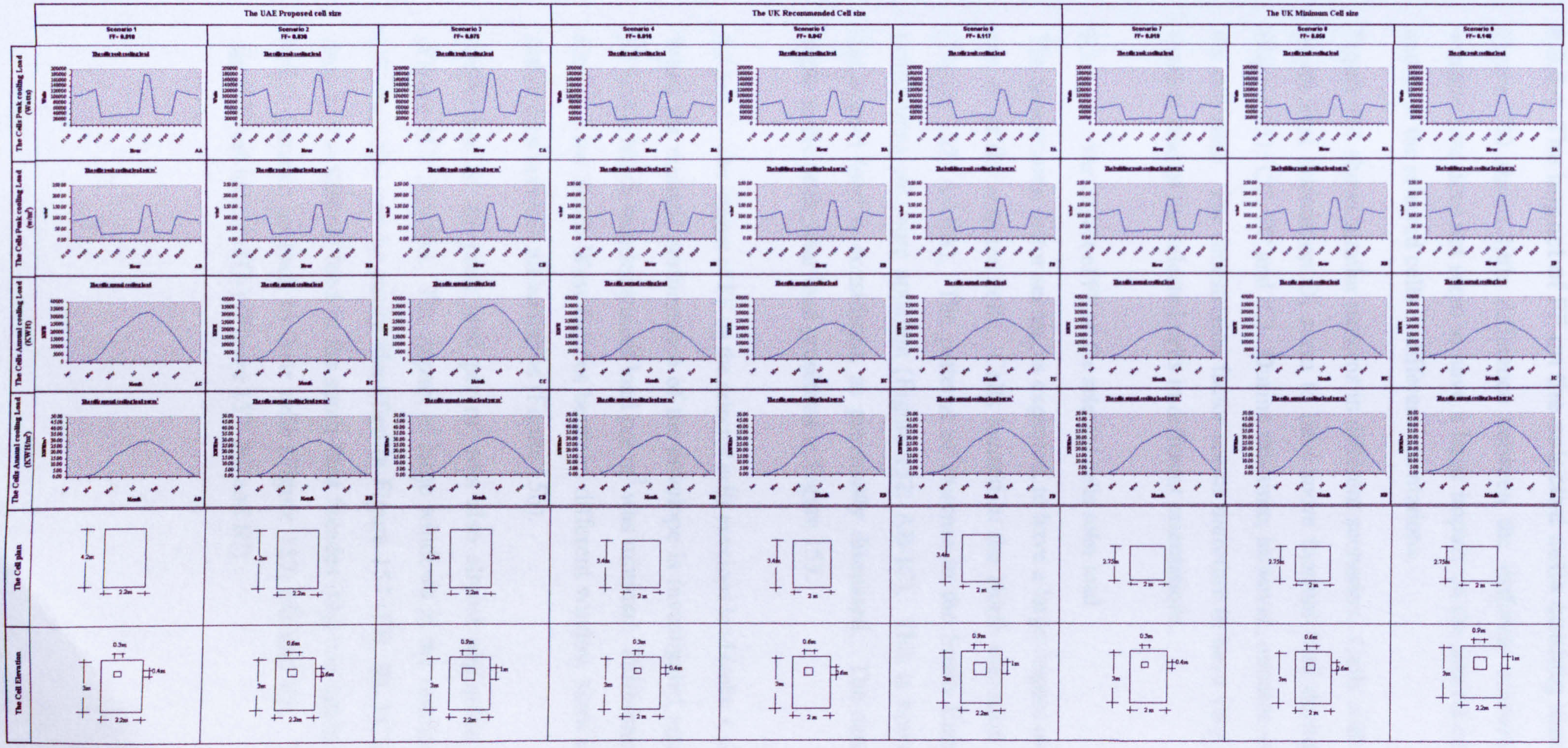


Figure 149: The impact of FF on the cells cooling load in the different scenarios

8.3.5.4 The impact of FF on the selected cells cooling load

Figure 150 shows little difference between the different scenarios. The increase of window size does not seem to have a large impact on the annual cooling load per square metre, in the selected cells in different orientations.

Figure 151 shows similar patterns in different scenarios. Cells with large windows in the South East orientation O_3 seem to have more thermal load during the morning period (Figure 151: CC, FC and IC). During this time, however, inmates would not be located in the cell zone. The fenestration factor seems therefore to have very little influence on the thermal load of the selected cells in different orientations.

8.3.5.4.1 The impact of FF on the selected cells solar load

The fenestration factor seems, as expected, to have a large impact on the annual solar load per m^2 of the selected cells. Cells located in the North elevation are the least affected (Figure 152: AA-IA). The patterns of increase in the South East and the South West orientations are more apparent (Figure 152: AB-IC). This is however very small when the overall load is considered, as previously discussed. The same argument can also apply to the peak solar load presented in Figure 153.

8.3.5.4.2 The impact of FF on the selected cells envelope load (solar + conduction)

When the thermal performance of the envelope is investigated separately, the impact of FF in the North facades annual load per m^2 was minimal. Differences appear in the South East and the South West façades between different window sizes in the three categories, rather than between all scenarios (Figure 156).

Difference in the peak load per m^2 was also almost negligible in the North facades (Figure 157: AA-IA). The impact of large windows in the minimum and recommended UK scenarios can be easily identified in Figure 157 (FB, IB, FC and IC). The evening drop of the thermal load in the south East facades (O_2) can again be useful, as it occurs before inmates go back to their cells (Figure 157: FB and IB). This is reversed in the South West façades (O_3) (Figure 157: FC and IC)

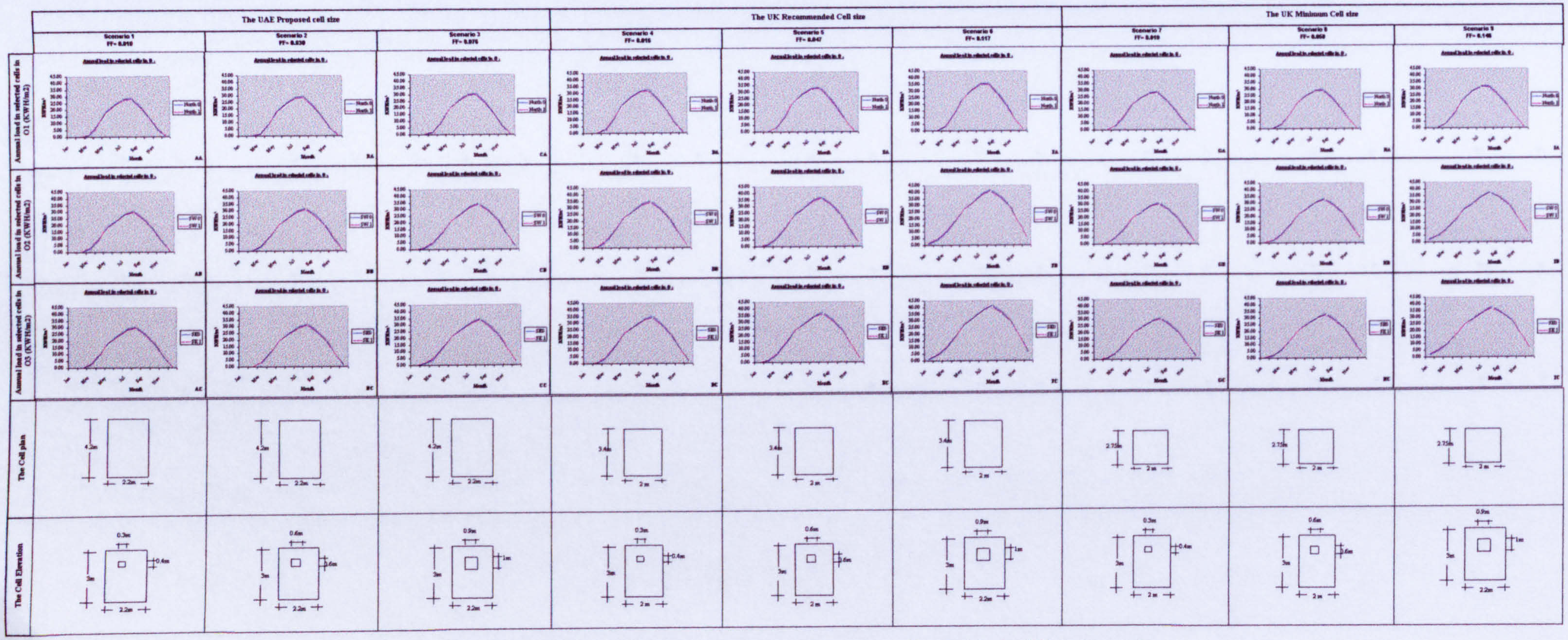
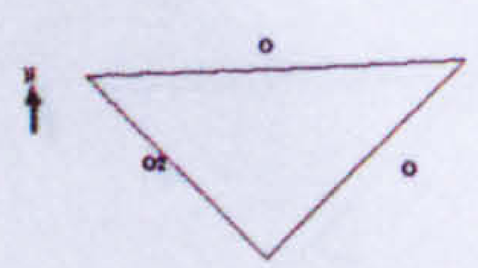


Figure 150: The impact of FF on the selected cells annual cooling load in the different scenarios



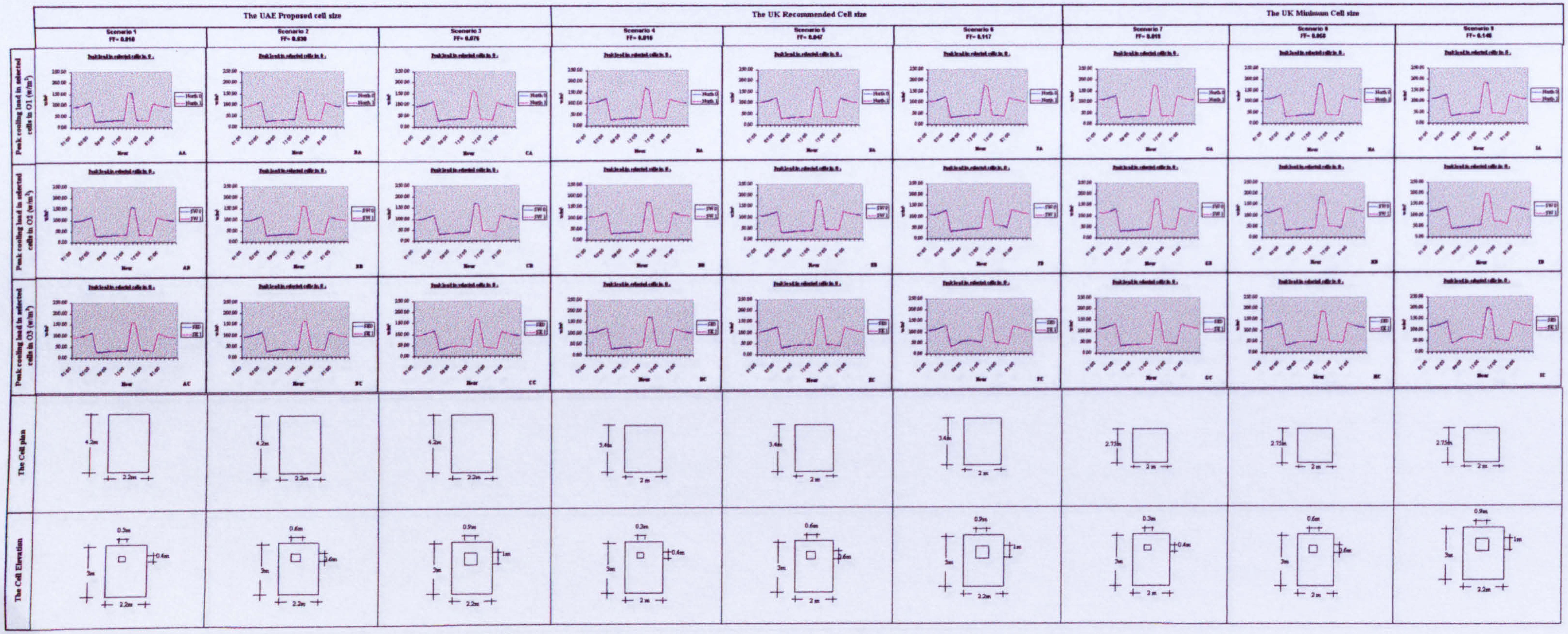
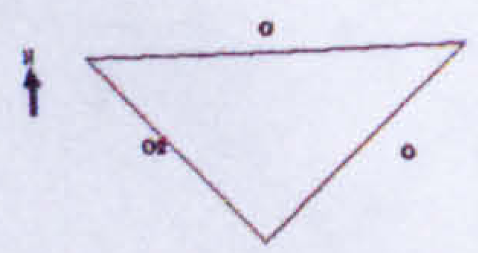


Figure 151: The impact of FF on the selected cells peak cooling load in the different scenarios



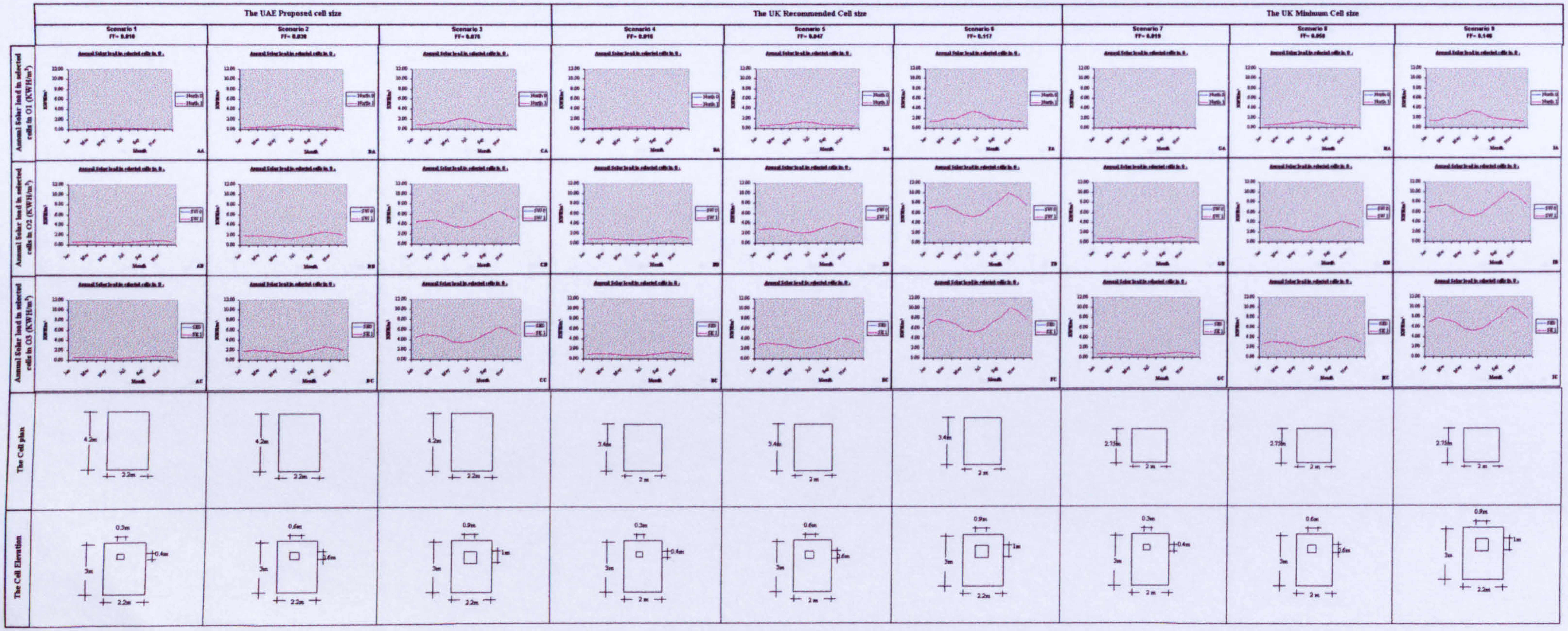
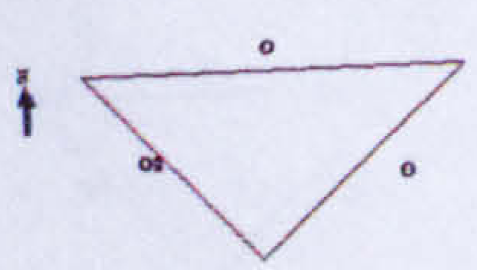
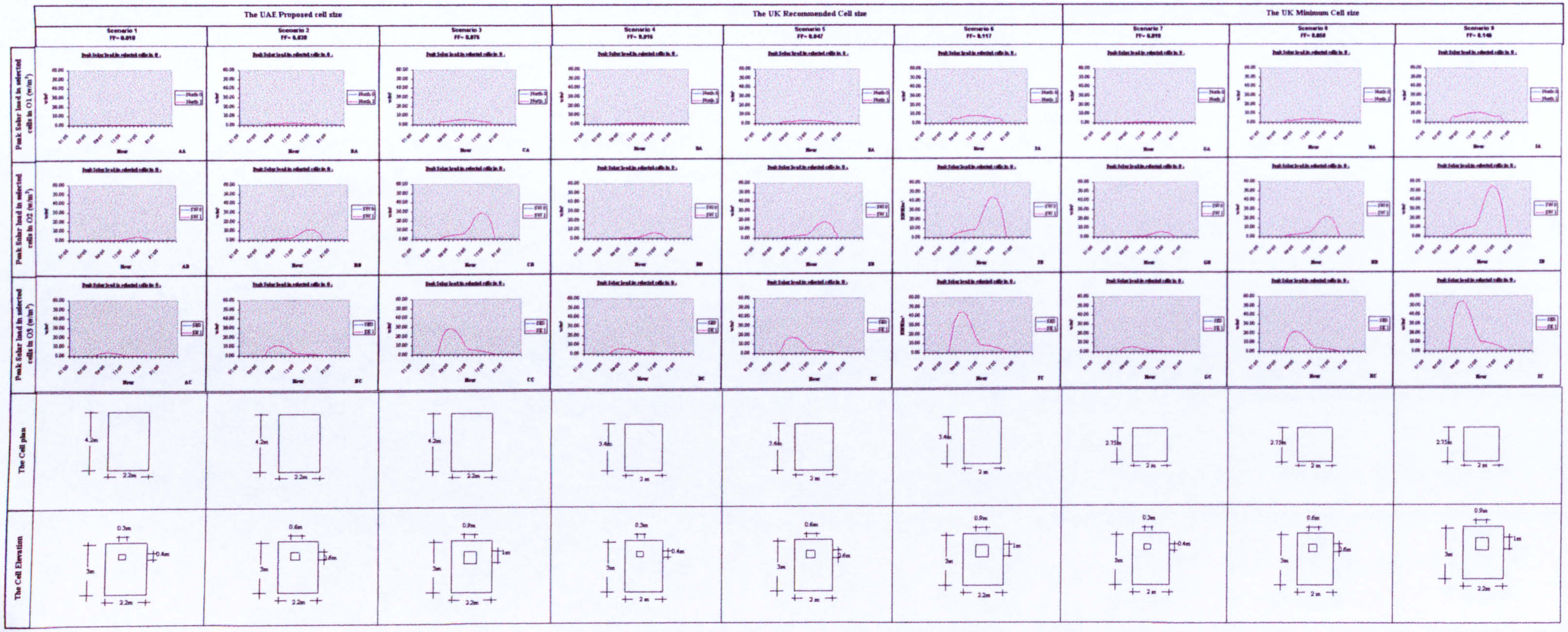


Figure 152: The impact of FF on the selected cells annual solar loads in the different scenarios





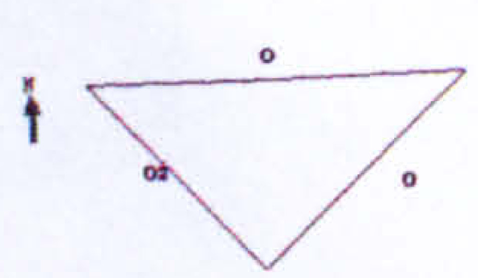


Figure 153: The impact of FF on the selected cells peak solar load in the different scenarios

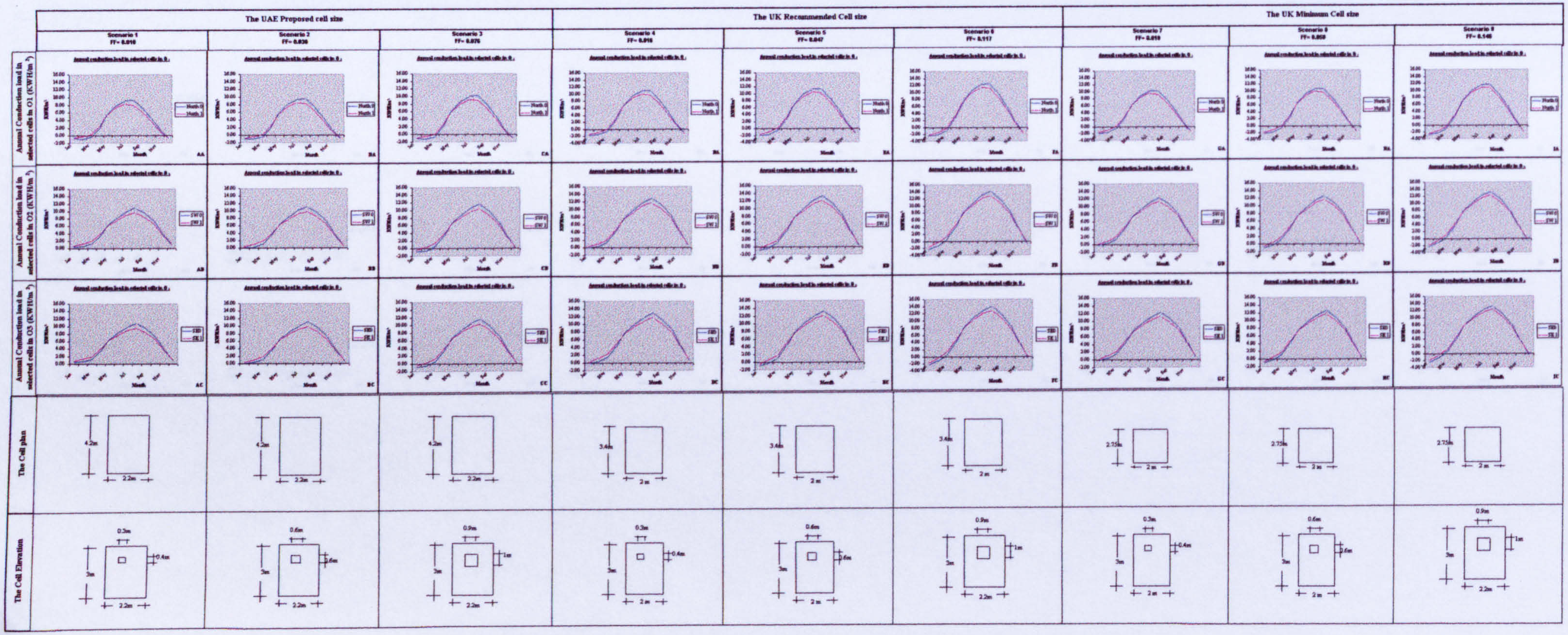
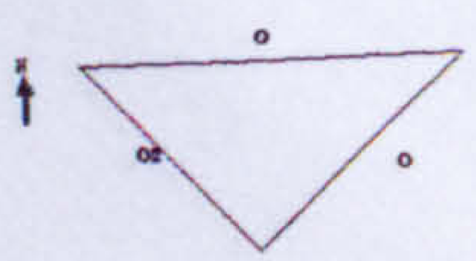


Figure 154: The impact of FF on the selected cells annual conduction load in the different scenarios



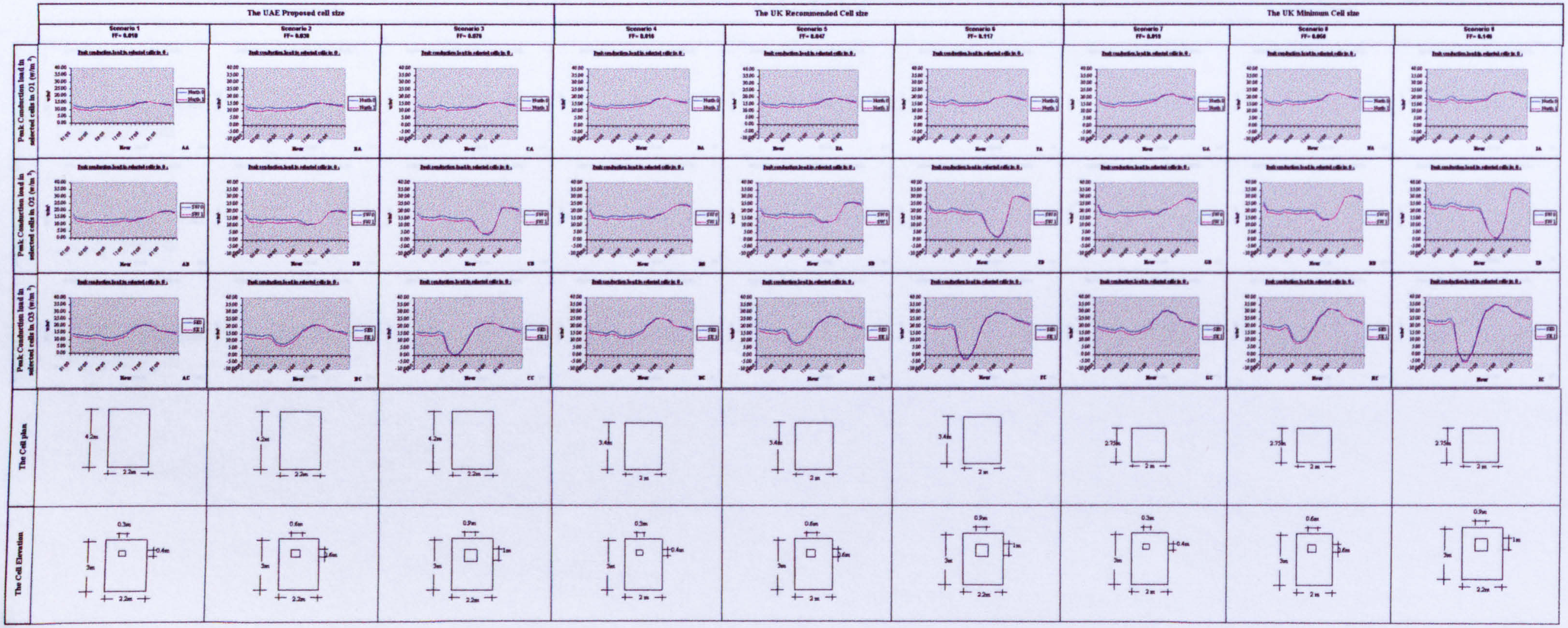
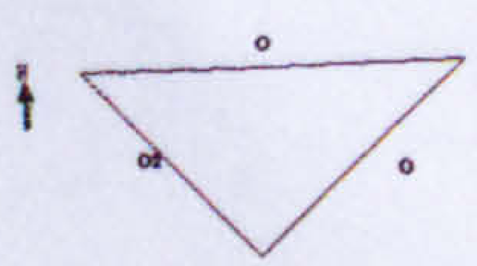


Figure 155: The impact of FF on the selected cells peak conduction load in the different scenarios



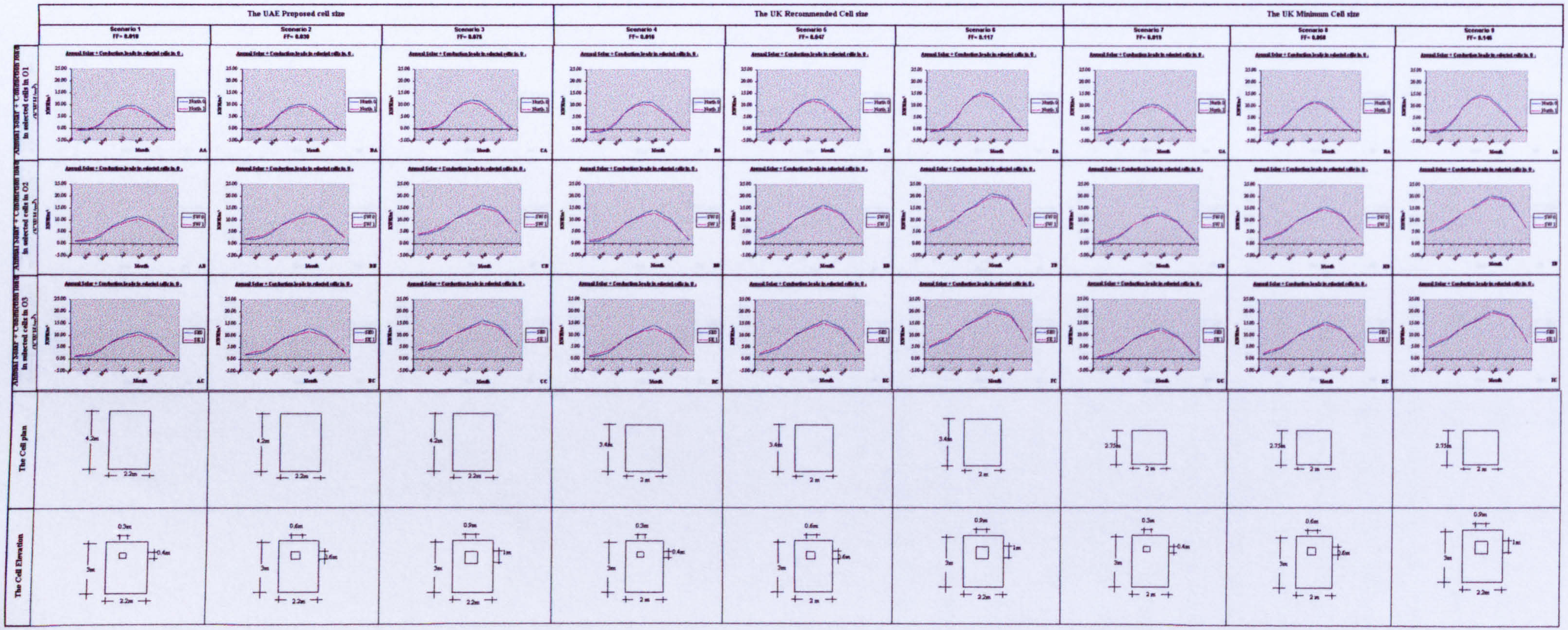
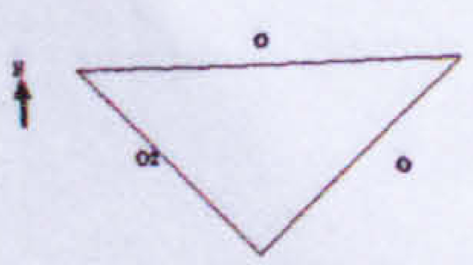


Figure 156: The impact of FF on the selected cells annual envelope load in the different scenarios



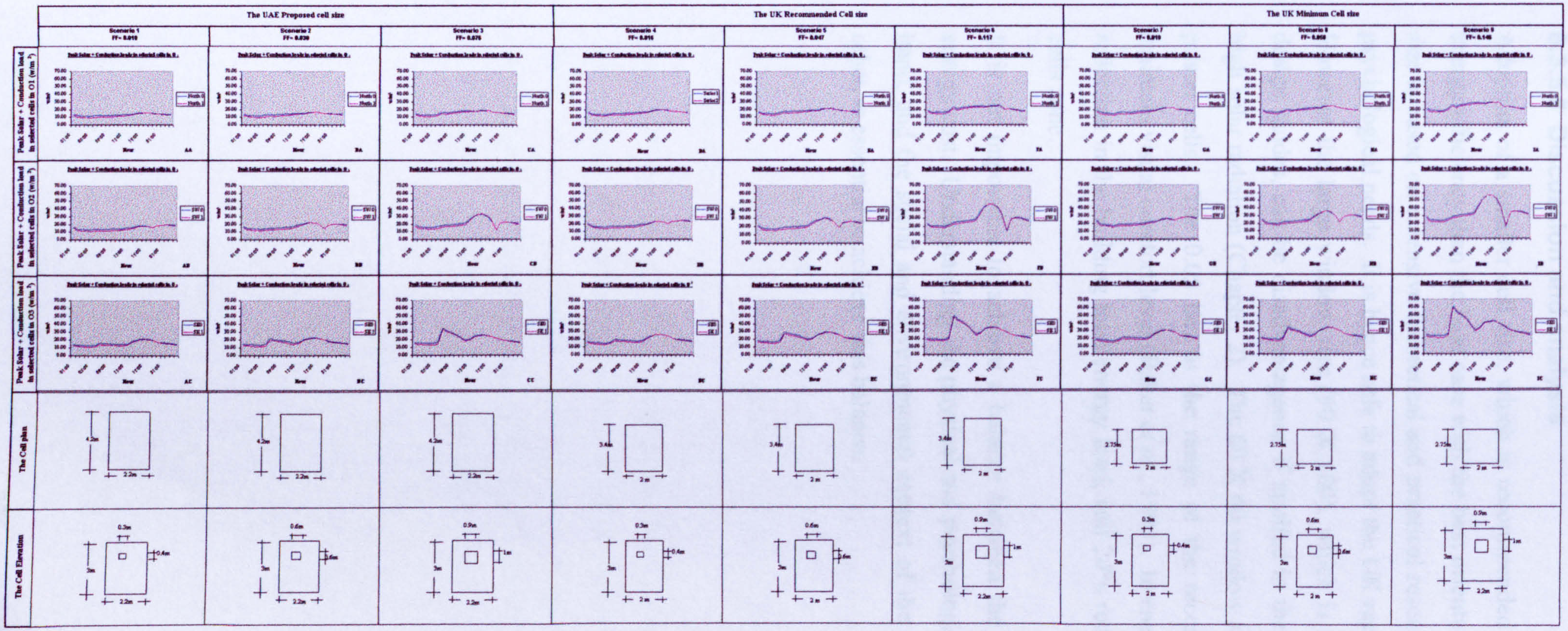
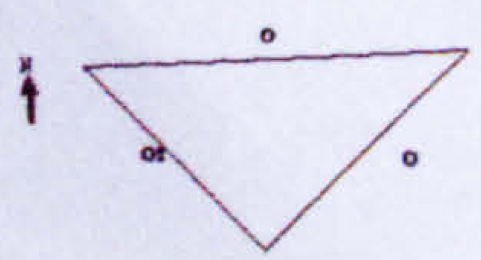


Figure 157: The impact of FF on the selected cells peak envelope load in the different scenarios



8.3.5.5 Discussion and analysis

Adoption of a smaller cell size, which is recommended in the UK, led to better overall energy efficiency than the base case with the best orientation. The UK recommended cell size is based on extensive theoretical and practical research on the inmate's physical and psychological needs. It is hence safe to adopt the UK recommended cell size in the UAE. However the large window size (90 X 100), which is recommended in the UK prison design guides, can be disadvantageous if applied in the UAE prisons as a result of the high solar radiation (Chapter 2). The 60 X 60 window size is more appropriate for UAE prison cells. The 0.05 lies in the range of the recommended fenestration factor to maintain visual comfort level (Baker *et al.*, 1993). In energy terms this will lead to a 25% reduction in the building total energy load, and 24% reduction in the energy load of the cells zone.

It is not impossible to achieve a balance between the inmate's human needs and the energy cost. Understanding the physical and psychological needs of the inmates, on one hand, and the social and environmental context of the prison building facilities on the other, is essential to achieve this balance.

8.3.6 The impact of shading devices on the building cooling loads

The analysis carried out in the previous sections showed that when the window size is increased, the solar gain in the cells does, as expected also increase. Further analysis showed that introduction of appropriate orientation leads to a reduction of the solar gain. In this section attempts are made to investigate the possibility of whether further reduction of the solar load can be obtained by applying appropriate shading devices.

The size of the shading device examined is 0.36 m, based on the calculation carried out in a previous study in the same region (Monawar, 2001). The three window sizes under investigation are the Abu Dhabi proposed prison window size (30 cm X 40 cm), the suggested window size (60 cm X 60 cm) and the UK recommended window size (90 cm X 90 cm). The base case with the best orientation is used as a reference case in the analysis, and labelled "Base Case 1".

8.3.6.1 The impact of shading devices on the total loads

Figure 158 shows the impact of applying shading devices on the building total and per square metre cooling loads. It is clear that the impact is insignificant. This however is related to the fact that in the specific case of an Abu Dhabi prison, the impact of the ceiling conduction and the mechanical ventilation load dominates the building total cooling loads.

Figure 159 shows that, although very minor, there is a reduction in the peak cooling load in the suggested window case when shading devices are introduced (0.2%). The figure shows that the impact of shading devices increases when larger windows are examined. For example, introduction of shading devices on the UK recommended windows leads to 2.5% reduction in the building annual cooling load.

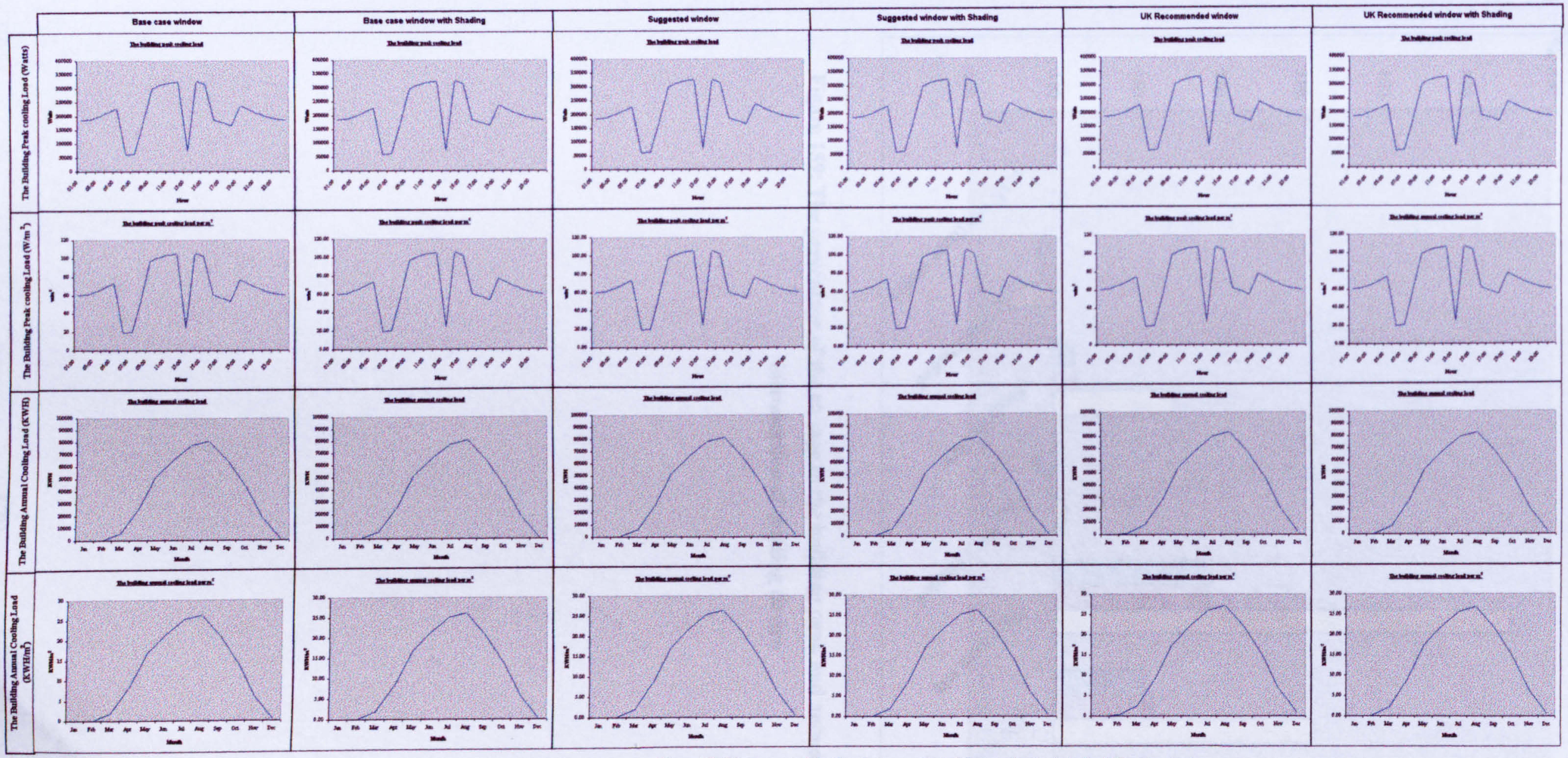


Figure 158: The Impact of shading devices on the building cooling loads in the different scenarios

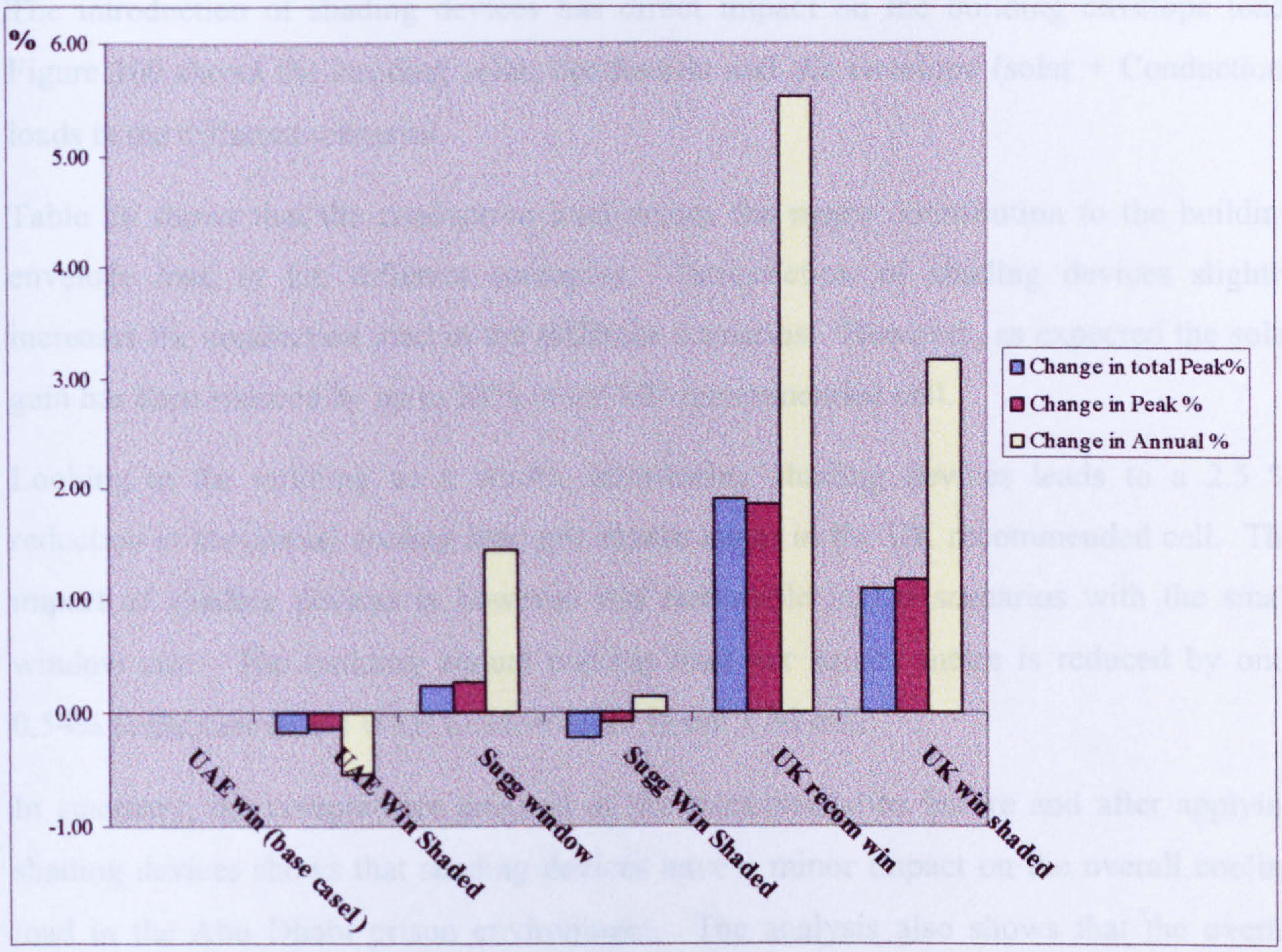


Figure 159: The percentage of the change in the building peak and annual cooling loads with introduction of shading device

The introduction of shading devices has direct impact on the building envelope load. Figure 160 shows the building solar, conduction and the envelope (solar + Conduction) loads in the different scenarios.

Table 26 shows that the conduction load makes the major contribution to the building envelope load in the different scenarios. Introduction of shading devices slightly increases the conduction load in the different scenarios. However, as expected the solar gain has been reduced by up to 58% in the UK recommended cell.

Looking at the building as a whole, introducing shading devices leads to a 2.5 % reduction in the annual cooling load per square metre in the UK recommended cell. The impact of shading devices is however less noticeable in the scenarios with the small window size. The building annual cooling load per square metre is reduced by only 0.54% in the case of the UAE window size (30 cm x 40 cm).

In summary, the comparative analysis of the three scenarios before and after applying shading devices shows that shading devices have a minor impact on the overall cooling load in the Abu Dhabi prison environment. The analysis also shows that the overall cooling load is more sensitive to change in shading device with larger windows.

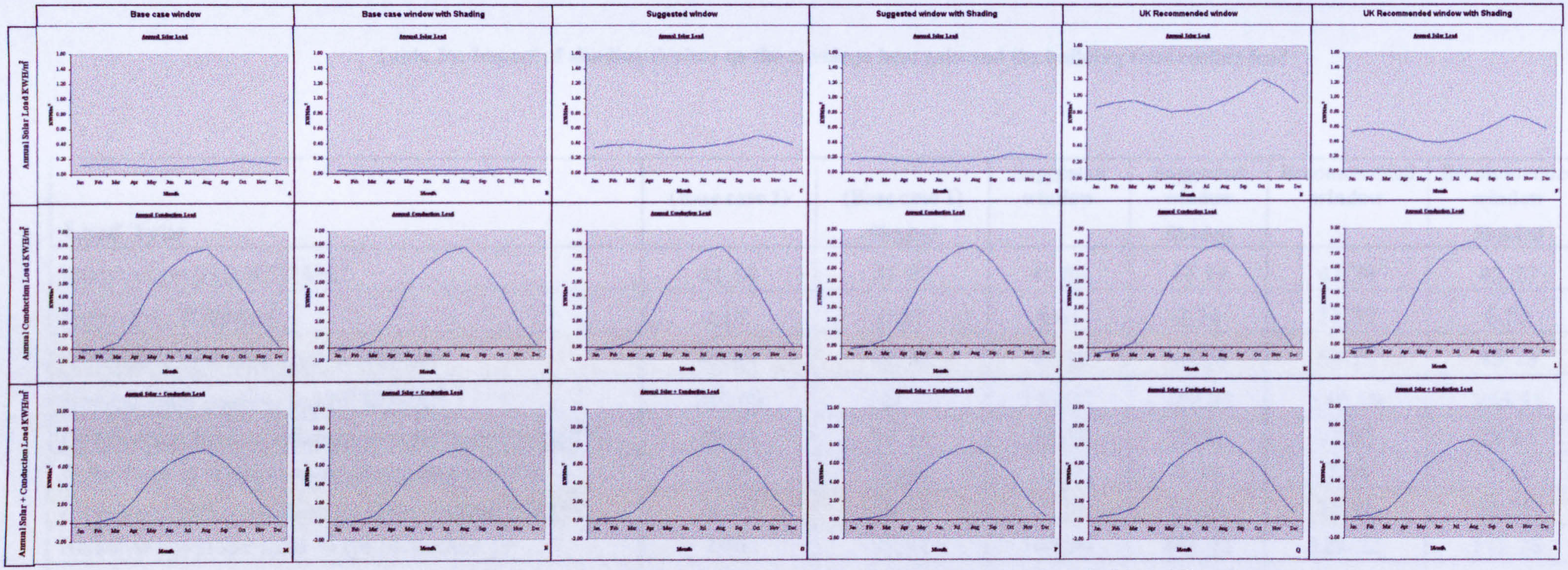


Figure 160: The impact of shading devices on the building solar and conduction loads in the different scenarios

Table 26: Impact of shading devices on the envelope heat gain and the building total cooling load

Load Type	(Base case 1)	(Base case 1) Shaded	Suggested window	Suggested window Shaded	Recommended window	Recommended window Shaded
Conduction gain KWH/m^2	41.84	41.97	41.86	42.14	41.79	42.27
Solar gain KWH/m^2	1.61	0.57	4.61	2.14	11.32	6.52
Total envelope heat gain KWH/m^2	43.45	42.54	46.46	44.28	53.10	48.78
Annual total cooling load KWH/m^2	141.88	141.12	143.97	142.09	150.19	146.51
Conduction load in relation to total cooling load %	29.49	29.74	29.07	29.66	27.82	28.85
Solar load in relation to total cooling load %	1.13	0.40	3.20	1.51	7.54	4.45
Envelope load in relation to total cooling load %	30.62	30.14	32.27	31.16	35.36	33.30
Relative envelope load % (to base case 1)	100	97.91	106.94	101.92	122.22	112.28
Relative total cooling load % (to base case 1)	100	99.46	101.47	100.15	105.86	103.26
Relative envelope load % (to each window size)	100	97.91	100	95.30	100	91.86
Relative total cooling load % (to each window size)	100	99.46	100	98.70	100	97.55

8.3.6.2 The impact of shading devices on the overall cell area cooling loads

The overall cell zone cooling load sensitivity to applying shading devices follows the same pattern as for the whole building. The total, the annual and peak cooling loads per square metre in the cells are presented in Figure 161.

Figure 162 shows the percentage of the change (from base case 1) in peak day, peak load and the annual load in the cells zone in the different scenarios. Interestingly, the cells peak cooling load in the suggested window with shading devices is lower than the same load in base case 1. The suggested window annual load is slightly higher than the base case (0.4 %).

As the cells are located on the periphery of the building, they become slightly more sensitive to change of the façade configuration. While the overall increase in total cooling load is about 3% for the whole building, the ratio becomes around 7% for the cell area. It is however important to also investigate the impact of shading devices, on the different types of cells.

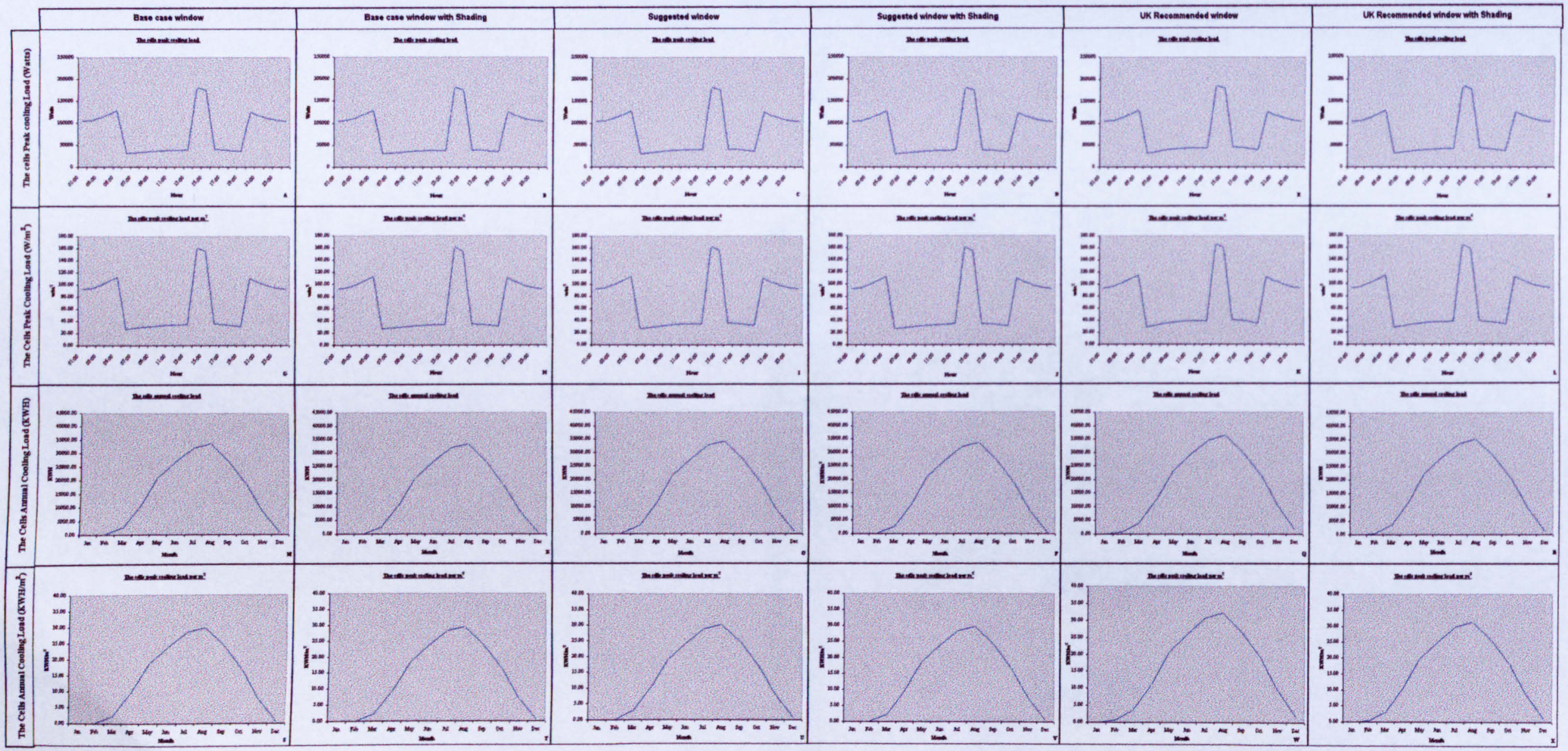


Figure 161: The impact of shading devices on the cells cooling load in the different scenarios

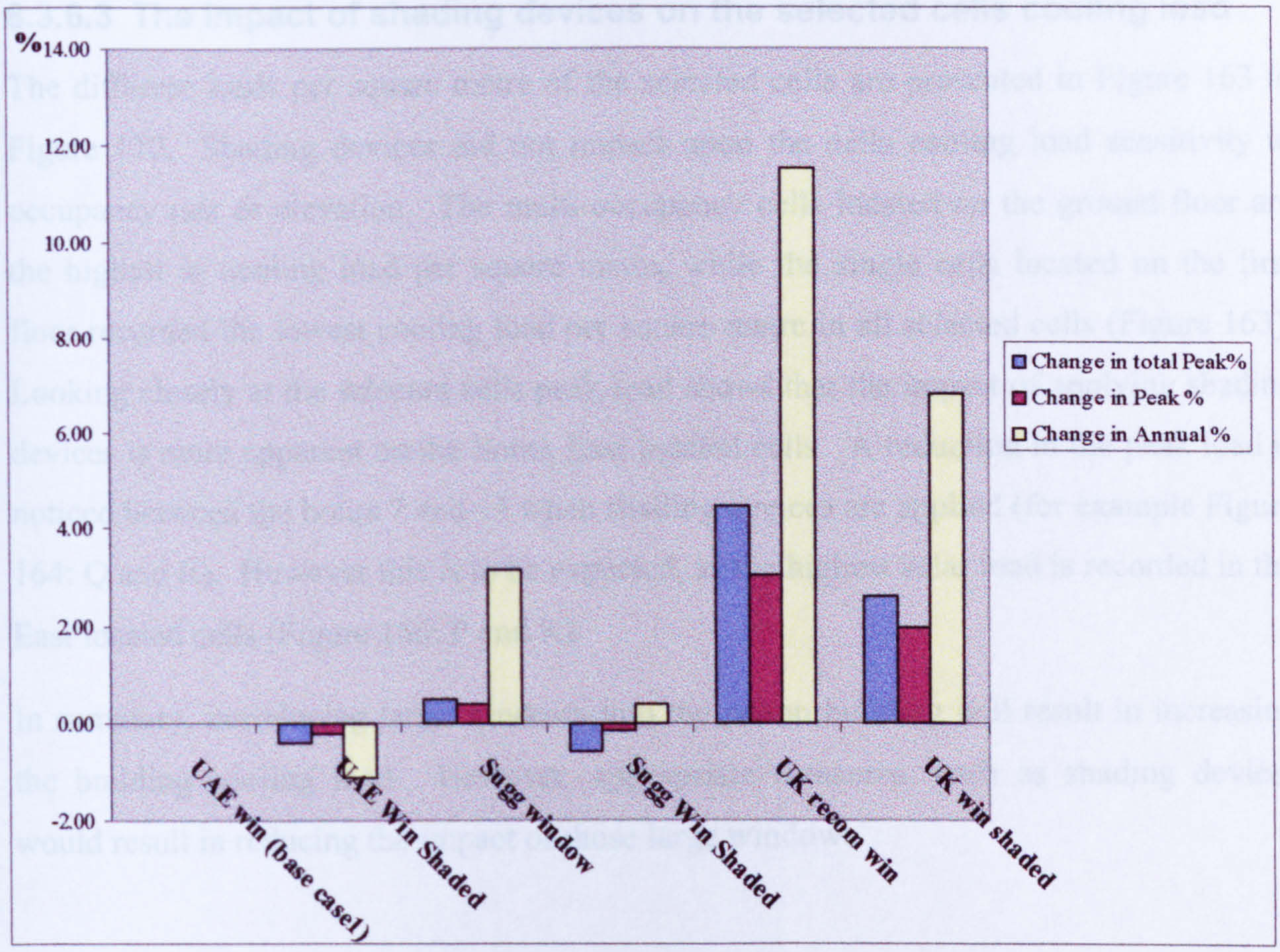


Figure 162: The percentage of the change in the cells peak and total cooling load before and after applying shading devices in the base case and best orientation

8.3.6.3 The impact of shading devices on the selected cells cooling load

The different loads per square metre of the selected cells are presented in Figure 163 to Figure 170. Shading devices did not impact upon the cells cooling load sensitivity to occupancy rate or elevation. The multi-occupancy cells located on the ground floor are the highest in cooling load per square metre, while the single cells located on the first floor recorded the lowest cooling load per square metre in all selected cells (Figure 163). Looking closely at the selected cells peak load shows that the impact of applying shading devices is more apparent on the South East located cells. A reduction in the peak load is noticed between the hours 7 and 13 when shading devices are applied (for example Figure 164: Q and R). However this is to be expected, as the highest solar load is recorded in the East located cells (Figure 166: P and R).

In summary, introducing large windows into the prison building will result in increasing the building cooling load. However, appropriate measures, such as shading devices would result in reducing the impact of those large windows.

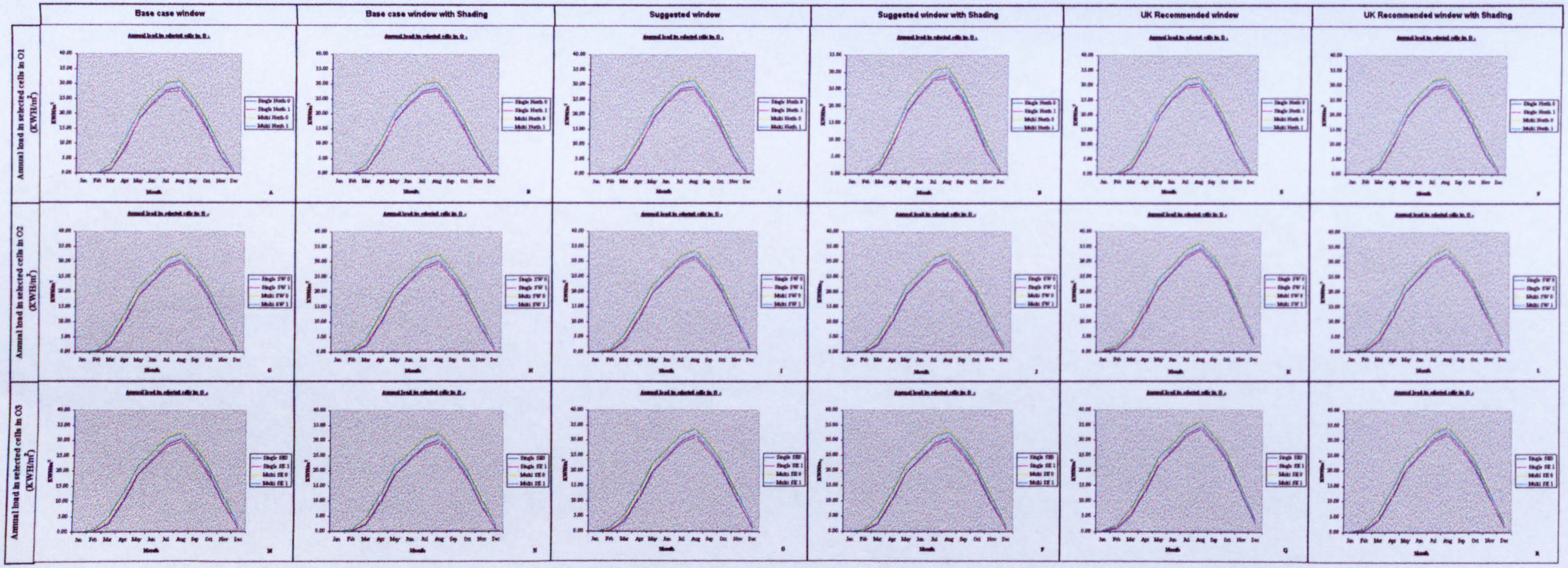
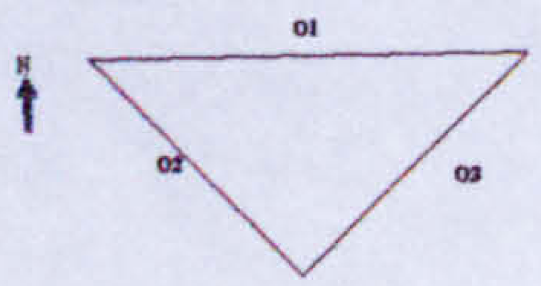


Figure 163: The impact of shading device on the annual cooling load in the selected cells in the different scenarios



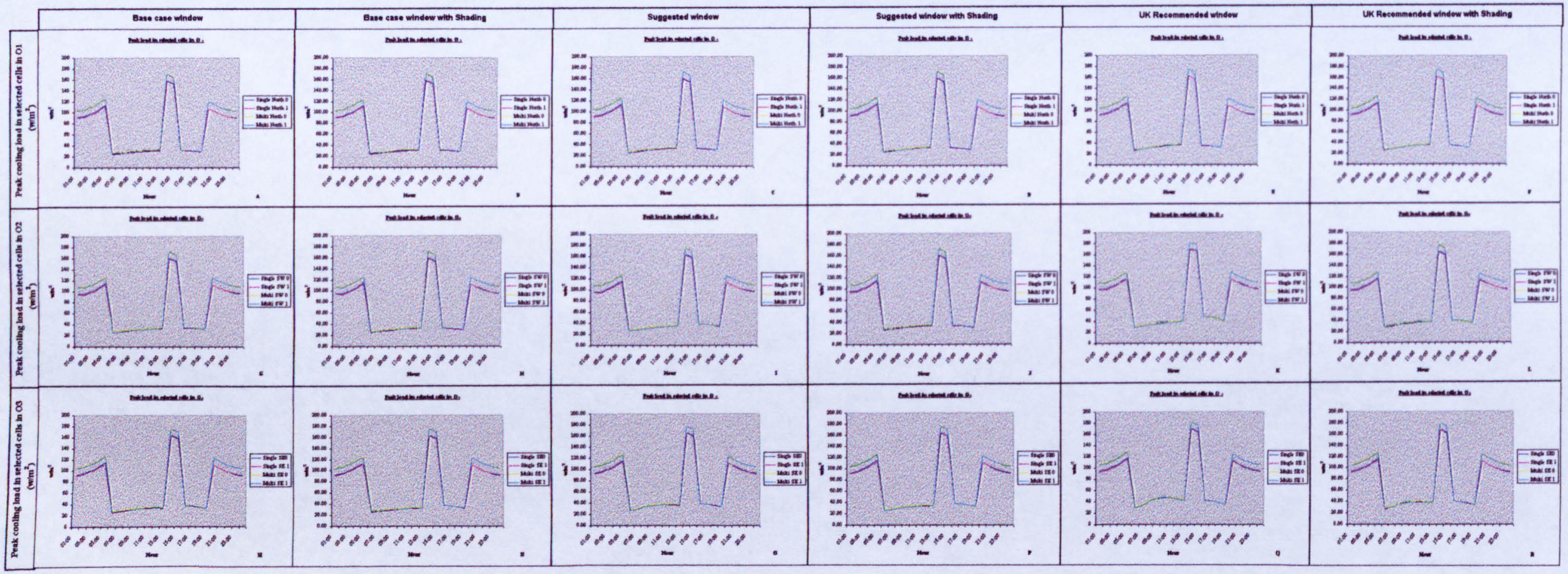
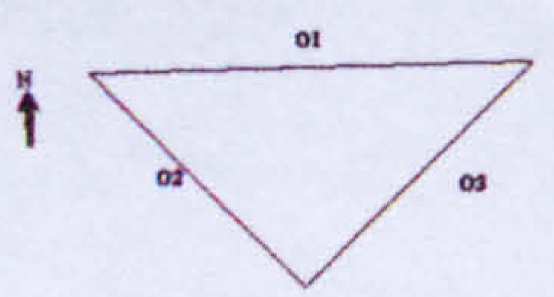


Figure 164: The impact of shading devices on the selected cells peak cooling load in the different scenarios



8.3.6.3.1 Shading devices and the selected cells solar cooling load

The previous discussion of the impact of shading devices on the overall annual and peak cooling load is reflected in the selected cells. Figure 165 shows that shading devices have a remarkable impact on the annual solar load per square metre in the selected cells. The same is apparent in the peak solar load per square metre (Figure 166). The solar load in the UAE windows (the base case 1) became almost negligible with the introduction of shading devices Figure 165: B, H and N, and Figure 166: B, H and N.

Figure 166 also shows that introducing shading devices minimised the impact of the occupancy rate. This is most apparent in Figure 166: K and L, Q and R.

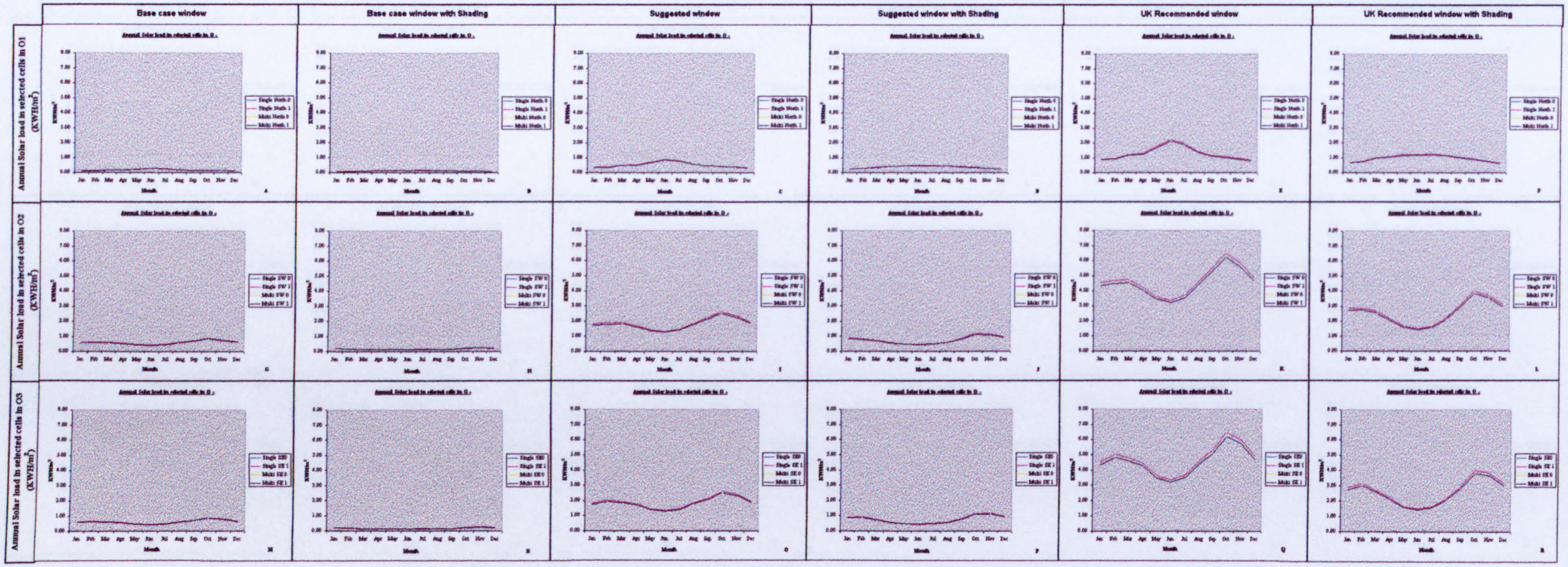
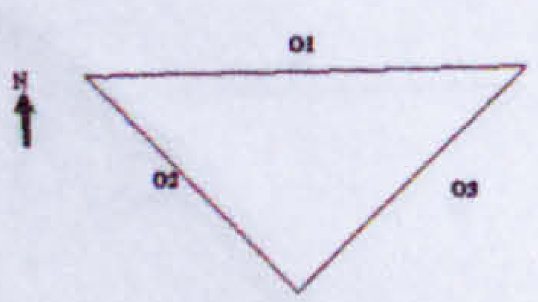


Figure 165: The impact of shading devices on the selected cells annual solar load in the different scenarios



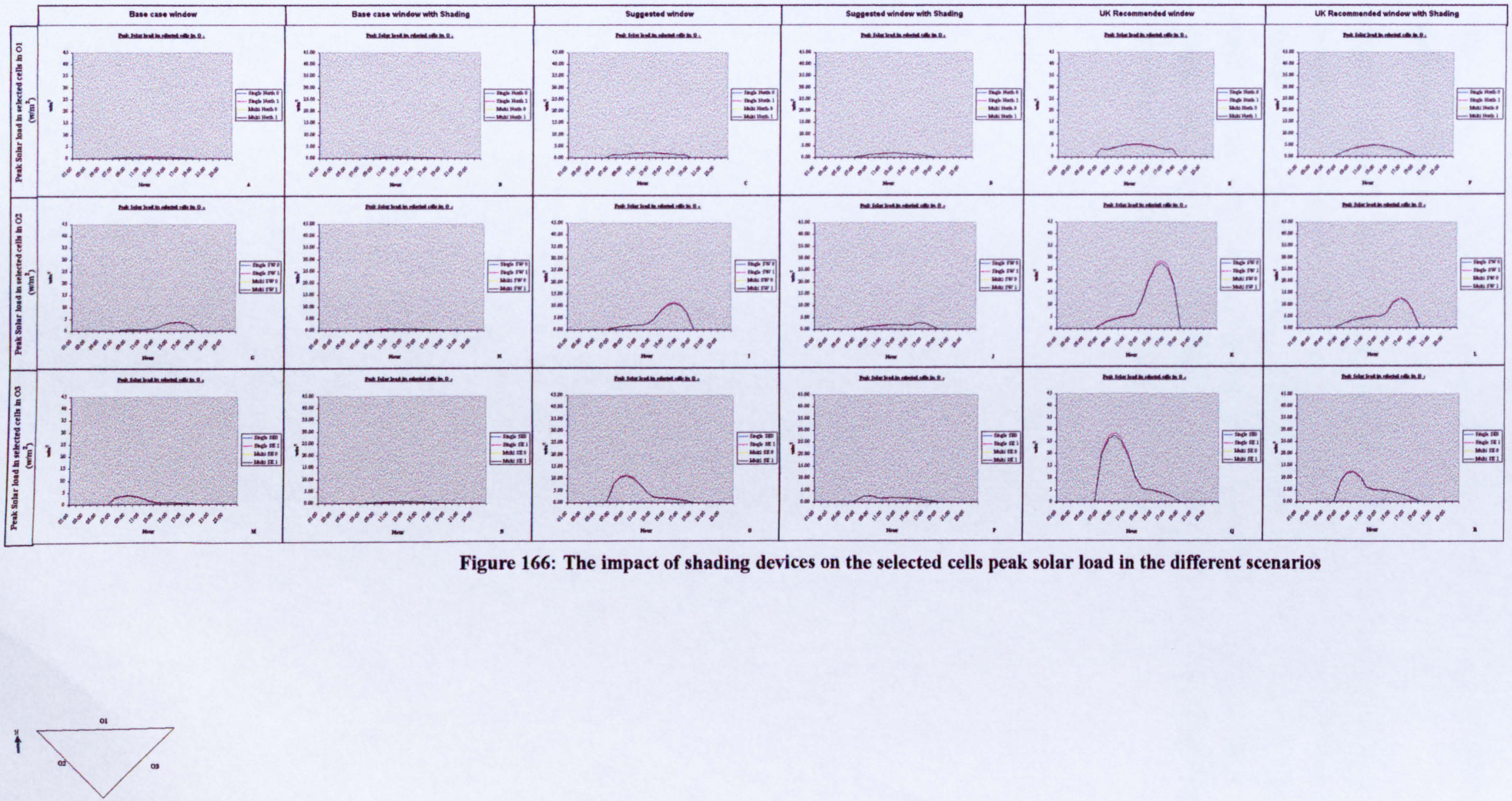


Figure 166: The impact of shading devices on the selected cells peak solar load in the different scenarios

8.3.6.3.2 Shading devices and the selected cells conduction load

The impact of shading devices on the selected cells annual conduction load is less apparent (Figure 167).

Figure 168 shows that the peak conduction load per square metre is more sensitive to the introduction of shading devices. The deep drop in the conduction load recorded in the South West cells (Figure 168: K) between the hours 15:00 and 19:00, and the South East cells (Figure 168: Q) between the hours 7:00 and 11:00 has been reduced. The conduction load has increased in these cells during these particular hours, after introducing shading devices (Figure 168: L and R).

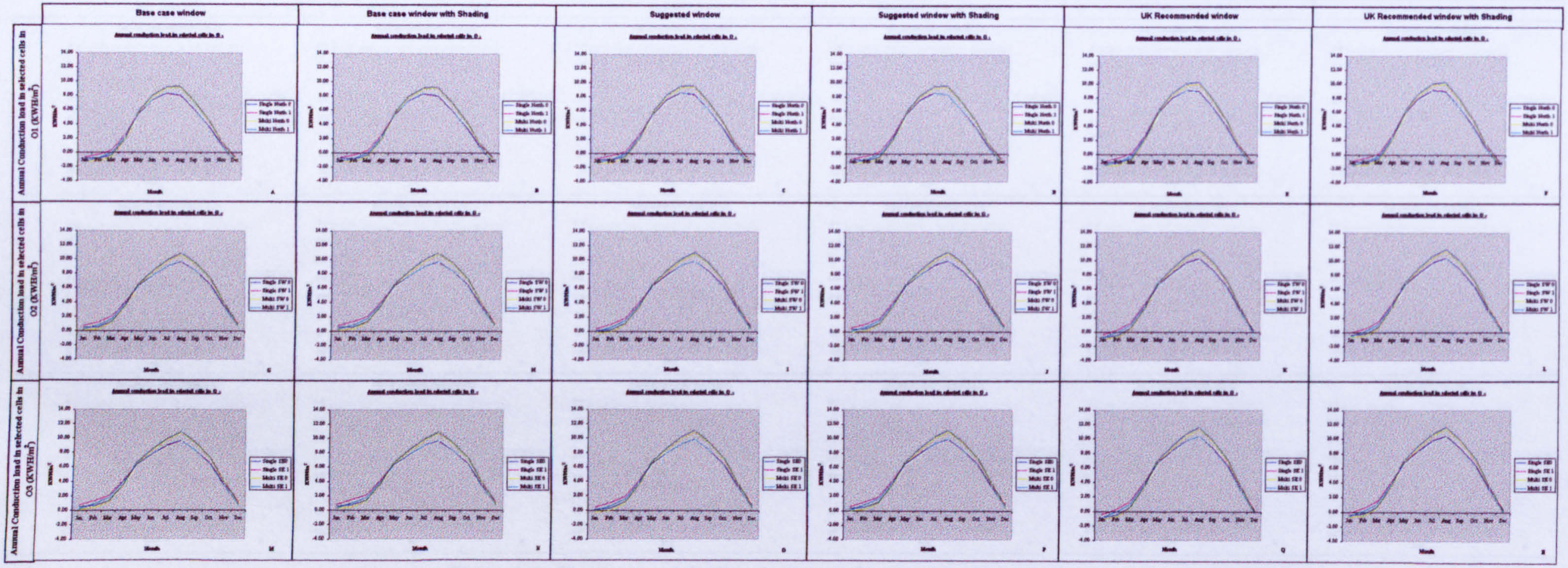


Figure 167: The Impact of shading devices on the selected cells annual conduction load in the different scenarios

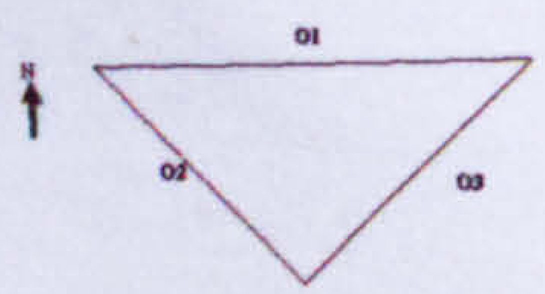


Figure 168: The impact of shading devices on the selected cells peak conduction load in the different scenarios

8.3.6.3.3 Shading devices and the selected cells envelope load (solar + conduction)

As the conduction load represents in most cases the main thermal load. The increase in the conduction load leads to an increase in the overall envelope load, in the different scenarios. This increase is mainly apparent in the winter months (October to March) (for example: Figure 169: K and L, and Q and I).

Simulation results of the peak envelope gain per square metre show a reduction in the peak load in the different scenarios (Figure 170). The sharp peaks in the South West and South East cells, as well as the sharp drops are softened with the introduction of shading devices (Figure 170: K and L, and Q and I).

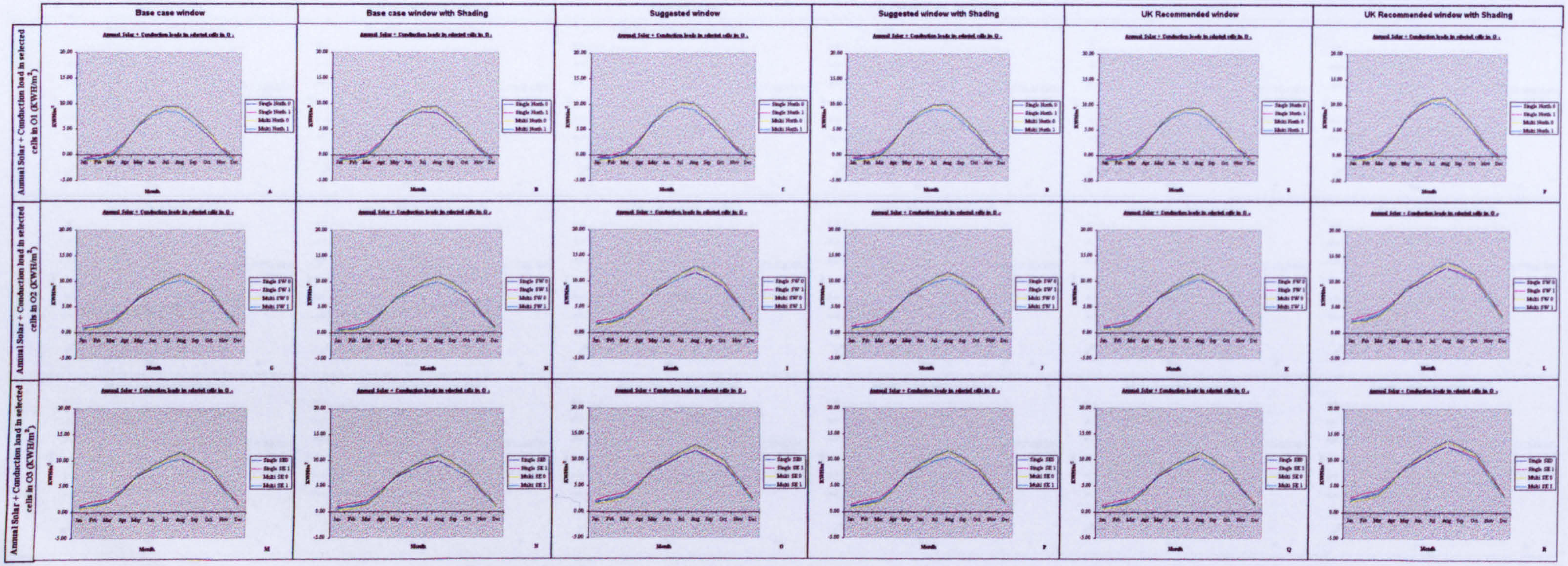
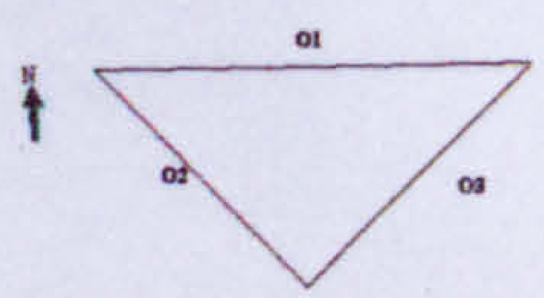


Figure 169: The impact of shading devices on the selected cells annual envelope load in the different scenarios



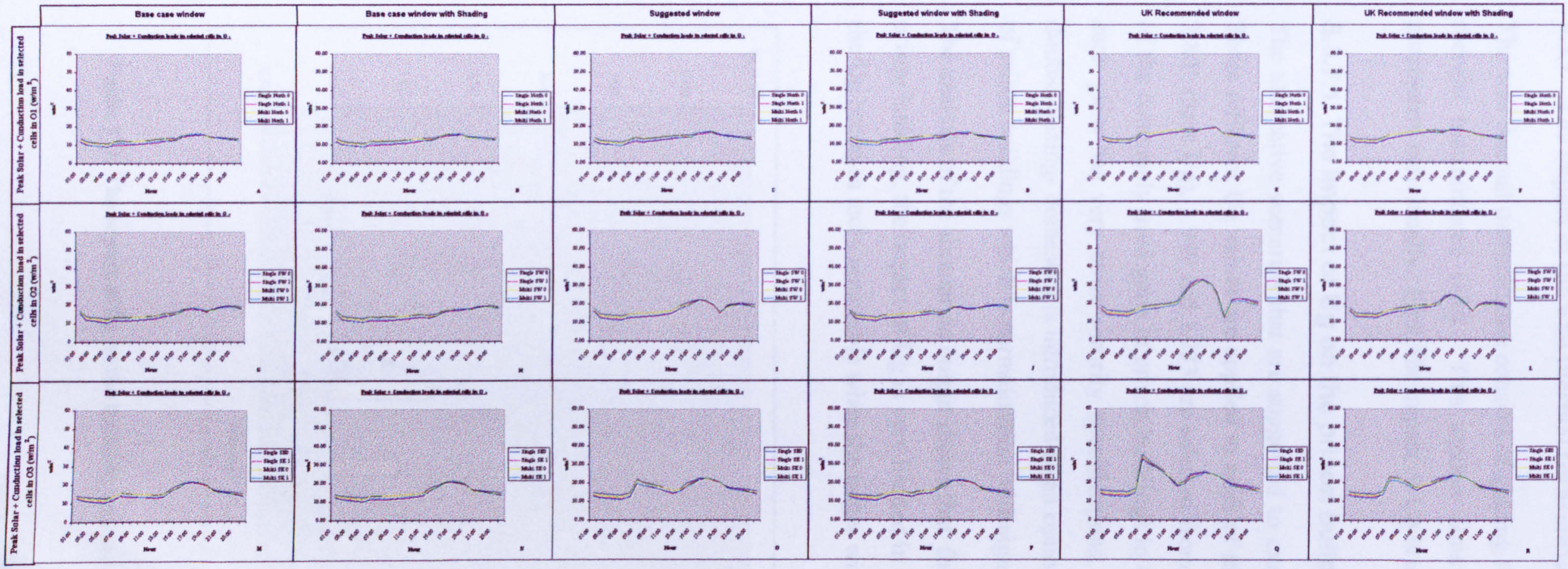
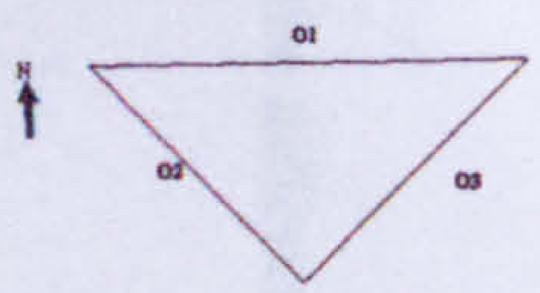


Figure 170: The impact of shading devices on the selected cells peak envelope load in the different scenarios



8.3.7 The impact of the wall thermal transmittance on the building cooling load

The wall thermal transmittance consists of glazing thermal transmittance (Ug) and opaque thermal transmittance (Uo). This section aims to investigate the impact of these parameters individually. First, the impact of Ug is examined in the following section.

8.3.7.1 The impact of Ug on the prison building cooling load

The alternative scenarios that are suggested to examine Ug are illustrated in Table 15. Three different Ug values are applied to each of the three window sizes. The values of 2.801 (base Ug), 1.949 and 1.733 are selected from the base case, and from specification of the commonly used glass in prison buildings in the UAE. It has to be noted here that such glass has very strict security specifications. The third glazing scenario (Low-e double glazing- domestic) is introduced as an option to satisfy the new design movement of prison buildings which is normalisation of design materials.

The analysis of the simulation output shows that, following the limited glazing area in the prison building, the impact of Ug is very limited in scenarios 1-3. The effect of changing the Ug becomes more noticeable when the larger windows are investigated (Figure 171).

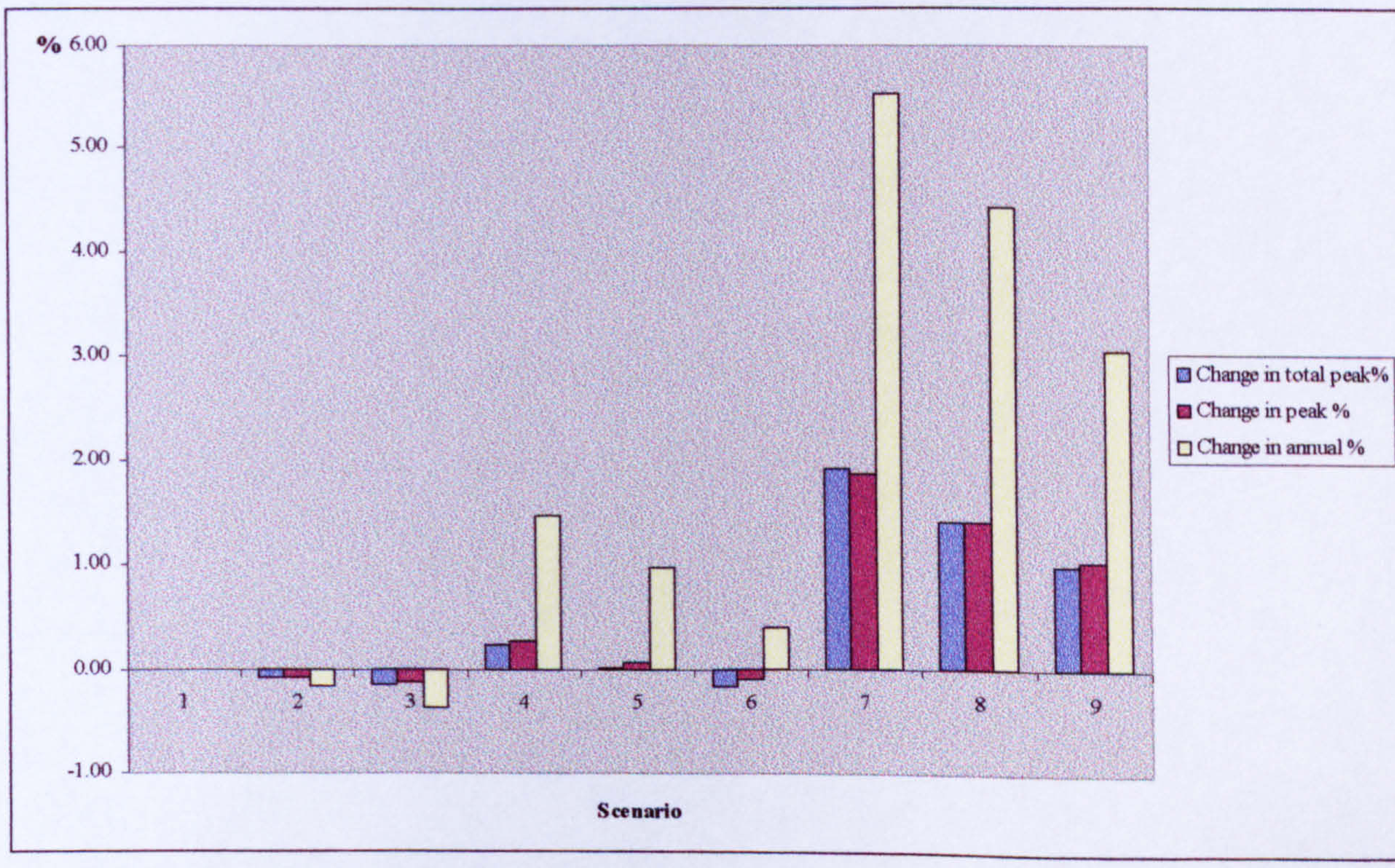


Figure 171: The impact of Ug on the building peak and annual loads in the different scenarios

The maximum change remains however under 6% for the calculations of annual load, while the change in the peak is only 2 % with the introduction of large windows with high Ug values (scenario 2).

Figure 171 shows almost identical patterns of cooling load in all scenarios despite change in the Ug values.

A similar pattern is identified when the impact of Ug on the building envelope is investigated (Figure 173 and Table 27). The annual envelope cooling load in the scenarios using the base case window was reduced by 1.4 %, while the total building load was reduced by 0.4% when the lowest Ug was applied (Figure 173: AB-CB). The influence on Ug increased in scenarios 7-9 when the large window was introduced (Figure 173: GB-IB). The annual envelope cooling load was reduced by 8 %, while the total building load was reduced by 3% when the lowest Ug was applied.

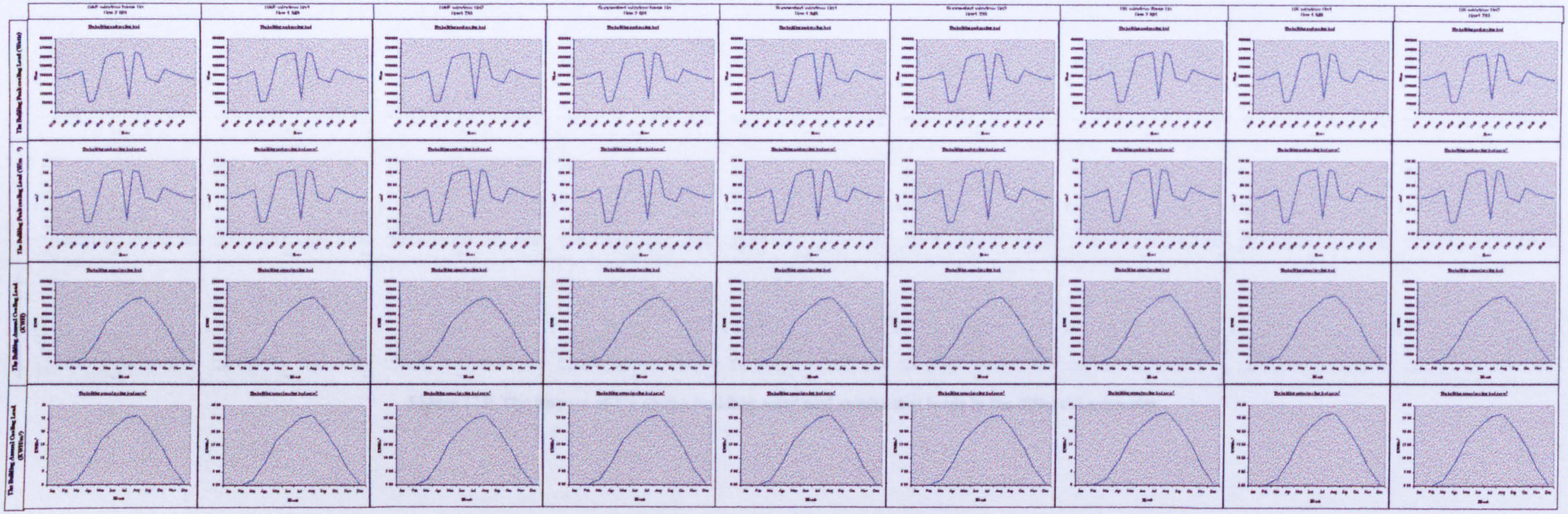


Figure 172: The impact of Ug on the building annual and peak cooling loads in the different scenarios

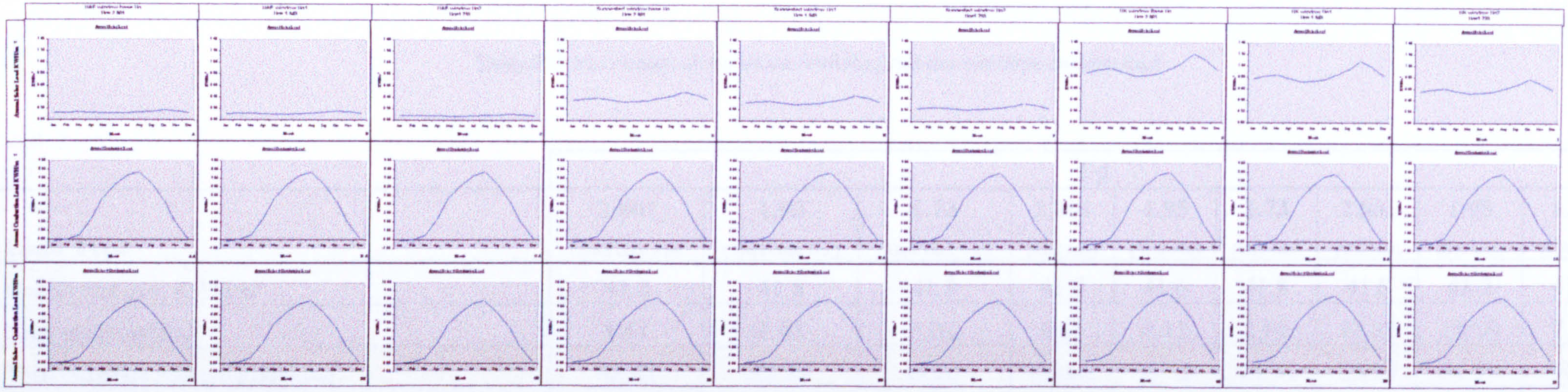


Figure 173: The impact of Ug on the building solar and conduction loads in the different scenarios

Table 27: The impact of Ug on the building and the envelope cooling load

Load Type	Ug								
	2.801 (Base case win)	**1.95** (Base case win)	**1.73** (Base case win)	**2.801** (Mid win)	**1.95** (Mid win)	**1.73** (Mid win)	**2.801** (UK win)	**1.95** (UK win)	**1.73** (UK win)
Conduction gain KWH/m^2	41.8	41.8	41.8	41.9	41.6	41.8	41.8	41.2	41.6
Solar gain KWH/m^2	1.61	1.43	1.03	4.61	4.11	2.96	11.32	10.10	7.27
Total envelope heat gain KWH/m^2	43.45	43.19	42.85	46.46	45.72	44.74	53.10	51.29	48.86
Annual total cooling load KWH/m^2	141.88	141.64	141.36	143.97	143.27	142.44	150.19	148.45	146.33
Conduction load in relation to total cooling load %	29.49	29.48	29.58	29.07	29.04	29.33	27.82	27.75	28.42
Solar load in relation to total cooling load %	1.13	1.01	0.73	3.20	2.87	2.08	7.54	6.80	4.97
Envelope load in relation to total cooling load %	30.62	30.49	30.31	32.27	31.91	31.41	35.36	34.55	33.39
Relative envelope load % (to base case 1)	100	99.40	98.62	106.94	105.22	102.97	122.22	118.05	112.45
Relative total cooling load % (to base case 1)	100	99.83	99.63	101.47	100.98	100.40	105.86	104.63	103.14
Relative envelope load % (to each window size)	100	99.40	98.62	100	98.40	96.29	100	96.58	92.01
Relative total cooling load % (to each window size)	100	99.83	99.63	100	99.51	98.94	100	98.84	97.43

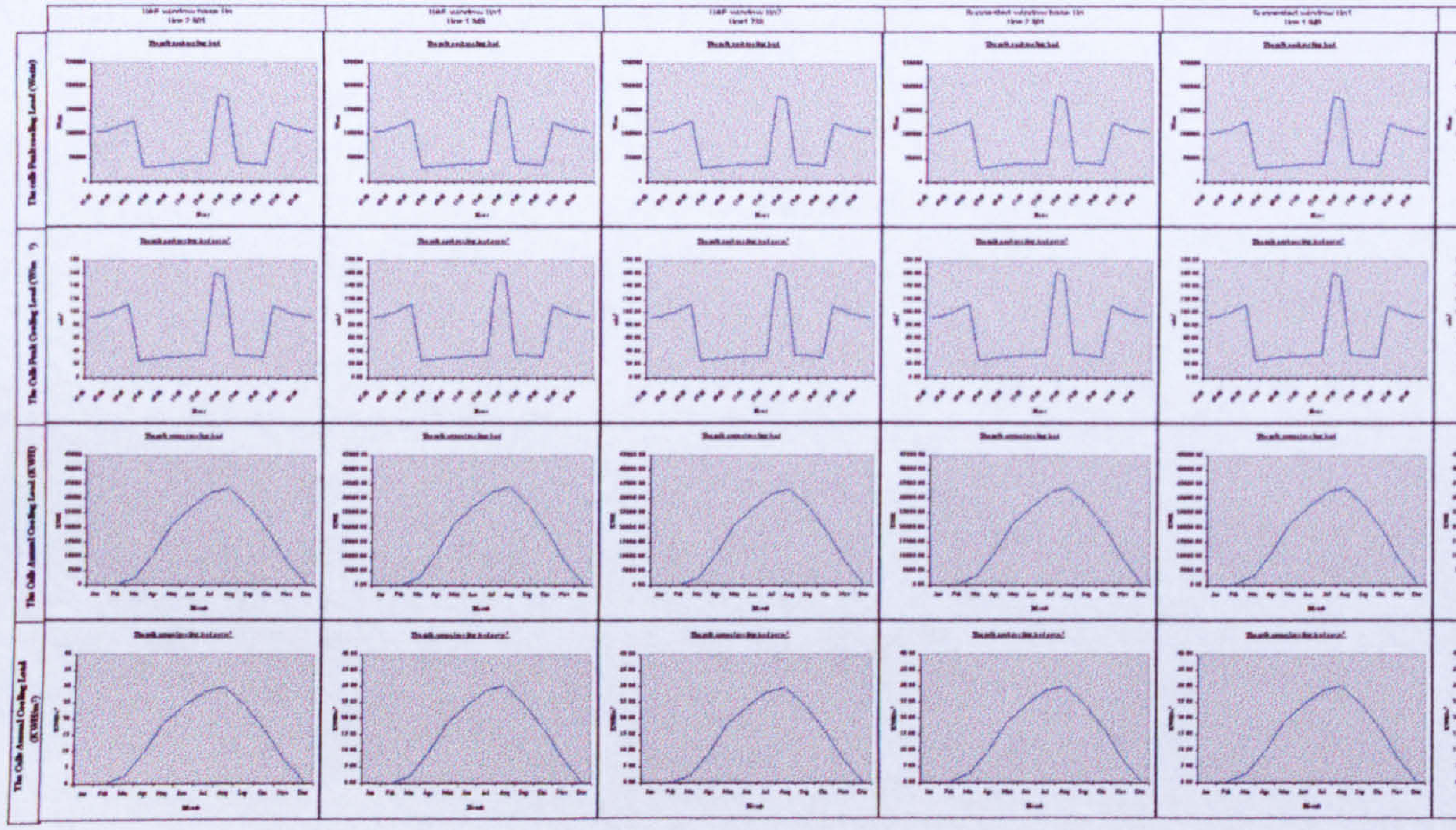


Figure 174: The impact of Ug on the cells total cooling loads in the different scenarios

8.3.7.2 The impact of Ug on the cells cooling load

The analysis of the impact of Ug on the cells annual and peak loads in the different scenarios shows slight increase in the change from the whole building, discussed in the previous sections. The maximum percentage change has increased from 8% for the whole building to 12% in the cell zone. Such increase is expected, as the cells are located on the peripheries of the form. The difference is however quite large when compared to previous analysis of the orientation, or the impact of the fenestration factor. It might be argued here that large Ug values might have impact on the transmittance quality of the glazing. This can hardly be important in a UAE environment in general, with the quality of daylighting. While transmittance might be also a determinant factor in an office building, this is not applicable in prison buildings.

Output of the simulation (Figure 174 to Figure 183) for the selected cells annual and peak load, solar load and conduction load shows similar patterns with different scenarios.

The following section investigates the impact of Uo on the prison building cooling loads.

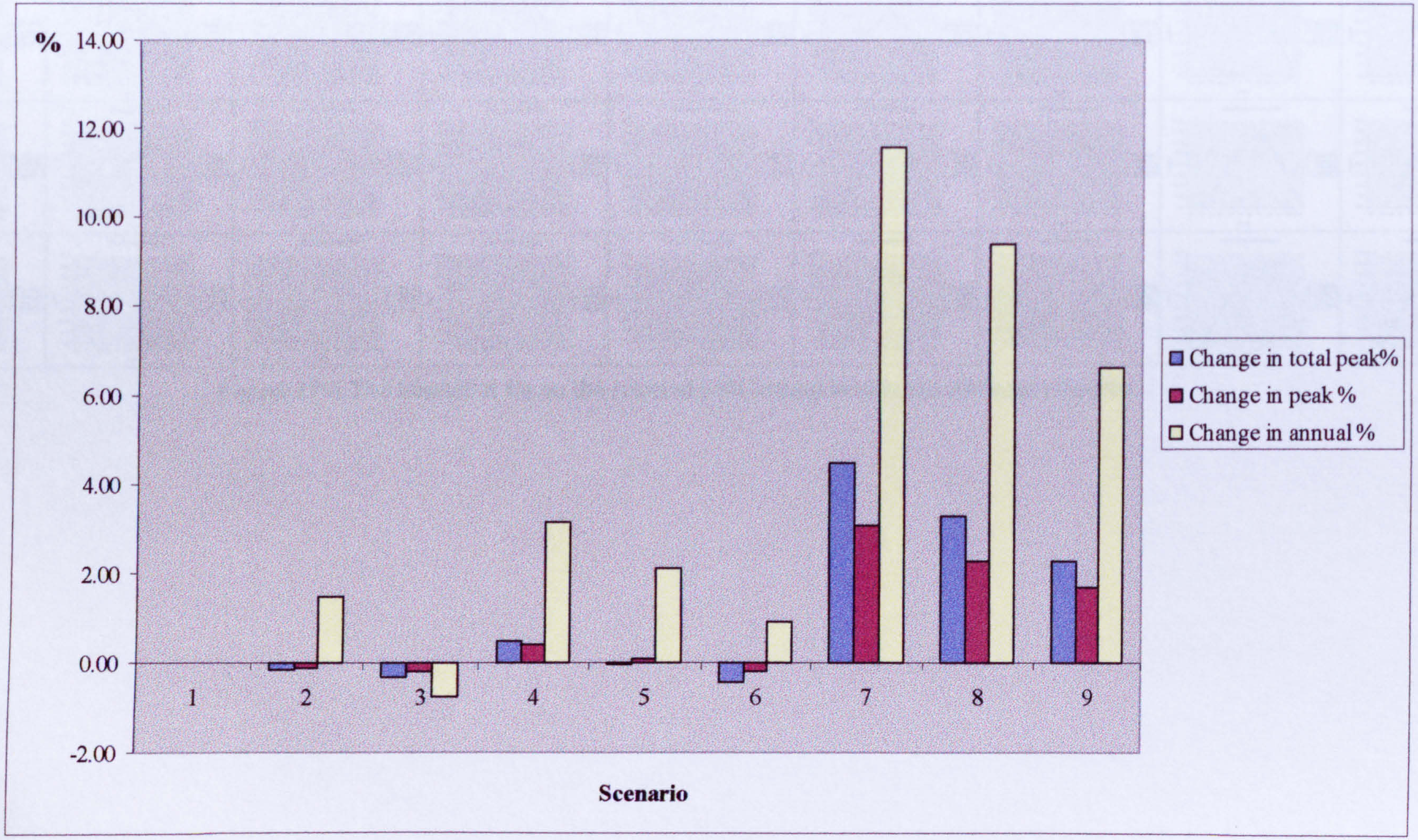


Figure 175: The impact of Ug on the cells peak and annual cooling loads in the different scenarios

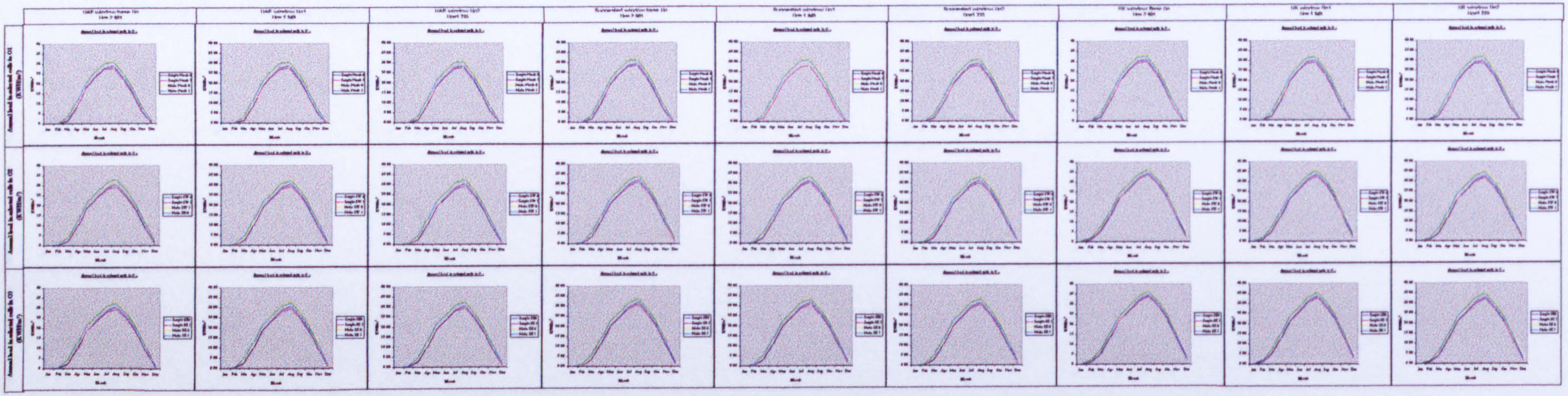
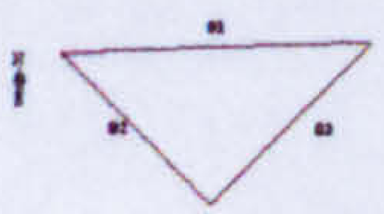


Figure 176: The impact of Ug on the selected cells annual load in the different scenarios



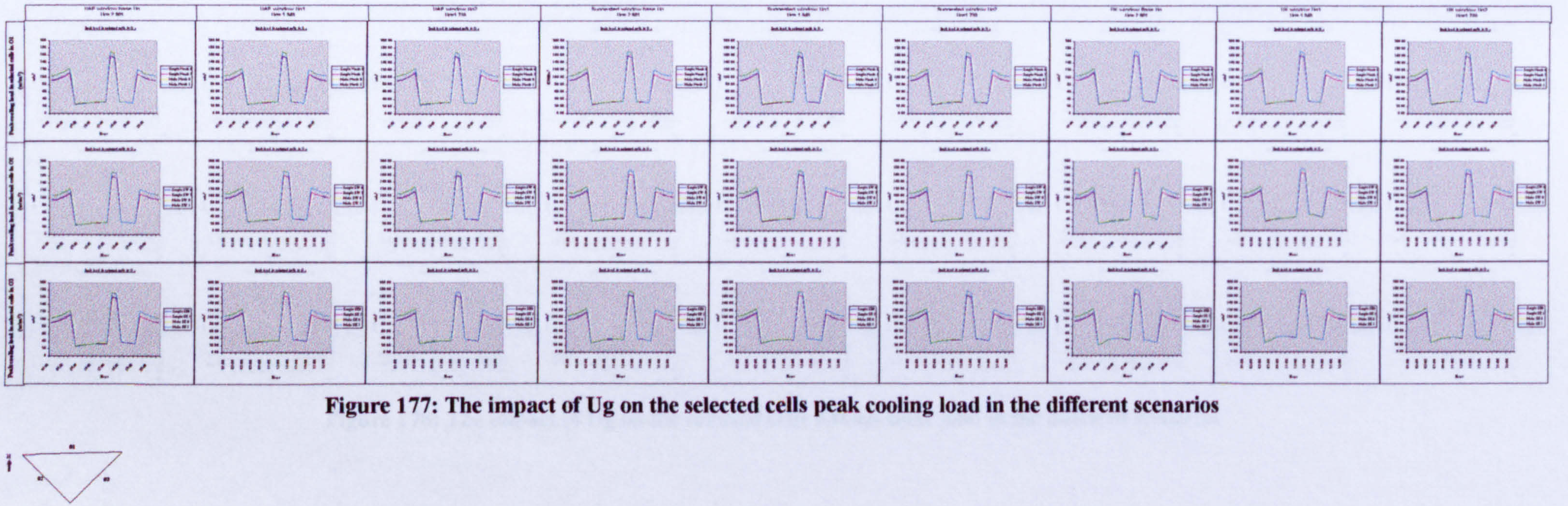


Figure 177: The impact of Ug on the selected cells peak cooling load in the different scenarios

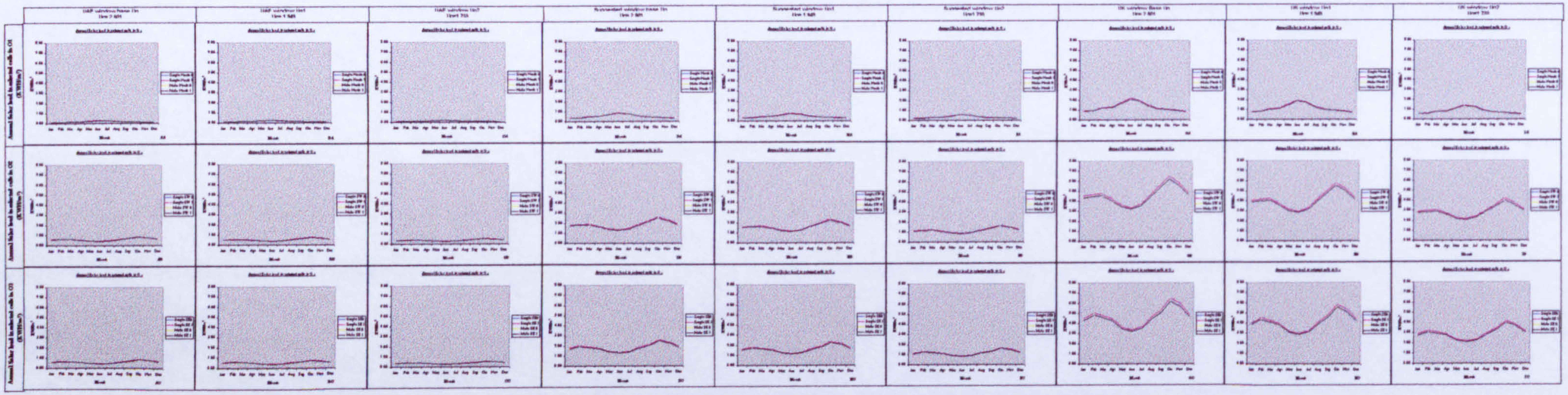
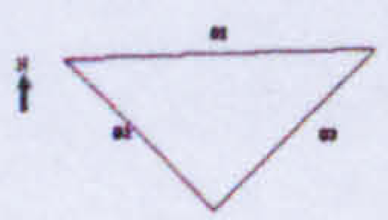


Figure 178: The impact of Ug on the selected cells annual solar load in the different scenarios



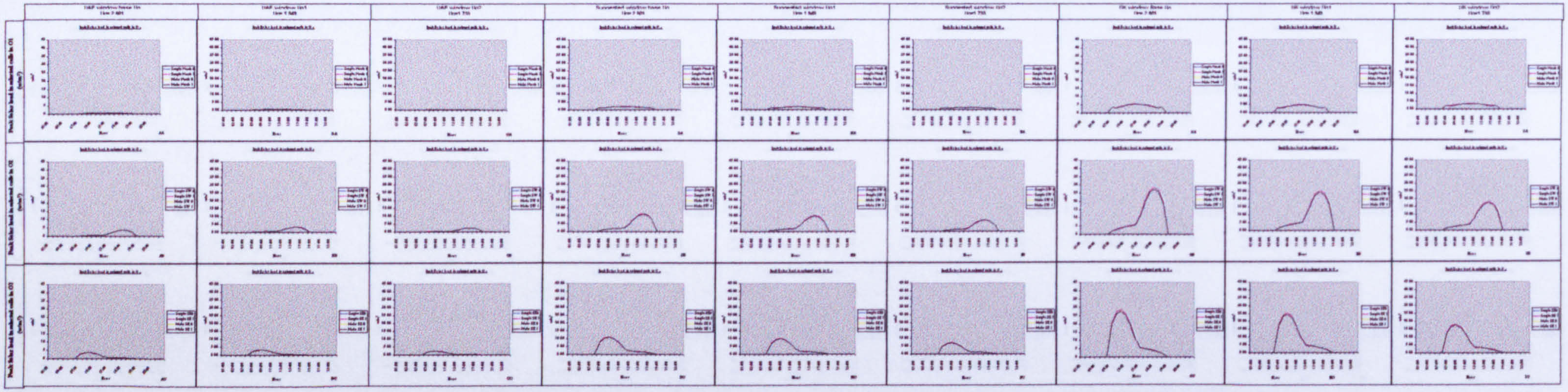
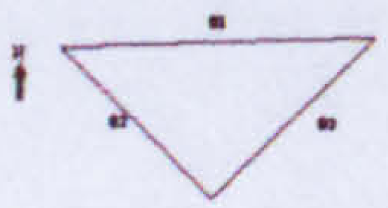


Figure 179: The impact of Ug on the selected cells peak solar load in the different scenarios



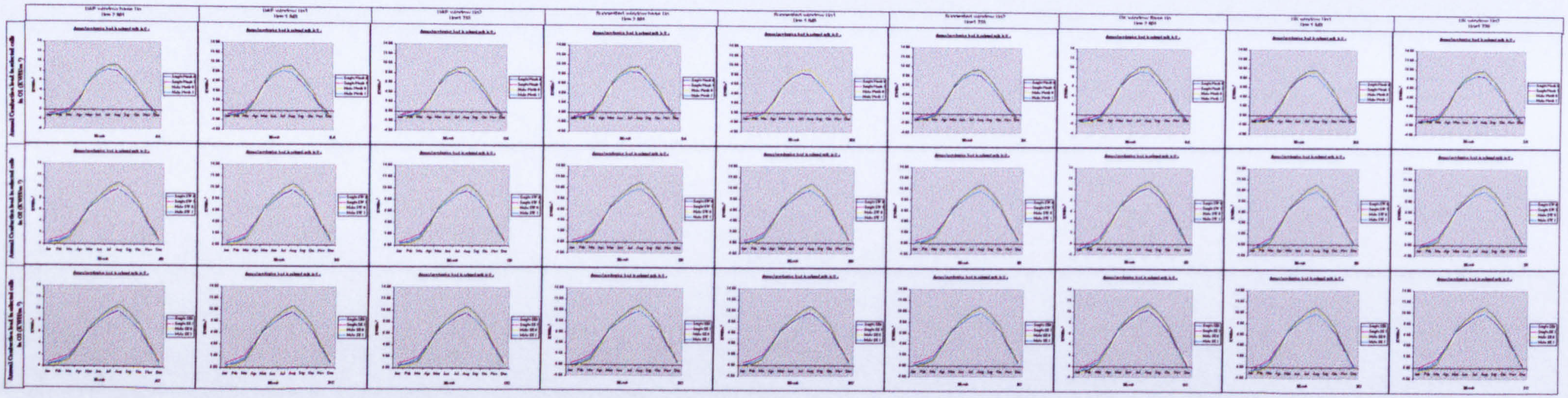
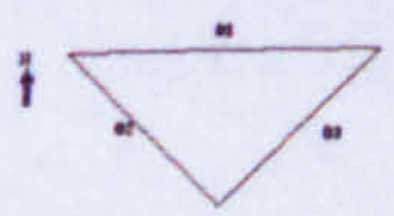


Figure 180: The impact of Ug on the selected cells annual conduction load in the different scenarios



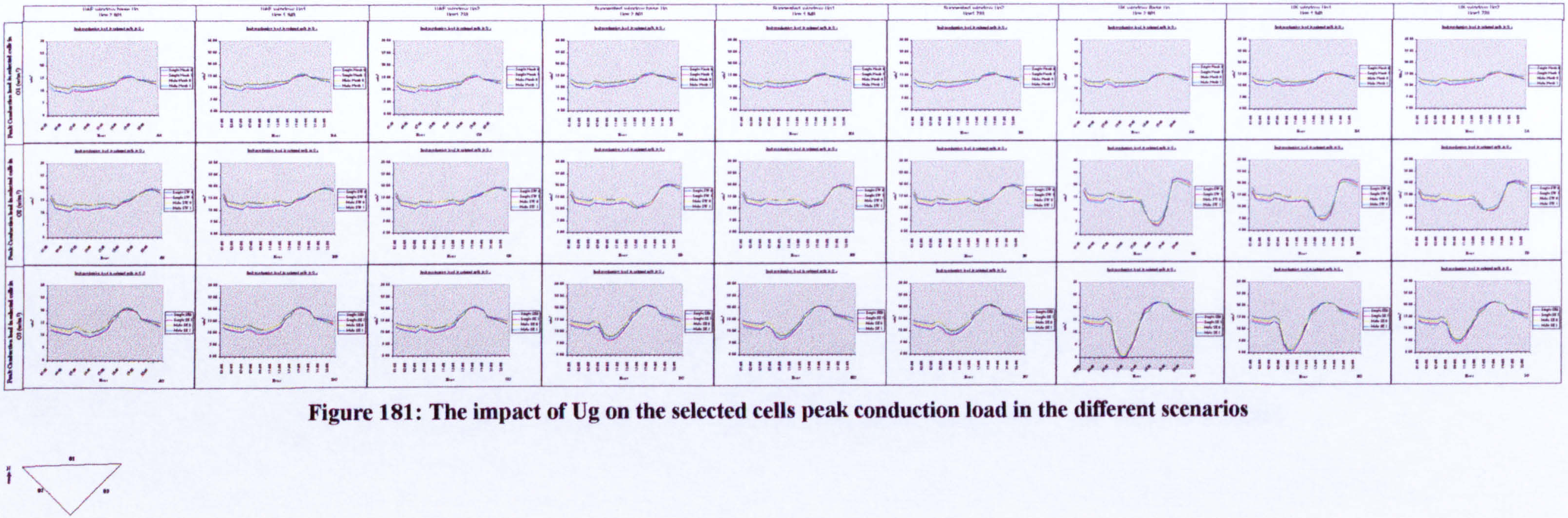


Figure 181: The impact of Ug on the selected cells peak conduction load in the different scenarios

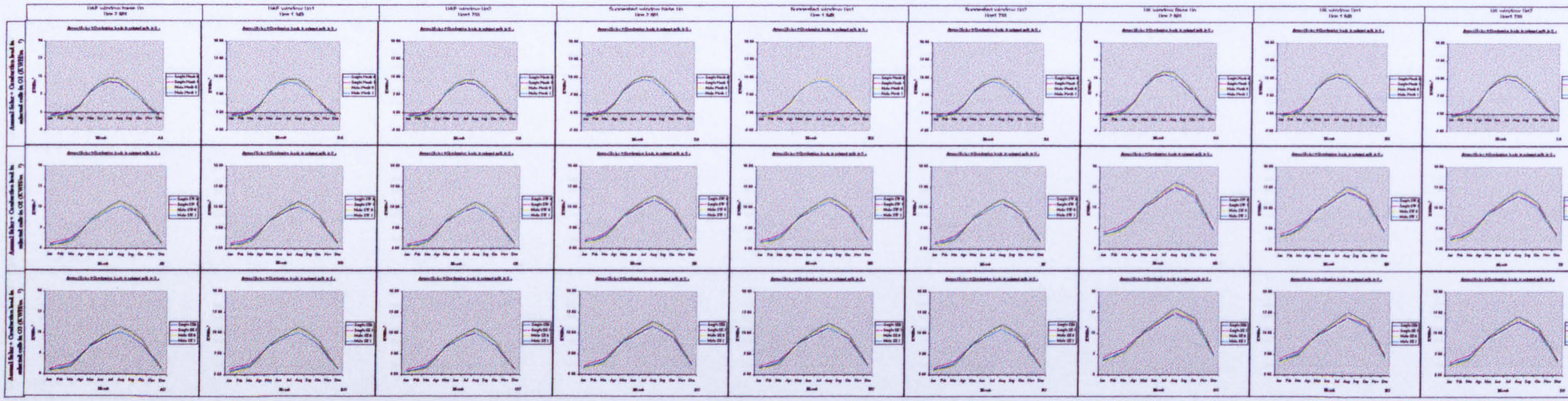
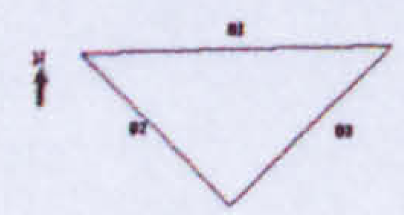


Figure 182: The impact of Ug on the selected cells envelope annual cooling load in the different scenarios



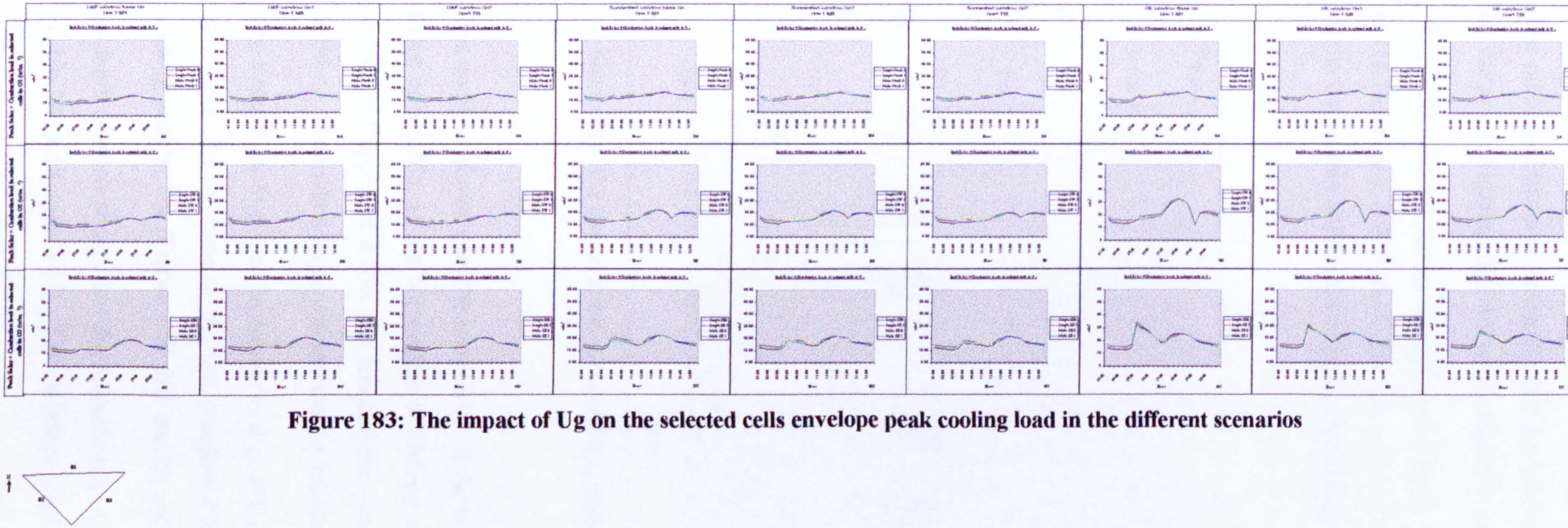


Figure 183: The impact of Ug on the selected cells envelope peak cooling load in the different scenarios

8.3.7.3 The impact of Uo on the prison building cooling load

The outline of the nine scenarios that are simulated in order to identify the impact of Uo on the prison building thermal performance is presented in Table 16.

Three different Uo values are applied to each of the three window sizes. The values of 0.918 (base Uo), 0.772 and 0.651 are selected from the base case and from specification of the commonly used walls in prison buildings in the UAE.

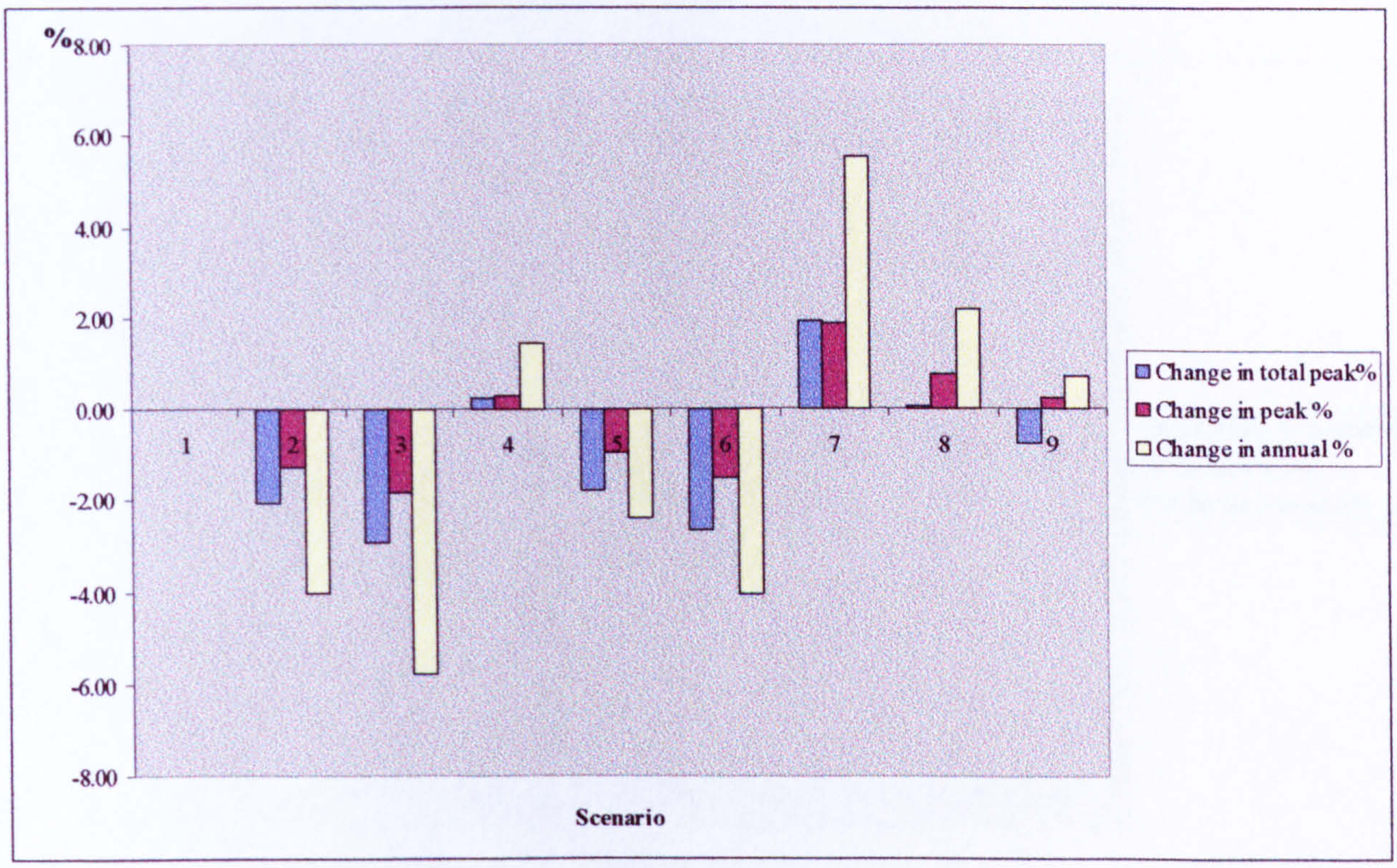


Figure 184: The impact of Uo on the building peak and annual loads in the different scenarios

The analysis shows that the sensitivity of the thermal load to the selected Uo values was more noticeable, as the percentage of change ranged between 4% and 6%. Figure 184 shows that applying a low Uo reduced the peak and annual cooling loads of the prison building, even when large windows were introduced.

The annual cooling load in Scenario 6 is 4% lower than the annual cooling load in the base case. In the case of the UK window (90 X100), the low Uo reduced the annual cooling load by 5% (Figure 186: GB and IB and Figure 186: GC and IC).

In-depth analysis shows that the impact of the Uo on the envelope load is more significant (Table 28 and Figure 187). The envelope load in scenario 6 is 11% lower than the base case. The low Uo resulted in reducing the cooling load in the scenario with the UK window size by 14%, which reduced the difference between this scenario and base case to a mere 5% (it was 22% with the base case Uo value).

The analysis of the impact of Uo on the cells cooling loads conforms with the building and the envelope cooling loads.

Figure 185 shows that the use of a low Uo reduced the peak and annual cooling loads in the different scenarios. Detailed analysis of the selected cells different cooling loads are presented in Figure 188 to Figure 196.

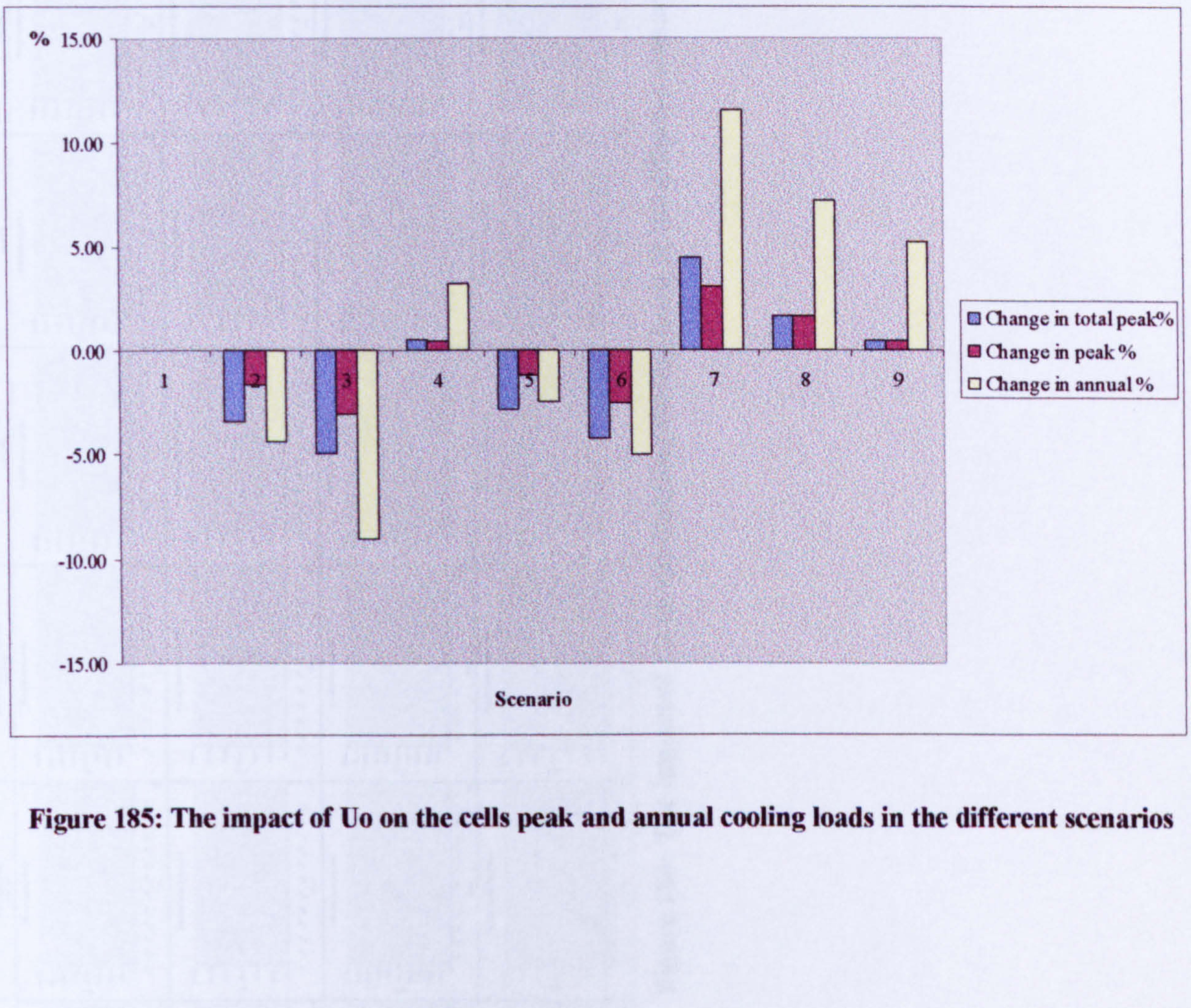


Figure 185: The impact of Uo on the cells peak and annual cooling loads in the different scenarios

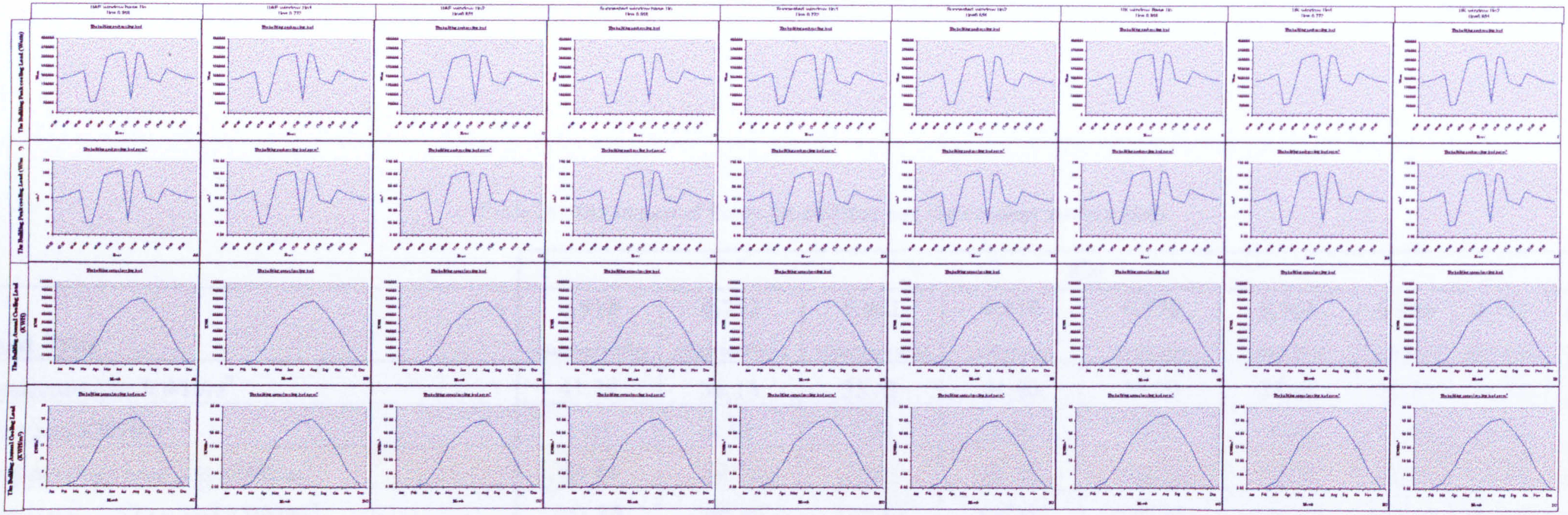


Figure 186: The impact of Uo on the building cooling loads in the different scenarios

Table 28: The impact of Uo on the building and the envelope cooling loads

	Uo								
Load Type	**0.918** (Base case win)	**0.772** (Base case win)	**0.651** (Base case win)	**0.918** (Mid win)	**0.772** (Mid win)	**0.651** (Mid win)	**0.918** (UK win)	**0.772** (UK win)	**0.651** (UK win)
Conduction gain KWH/m^2	41.84	36.15	33.81	41.86	36.30	34.01	41.79	36.52	34.35
Solar gain KWH/m^2	1.61	1.61	1.61	4.61	4.61	4.61	11.32	11.32	11.32
Total envelope heat gain KWH/m^2	43.45	37.75	35.41	46.46	40.91	38.62	53.10	47.84	45.67
Annual total cooling load KWH/m^2	141.88	136.41	134.13	143.97	138.60	136.36	150.19	145.07	142.92
Conduction load in relation to total cooling load %	29.49	26.50	25.20	29.07	26.19	24.94	27.82	25.17	24.03
Solar load in relation to total cooling load %	1.13	1.18	1.20	3.20	3.32	3.38	7.54	7.80	7.92
Envelope load in relation to total cooling load %	30.62	27.68	26.40	32.27	29.51	28.32	35.36	32.97	31.95
Relative envelope load % (to base case 1)	100	86.89	81.51	106.94	94.15	88.89	122.22	110.10	105.11
Relative total cooling load % (to base case 1)	100	96.14	94.54	101.47	97.69	96.11	105.86	102.25	100.73
Relative envelope load % (to each window size)	100	86.89	81.51	100	88.04	83.12	100	90.08	86.00
Relative total cooling load % (to each window size)	100	96.14	94.54	100	96.27	94.72	100	96.59	95.16

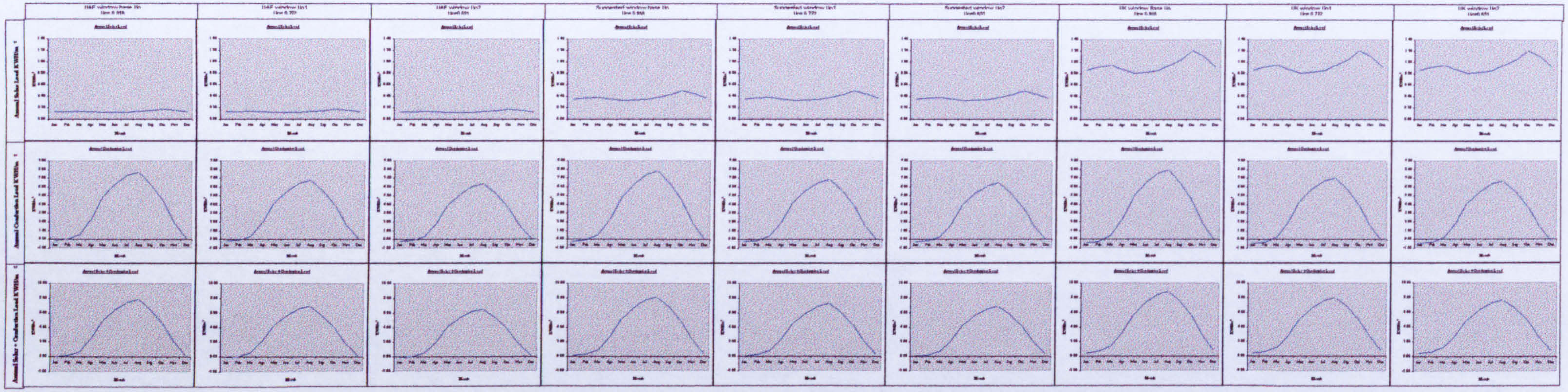


Figure 187: The impact of Uo on the building solar and conduction loads in the different scenarios

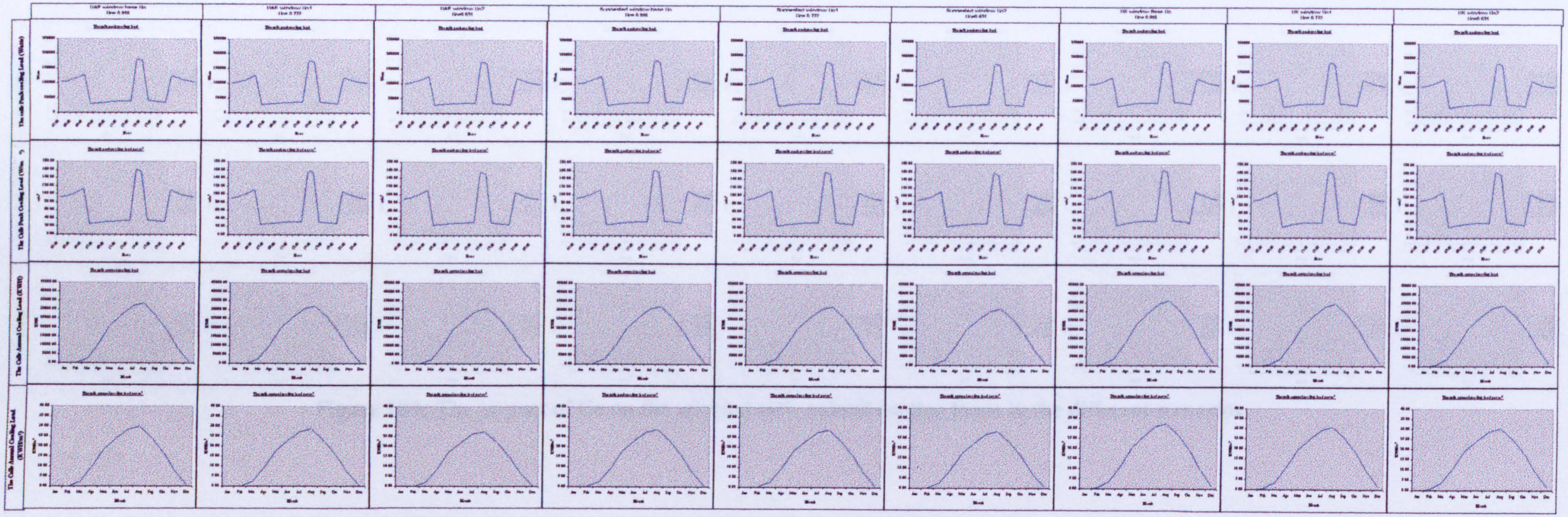


Figure 188: The impact of Uo on the cells cooling loads in the different scenarios

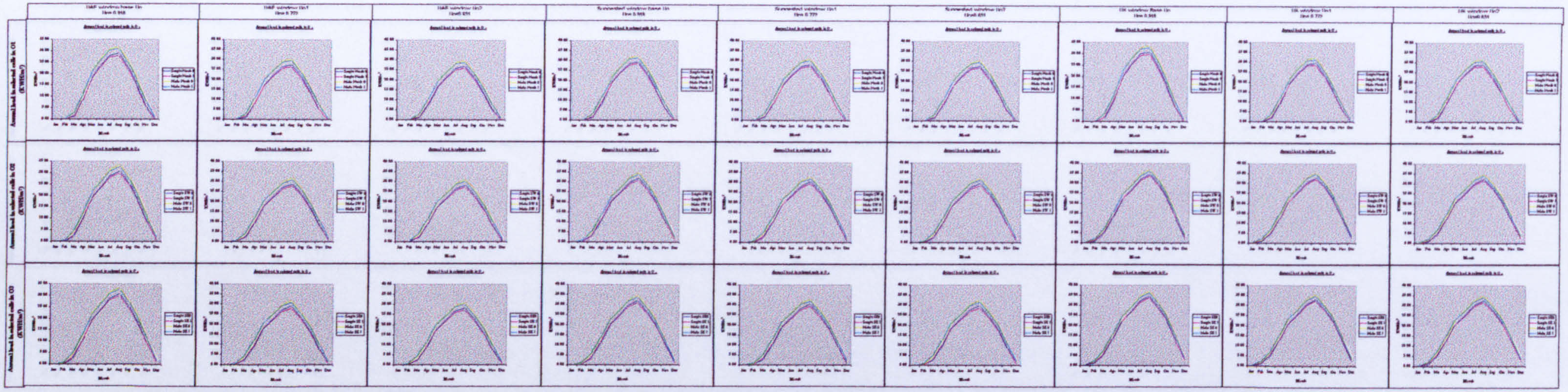


Figure 189: The impact of Uo on the selected cells annual cooling loads in the different scenarios

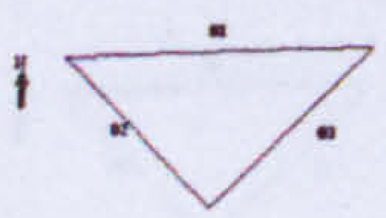
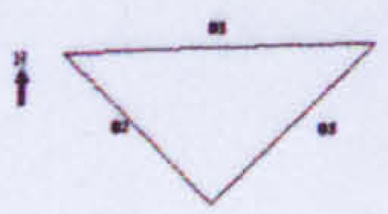


Figure 190: The impact of Uo on the selected cells peak cooling loads in the different scenarios



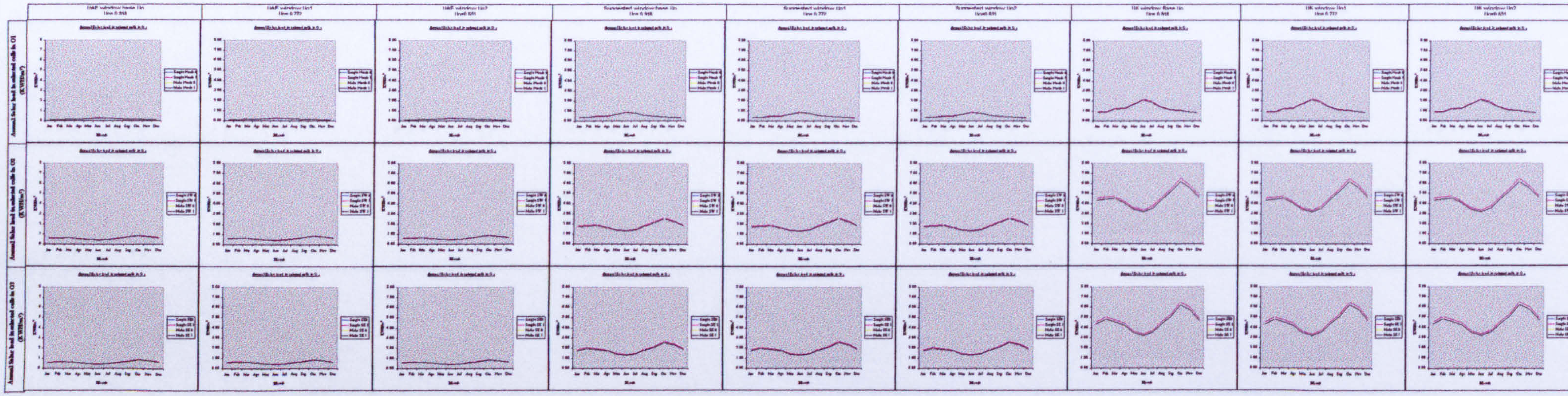
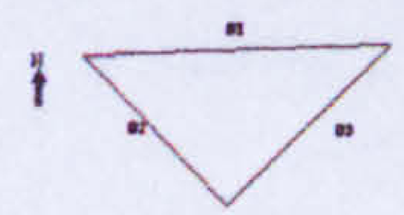


Figure 191: The impact of Uo on the selected cells annual solar cooling loads in the different scenarios



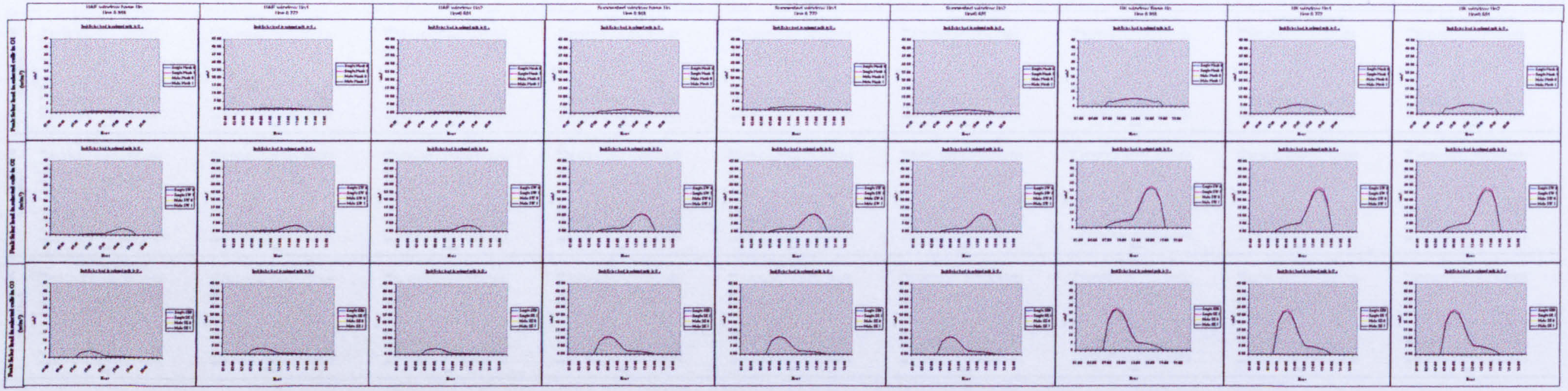
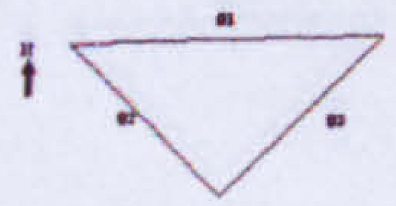


Figure 192: The impact of Uo on the selected cells peak solar cooling loads in the different scenarios



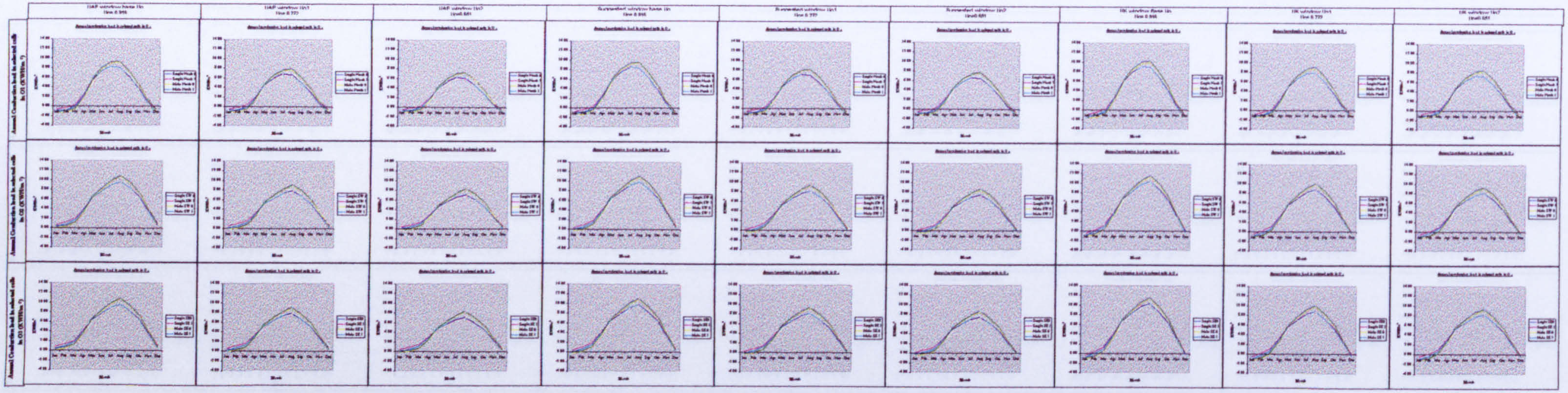
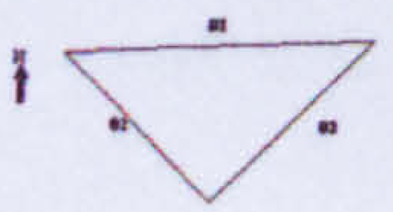


Figure 193: The impact of Uo on the selected cells annual conduction cooling loads in the different scenarios



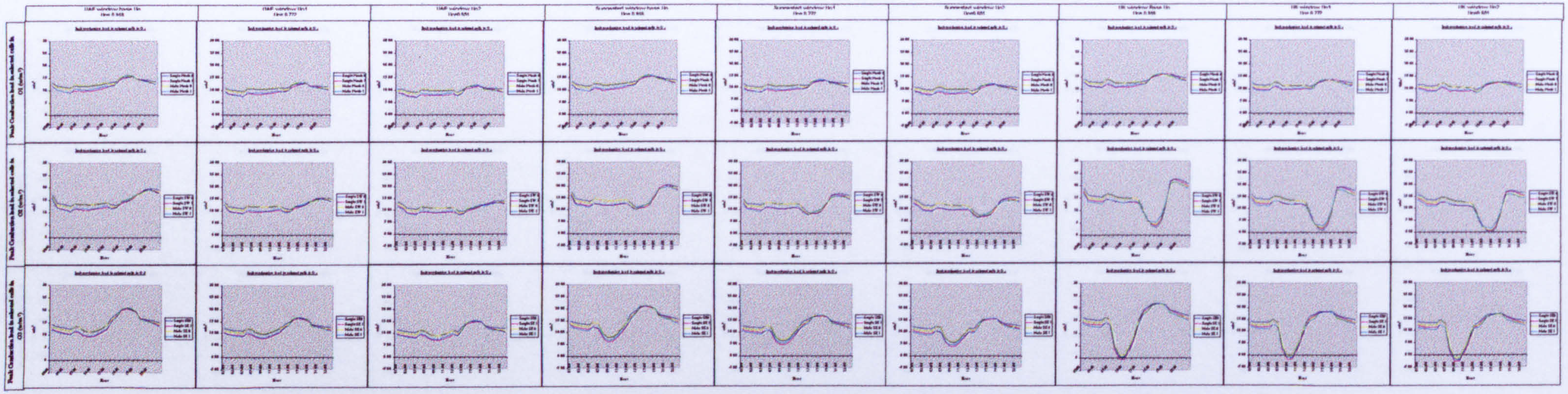
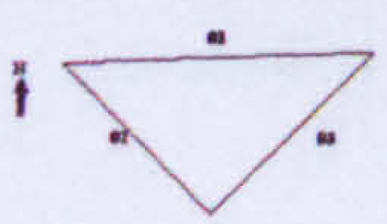


Figure 194: The impact of Uo on the selected cells peak conduction cooling loads in the different scenarios



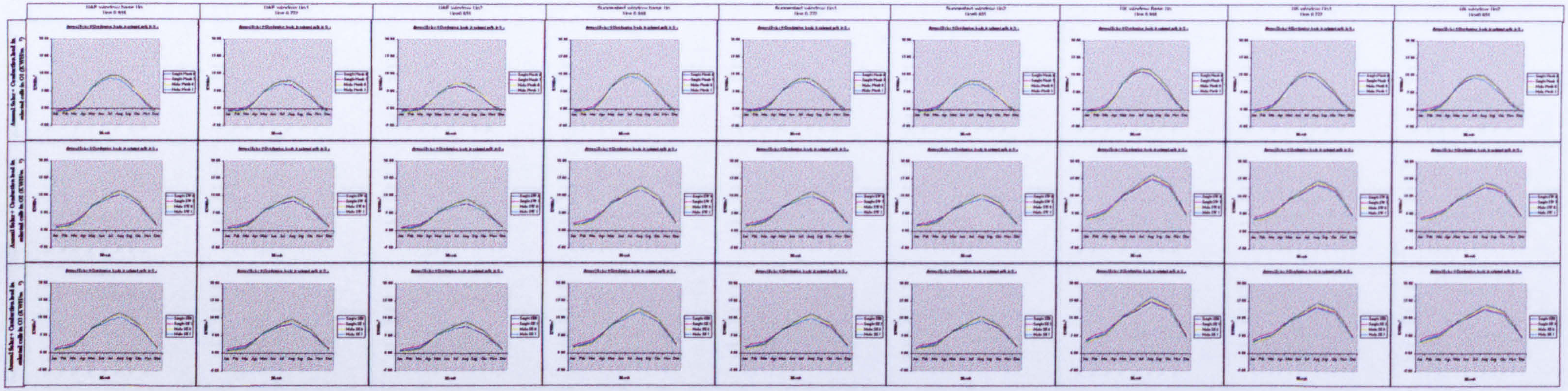
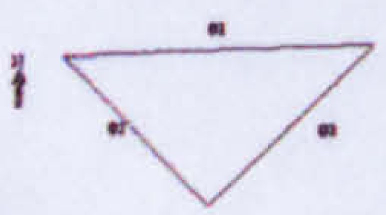


Figure 195: The impact of Uo on the selected cells annual envelope cooling loads in the different scenarios



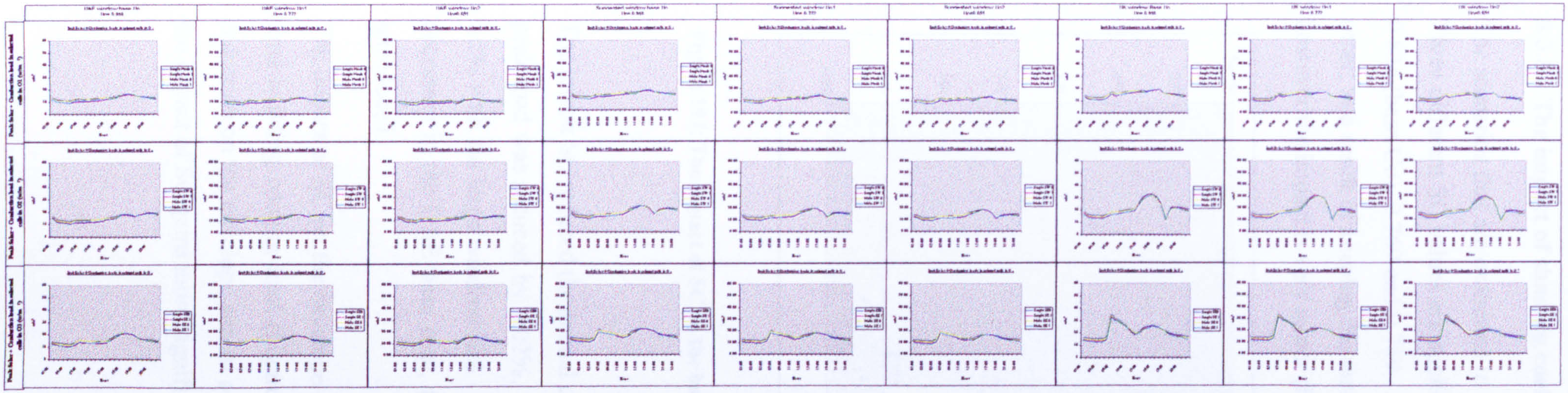
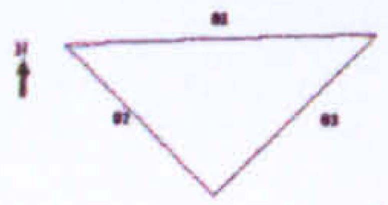


Figure 196: The impact of Uo on the selected cells peak envelope cooling loads in the different scenarios



8.3.8 The impact of shading coefficient on the prison building cooling loads

The scenarios that are examined to investigate the impact of SC are outlined in Table 17. Three different SC values are applied to each of the three window sizes. The values are 0.824 (base Uo), 0.769 and 0.759. The different alternatives to SC are very close to each other, as a result of keeping the same Ug. The SC is directly related to the cooling load; however the impact is very minor (Figure 197 and Figure 198).

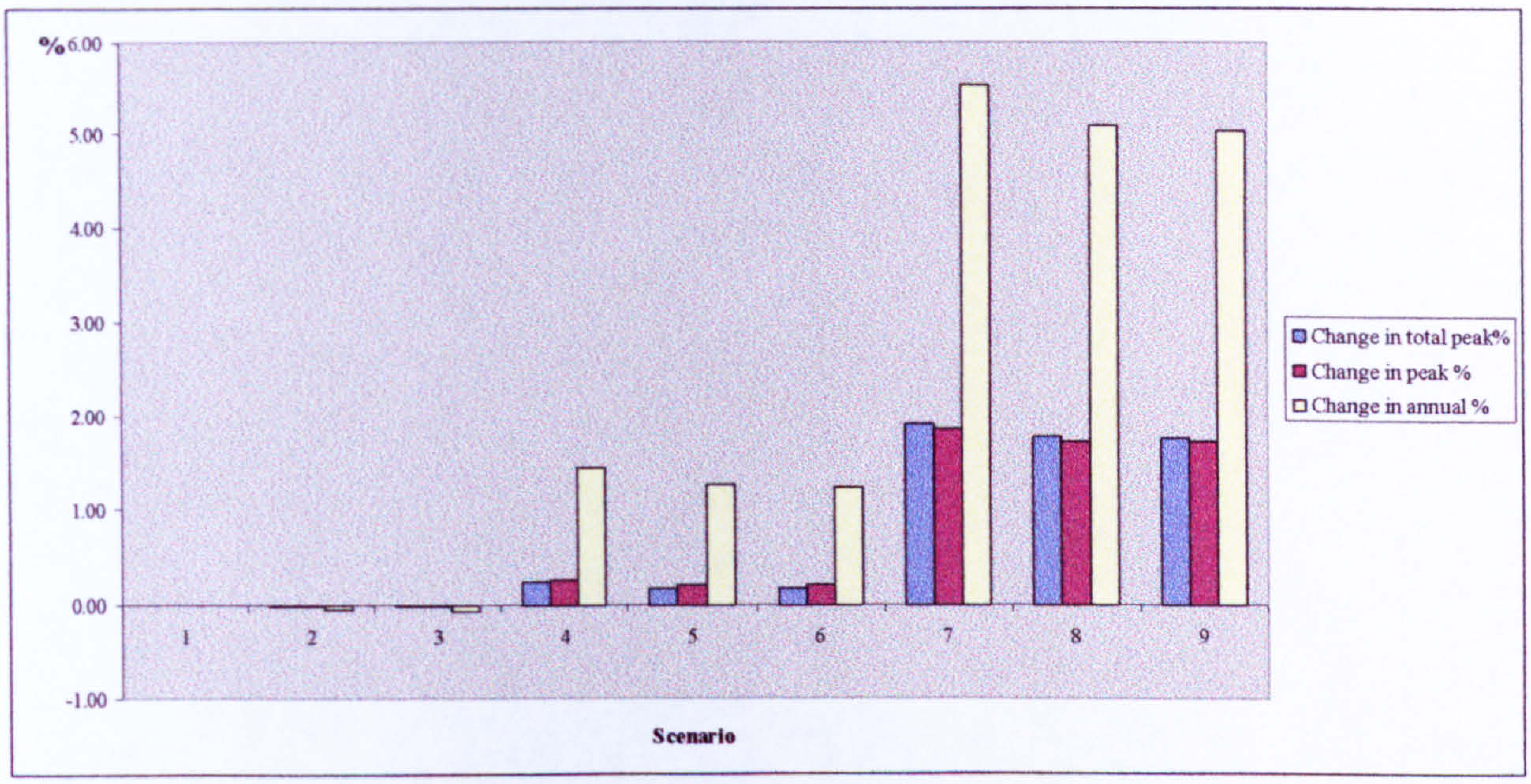


Figure 197: The impact of SC on the building annual and peak cooling load in the different scenarios

The lowest SC reduced the annual cooling load in scenario 9 by 0.5%. The same scenario peak load was reduced by 0.02%. The differences were however significant, and up to 5.5% with the large window size. So while changes in shading coefficient might not be necessary in the UAE base case, they would be beneficial if large size windows were introduced.

The impact of SC on the envelope cooling load is more significant than its impact on the total building cooling load (Figure 199). Table 29 shows that a low SC leads to the reduction on the envelope annual cooling load by 2%, in Scenario 9. It is noticeable that the impact of SC gains more significance with the larger window size.

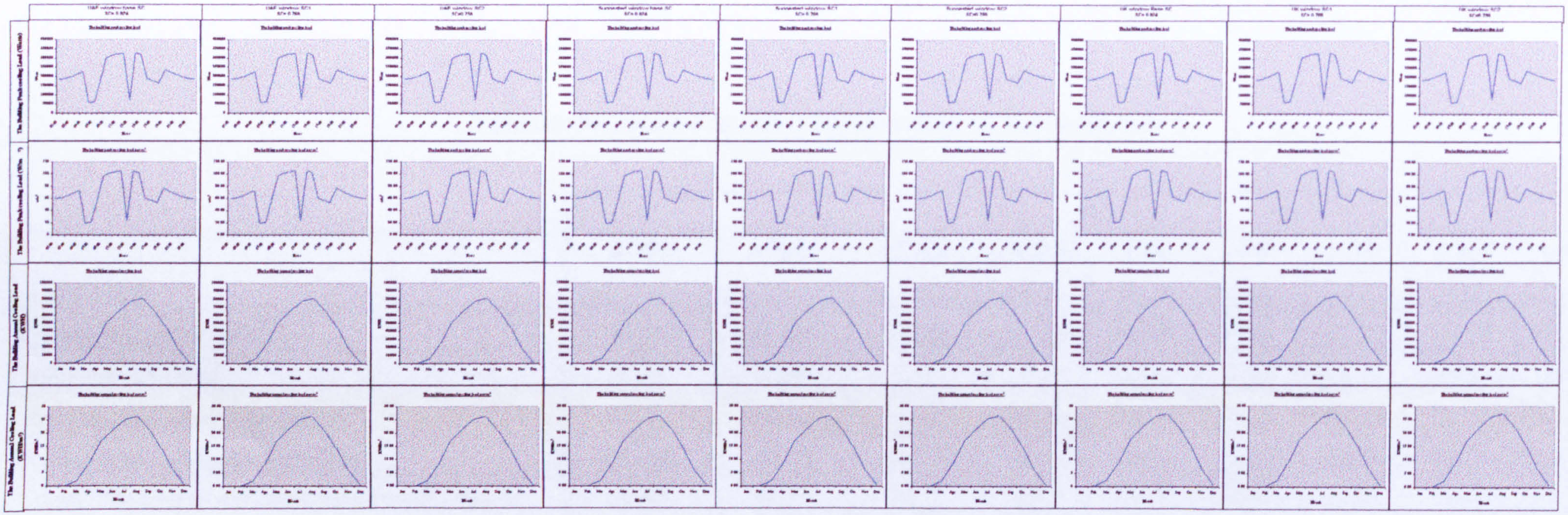


Figure 198: The impact of SC on the building cooling load in the different scenarios

Table 29: The impact of SC on the building and the envelope cooling load

	SC								
Load Type	**0.824** (Base case win)	**0.769** (Base case win)	**0.759** (Base case win)	**0.824** (Mid win)	**0.769** (Mid win)	**0.759** (Mid win)	**0.824** (UK win)	**0.769** (UK win)	**0.759** (UK win)
Conduction gain KWH/m^2	41.84	41.86	41.86	41.86	41.90	41.91	41.79	41.88	41.90
Solar gain KWH/m^2	1.61	1.49	1.47	4.61	4.26	4.20	11.32	10.47	10.32
Total envelope heat gain KWH/m^2	43.45	43.34	43.33	46.46	46.16	46.11	53.10	52.34	52.22
Annual total cooling load KWH/m^2	141.88	141.79	141.78	143.97	143.70	143.67	150.19	149.51	149.41
Conduction load in relation to total cooling load %	29.49	29.52	29.52	29.07	29.16	29.17	27.82	28.01	28.04
Solar load in relation to total cooling load %	1.13	1.05	1.03	3.20	2.96	2.93	7.54	7.00	6.91
Envelope load in relation to total cooling load %	30.62	30.57	30.56	32.27	32.12	32.09	35.36	35.01	34.95
Relative envelope load % (to base case 1)	100	99.76	99.72	106.94	106.23	106.12	122.22	120.47	120.20
Relative total cooling load % (to base case 1)	100	99.94	99.93	101.47	101.28	101.26	105.86	105.37	105.31
Relative envelope load % (to each window size)	100	99.76	99.72	100	99.34	99.24	100	98.56	98.34
Relative total cooling load % (to each window size)	100	99.94	99.93	100	99.82	99.79	100	99.55	99.48

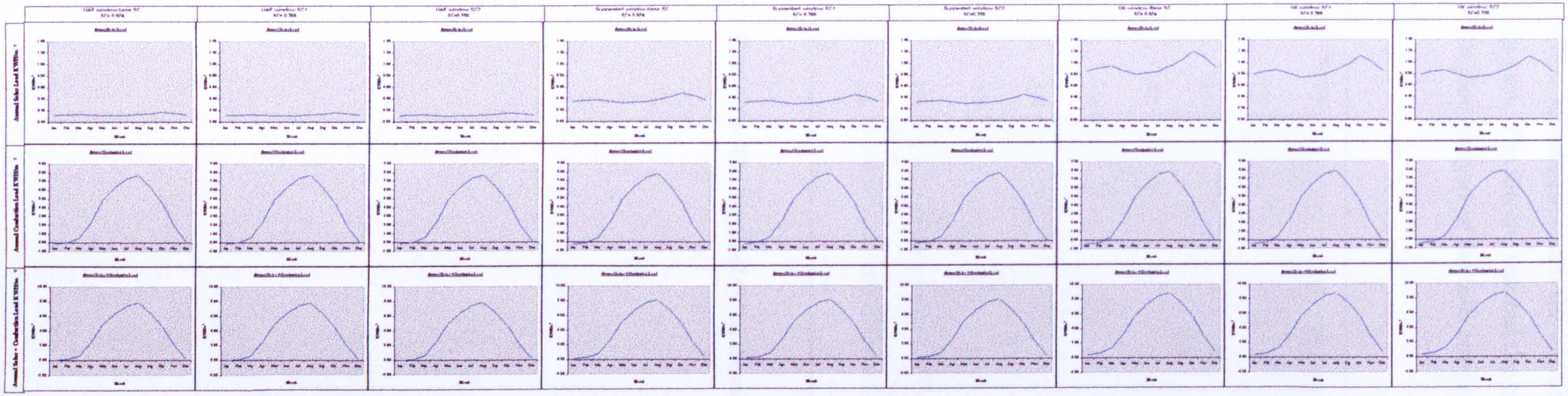


Figure 199: The impact of SC on the building solar and conduction cooling load in the different scenarios

Close investigation into the impact of the SC on the cells cooling load shows the same pattern. The low SC reduced the cells annual load in scenario 9 by 1% (Figure 200). The detailed analysis of the cells cooling loads are presented in Figure 201 to Figure 209.

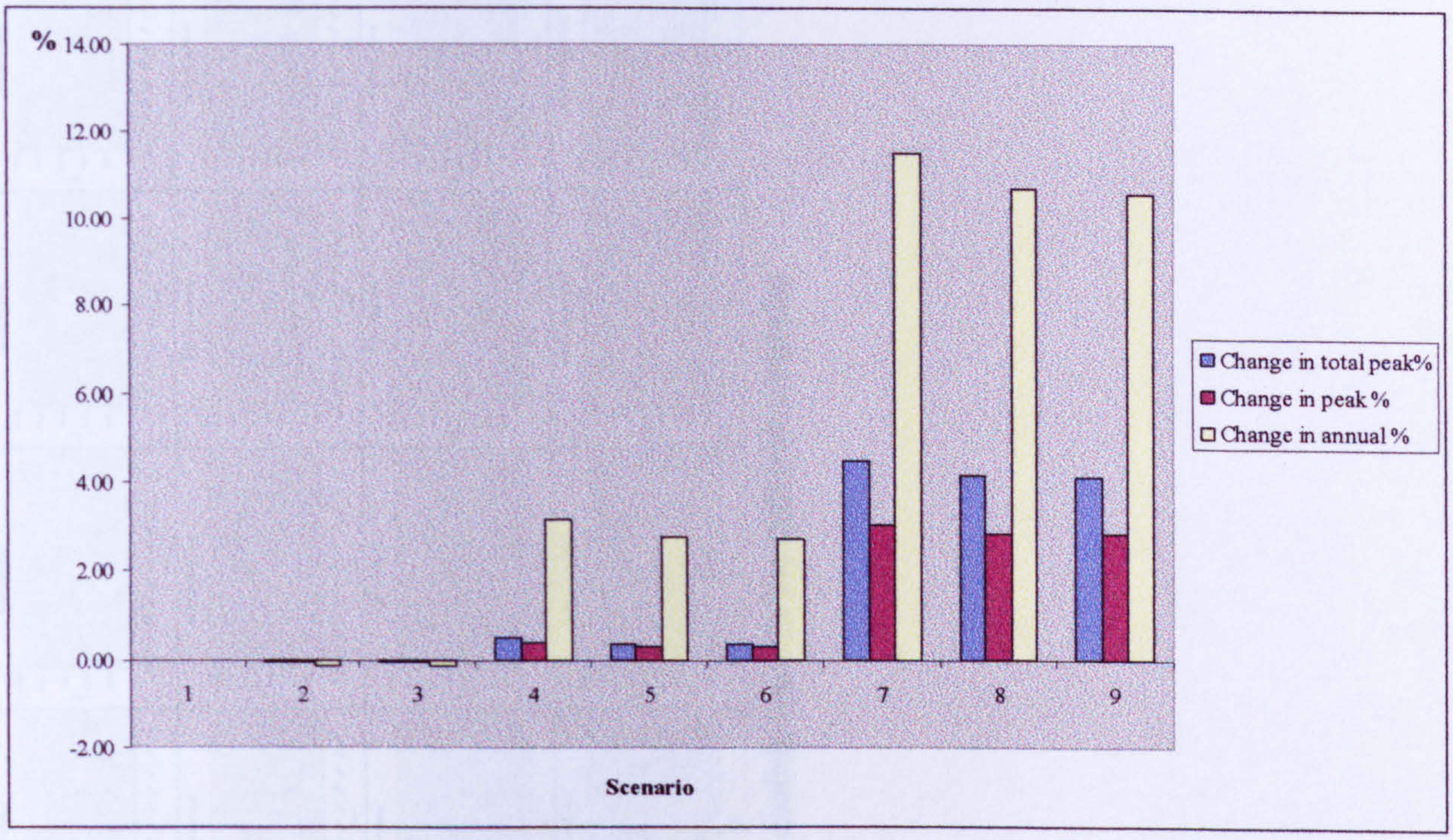


Figure 200: The impact of SC on the cells annual and peak cooling loads in the different scenarios

Figure 201: The impact of SC on the cells cooling loads in the different scenarios

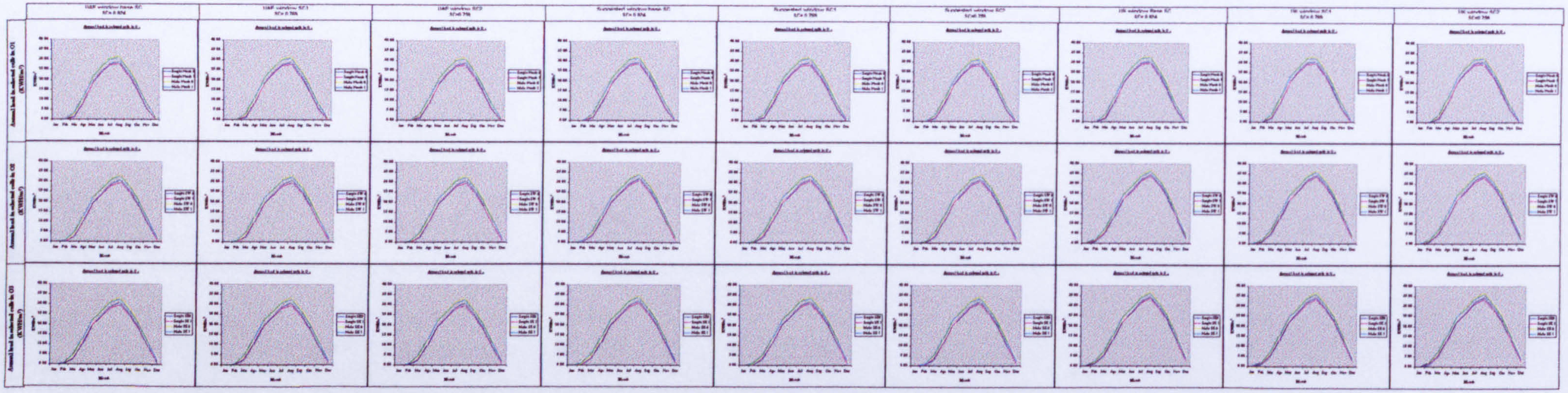
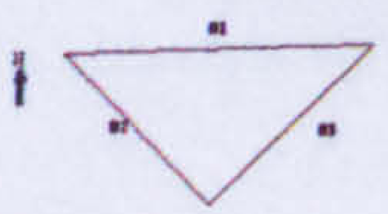


Figure 202: The impact of SC on the selected cells annual cooling load in the different scenarios



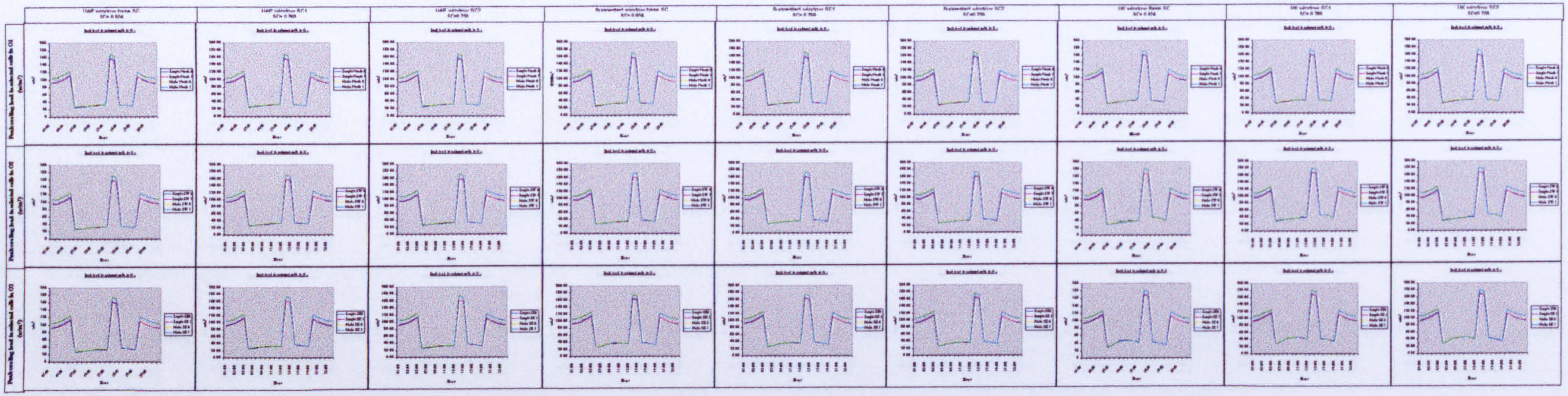
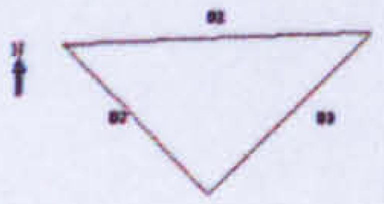


Figure 203: The impact of SC on the selected cells peak cooling load in the different scenarios



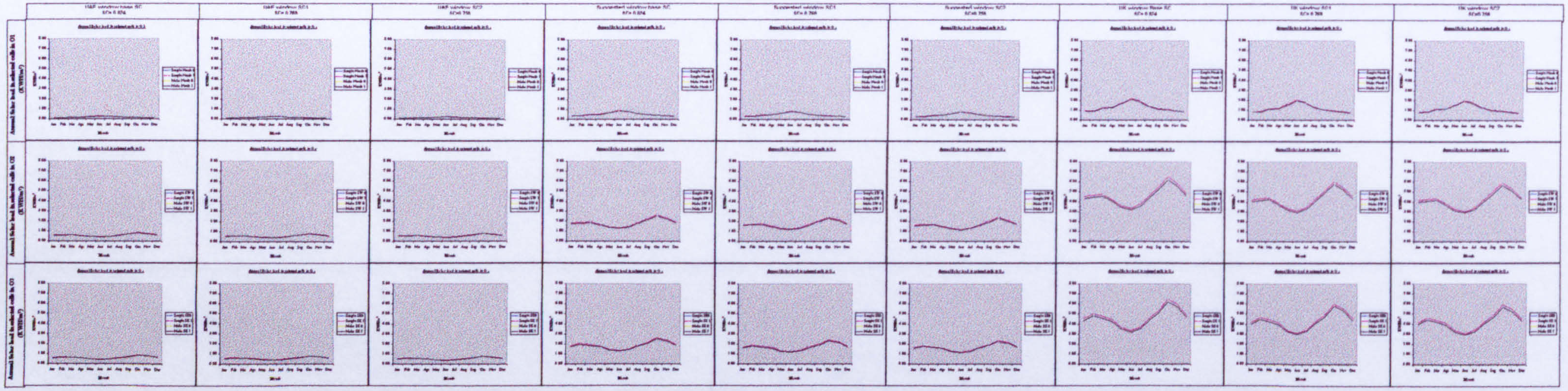
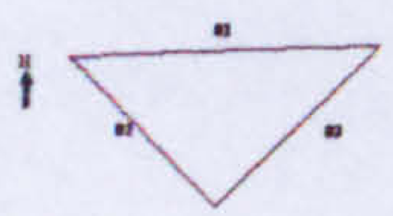


Figure 204: The impact of SC on the selected cells annual solar cooling load in the different scenarios



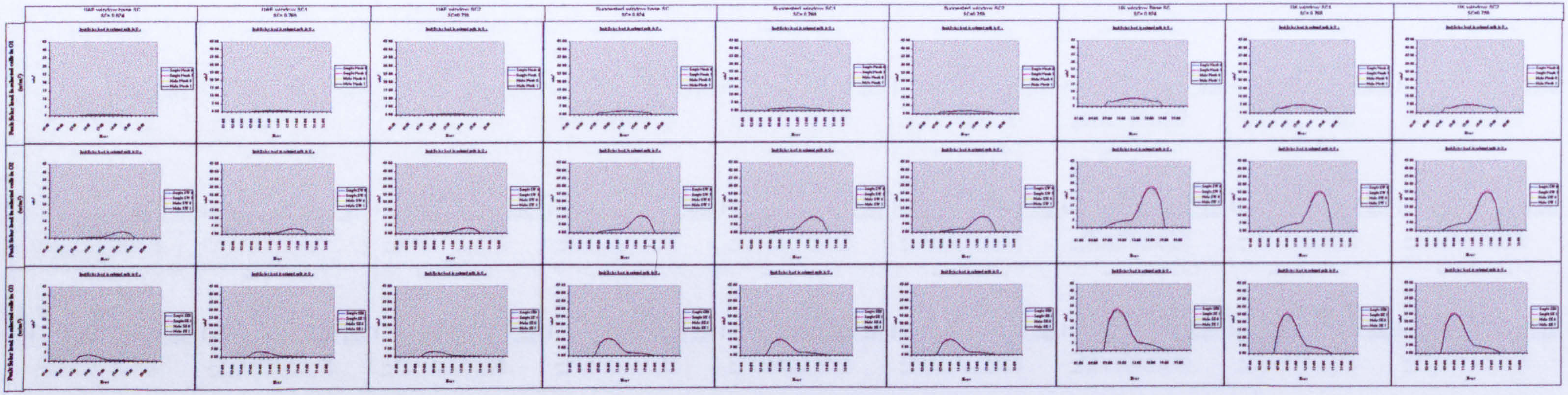
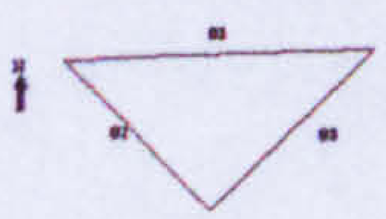


Figure 205: The impact of SC on the selected cells peak solar cooling load in the different scenarios



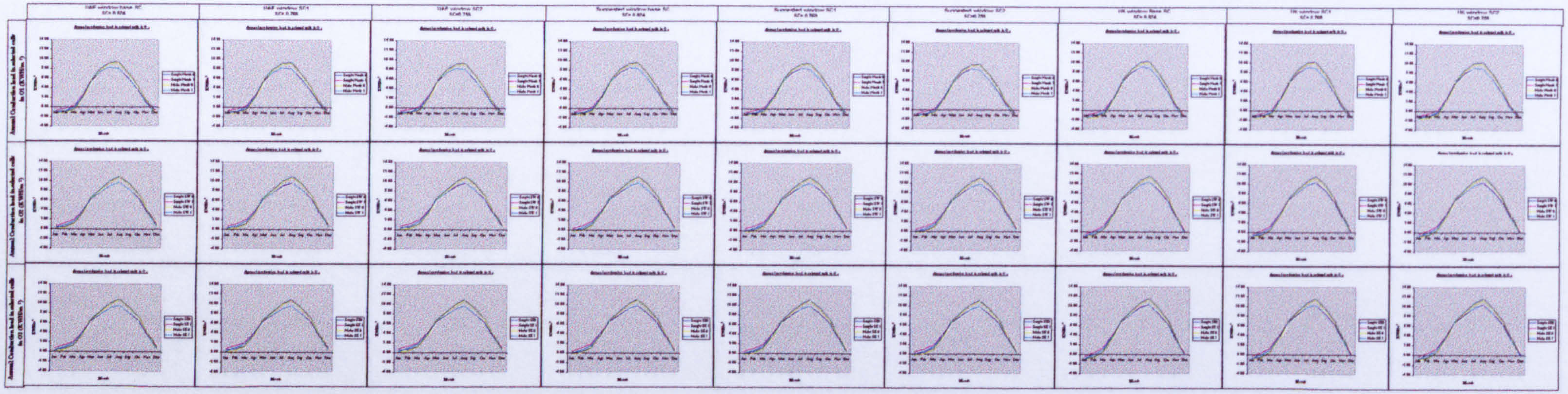


Figure 206: The impact of SC on the selected cells annual conduction cooling load in the different scenarios

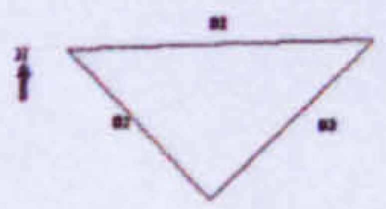
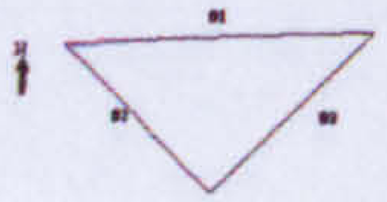


Figure 207: The impact of SC on the selected cells peak conduction cooling load in the different scenarios



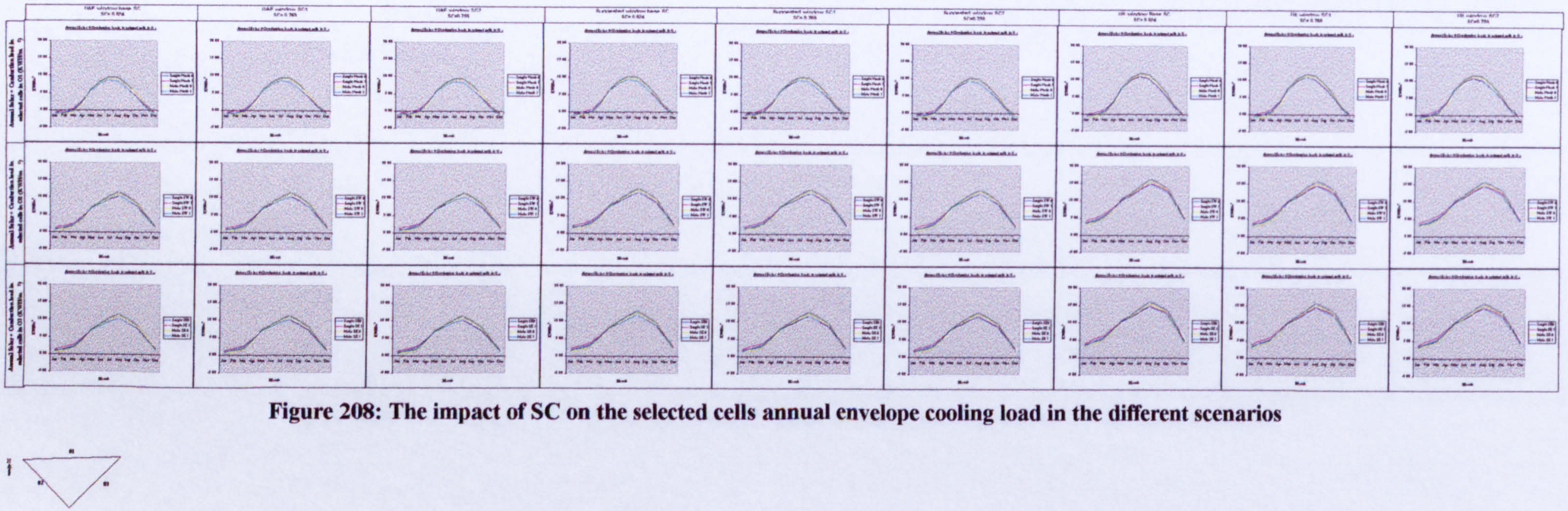


Figure 208: The impact of SC on the selected cells annual envelope cooling load in the different scenarios

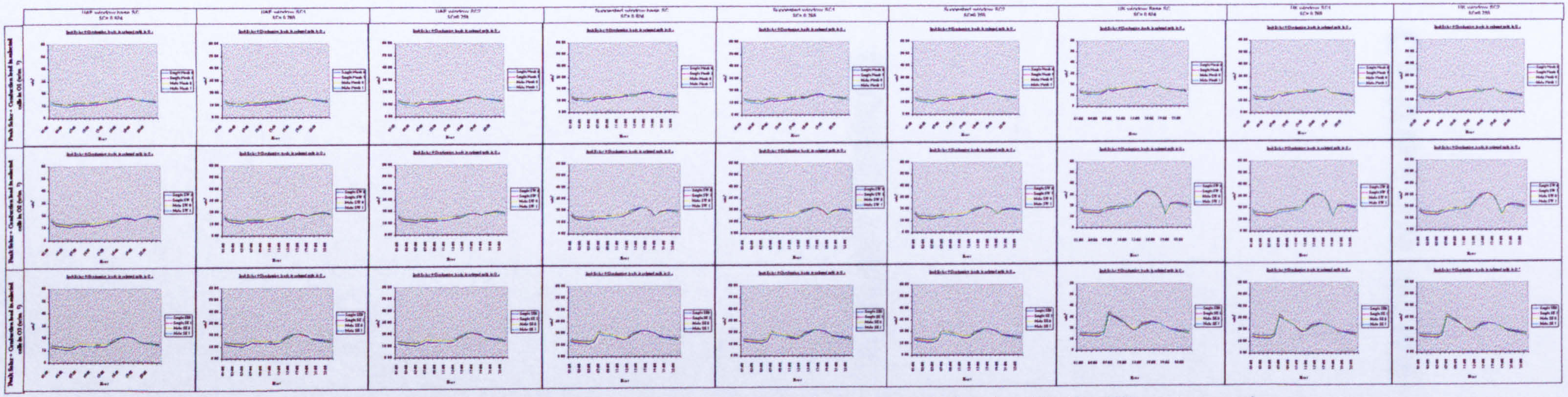
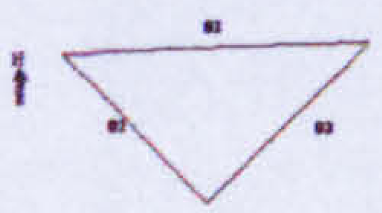
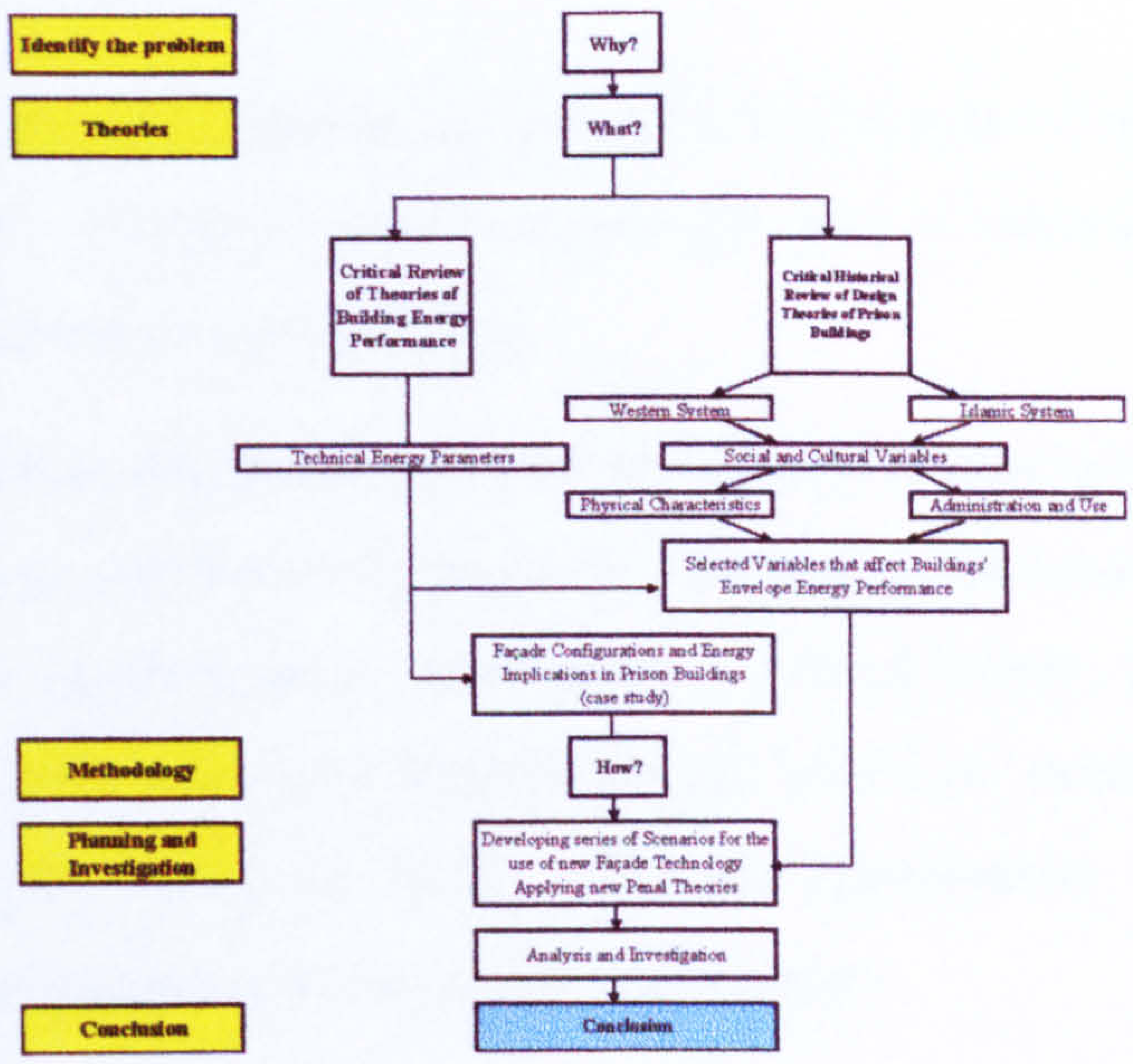


Figure 209: The impact of SC on the selected cells peak envelope cooling load in the different scenarios

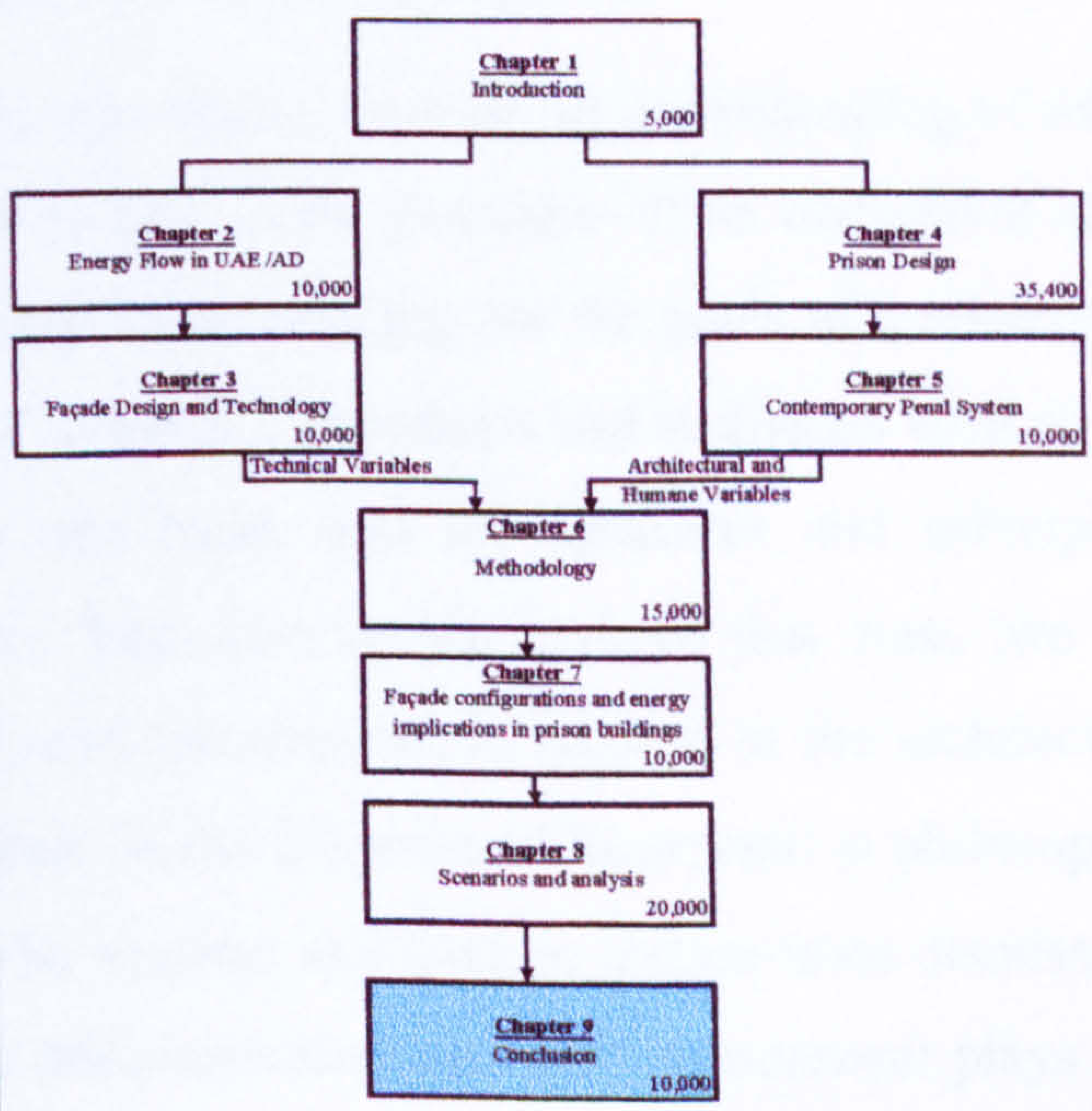


CHAPTER NINE

CONCLUSION



The Thesis Structure outline



The Thesis Chapters Outline

9 Conclusion

9.1 Introduction

It is very difficult for any society to ultimately determine adequate and humane comfort levels for the outlaws of that society. Foucault (1977) explained how contemporary societies still saw the body as an instrument or intermediary.

In modern societies, punitive practices had become more reticent. One no longer touched the body, or at least as little as possible, and then only to reach something other than the body itself. It might be objected that imprisonment, confinement, forced labour, penal servitude, prohibition from entering certain areas and deportation are 'physical' penalties; unlike fines, for example, they directly affect the body. But the punishment- body relationship is not the same as it was in torture or during public executions.

The debate has intensified in recent years, between the liberals who can see the long term benefits of rehabilitation programmes and those who adopt a more strict attitude towards criminals. The debate is not only limited to developing countries. Crimes such as child abduction, rape and similar that have high public profiles have intensified the argument. The recent global terrorist attacks have also placed the debate on the top of many government agendas in developed as well as developing countries.

This study aimed to look carefully into this debate, through an understanding of whether incarceration architecture has any role to play in the provision of an acceptable balance that ensures minimum cost to the society while carrying out the goals of a rehabilitation programme. This was not an easy task to tackle. The thesis had to discuss what could be considered as a cost to society on one hand, and the measures and principles of rehabilitation of inmates on the other. Literature review showed that these two topics were rarely discussed simultaneously, and certainly not in relation to the architecture of prisons. The latter proved more difficult, as the literature of incarceration philosophies is usually the work of social scientists who oversee, and have in certain cases dismissed, the role of architecture. This despite the admission that the built environment plays a vital role in rehabilitation programmes. The separation between the internal environment, interior architecture, and the architecture of prisons is evident in almost all contemporary prison literature. This thesis attempted to redress this balance as the other side of the equation, cost to society, is directly linked to the architecture of prisons as a whole.

Incarceration architecture is not only linked to the overall cost in monetary terms of buildings and maintenance, but also contributes to the current debate on sustainable development. The costs to society can also be measured in terms of environmental costs, level of CO_2 emission, the life cycle of buildings and the amount of energy used to maintain certain levels of comfort in prisons. Prison façades are the zones where interplay occurs between different environmental, technical, cultural and economic variables. Prison facades can provide instant indicators of the penal philosophy of the context in which they are placed. Prison facades, like those of any other building, can provide an instant indication of sensitivity to the local, cultural and climatic environment.

UAE prisons provided an extreme and excellent case for the subject of this thesis. For many years rehabilitation programmes were not considered in the UAE prisons. The prison buildings were not of high standard, and environmental conditions were not satisfactory. There were several reasons for not addressing rehabilitation more seriously. Prisoners were mainly foreigners, and were usually to be deported after finishing their sentences. The society could not see any direct benefits to investment and to re-thinking its penal philosophy. Given the change of cultural patterns in recent years and with the increase of local inmates, the society has had to shift its position. More attention is now placed on improving environmental conditions. Issues like classification of inmates, gender studies, and attention to comfort levels are more common in prison strategies. The new guideline for prison buildings are a good example of such changes. The emphasis on introducing air-conditioning to maintain a certain level of comfort is picked up by this study as a tool to discuss the complex issues of cost, sustainability and rehabilitation efforts of prisons. It was quickly realised that technical fixes for energy efficiency will not achieve the ambitious aim of rehabilitation which exists in the new thinking of the Ministry of Interior in the UAE. In-depth understanding of both social as well as technical issues is essential, for meeting the challenge raised by prison buildings.

9.2 Concluding Remarks of Different Chapters

Chapter 2 highlighted the dramatic growth and unsustainable use of electricity in the UAE. It was established that more than 80% of the electricity consumption is in buildings. This can be compared to the 50% figure for buildings in the developed Western world. The analysis of daily and monthly temperature profiles in relation to electric consumption shows a direct relationship. This explains the obvious relation with the use of air-conditioning in the city. The chapter discussed the contribution of building façades to this high level of electric consumption by air-conditioning in the UAE. It was established that the façades contribute as much as 30% of the thermal load in buildings in the UAE. This discussion was put in perspective, and was then related to prison buildings in the UAE. A brief discussion was then carried out to explain the overall situation of prison buildings in the UAE, and their data compared to other European and American standards. This provided the basis for the critique in the last section, of the current proposal for newly designed prison buildings in the UAE.

Chapter 3 explained the development of façade design generally, and in prison buildings in particular. The review identified the main variables of the building façade that have influenced development of façades in prison buildings. The output of this chapter helped to set the technical variables for a sustainable prison façade, which were closely explained and examined in Chapter 7.

Chapter 4 provided the background of all the penal theories applied throughout history in different cultures. The review aimed to give a full explanation of the social and cultural reasons that led to certain penal philosophies, and how this in turn affected the form and configuration of prison buildings. Chapter 4 also provided an insight into Islamic penal theories and their relation with contemporary rehabilitation approaches. It was quite interesting to note how many of the principles of a penal philosophy using the Islamic rehabilitation approach, are adopted in contemporary efforts.

Chapter 5 provided the philosophical background of the adoption of social concerns, as part of the developed scenarios in Chapter 8. The Chapter explored the evolution of rehabilitation approaches in the 20th Century. The discussion was extended to identify the social concerns in the contemporary prison environment. Alternative and non-custodial penology were also explored. It was clear that prisons will remain as the main penal system, for the foreseeable future. Social concerns seem to be gaining ground, despite the setbacks of the last couple of years.

Chapter 6 set out the methodological approach adopted in this study. The study leans towards the understanding of new trends in environmental studies, namely the sociology of environment, as well as the tradition of research methods of energy studies in buildings. Chapter 6 reviewed different research methods for sustainable prison design. The review examined different research methods for energy-related built environment studies in the past. The Chapter also explored the new trends in such studies and explained how social science has gained credibility in energy studies, in buildings. The failure of the prison systems in the 19th and early 20th Centuries marginalised the role of architects in the penal system. The contemporary prison systems are developed and run mainly by sociologists and criminologists, who develop the regimes that architects are requested to supply a building to fit. The later approach, however, also proved a failure. It was necessary therefore to investigate the research methods in prison design and rehabilitation strategies. The Chapter concluded with the need to establish a closer collaboration between architects and sociologists, in the early stages of development of a new imprisonment regime or philosophy.

Chapter 7 explored the methods that can be adopted to relate the identified social and technical variables that relate to the energy performance of prison facades. A set of tables were introduced that provided the boundaries for investigation. The Chapter explained the selected variables for investigation, the methods of investigation, and the reasons for selecting the APACHE tool for the investigation.

Chapter 8 explained the selected scenarios, and provided the in-depth investigation that led to a series of conclusions which are explained in the following section.

9.3 Prison Façade Design and Energy Implications

9.3.1 Introduction

Development of building facades has evolved through different stages of history. In Chapter 3, the development of different design stages was reviewed and the role of façades was highlighted in each stage. A summary of the findings is provided in Table 30. Prison design did not follow the same movement as in other building typology. The peculiarity of the nature, function and requirements of prison buildings led to a different evolution. Prison façades have evolved accordingly (Table 31). Prison façades are one of those rare architectural features where the function of the building has strongly dictated its evolution. Prisons are a type of building where the role of the operators exceeds the vision of architects. Design and configuration of prison façades also reflects the progression of penal theories in different cultures. The strong grip of social scientists and criminologists in dictating the form and spatial distribution of prison buildings has lifted slightly, in recent years. This is mainly the result of a more liberal attitude in the contemporary penal philosophy that allows 'normalisation' of the design of prison buildings, and in turn of prison façades.

In an environment which places very little constraint on the architect's design freedom, unsustainable development of the built environment flourishes. Despite all the good intentions of architects, the forces of economics, clients' self interest and fashions can dictate their decisions. Strict building regulations in certain societies, on the other hand, can result in diminishing the creativity and inspiration of building designers. So far, the UAE belongs to the first category. Large amounts of energy are consumed daily in the built environment there. Prison buildings, however, have their own micro design environment. Prison buildings belong to both the categories of design stated above; there is absolute freedom from energy codes in the UAE building regulations, while at the same time the strict rules applied by prison and penal philosophies dominate the architecture. The friction and tension between the two positions reaches its peak in the design of the prison façade. Investigation in Chapter 8 showed that facades are responsible for more than 30% of total energy flow in buildings. A required comfort level within the prison, with its large energy consumption implications, therefore requires careful consideration of the design, construction and role of facades in the prison buildings. Four areas have been identified for investigation; **Orientation, Façade Configuration, Cell Variables** and **Spatio-Temporal allocation of Activities.**

The following sections summarise the results obtained from the analysis of the case studies in Chapter 8.

Table 30: The general development of façade design

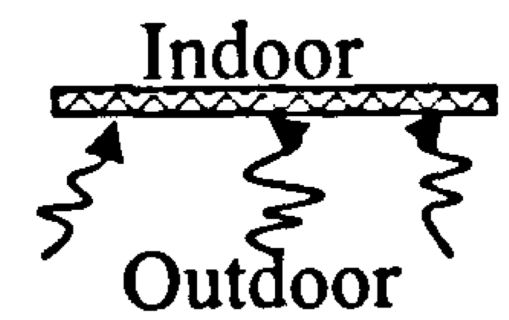
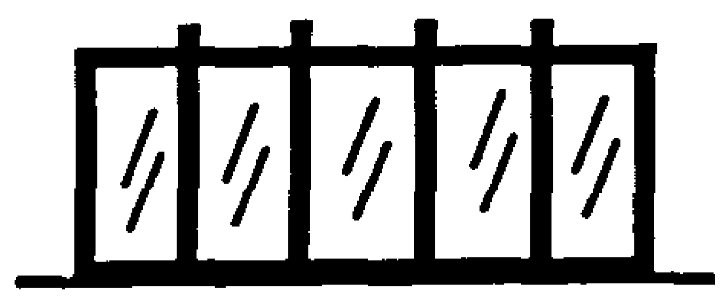
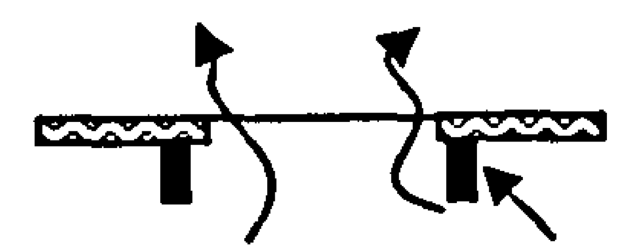
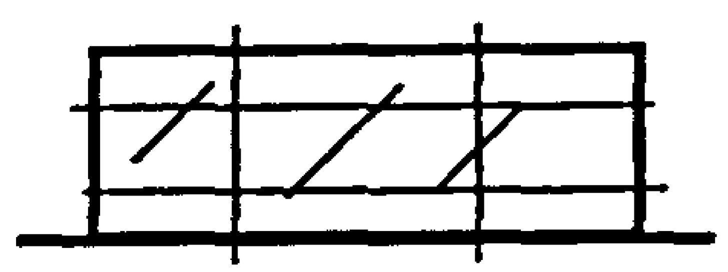
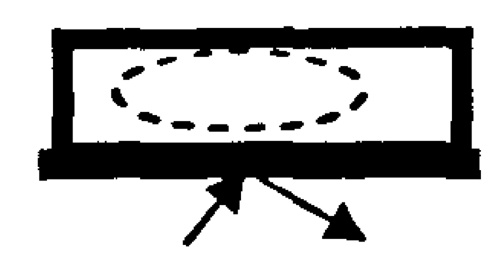
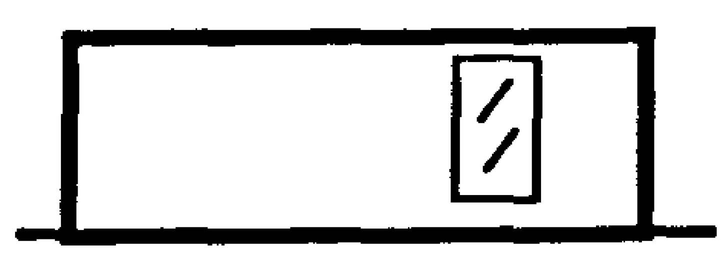
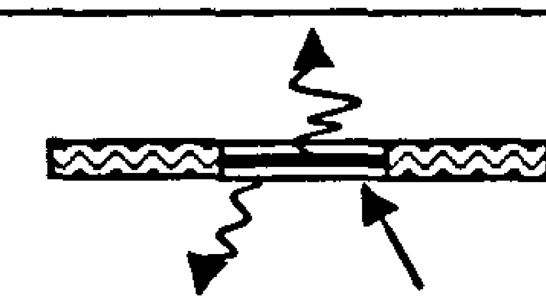
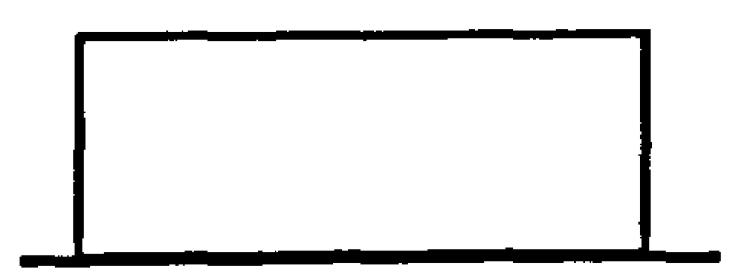
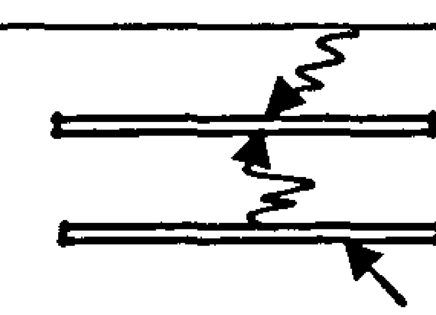
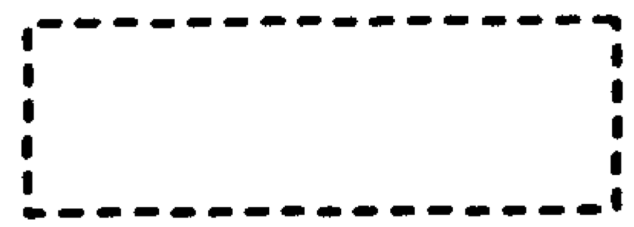
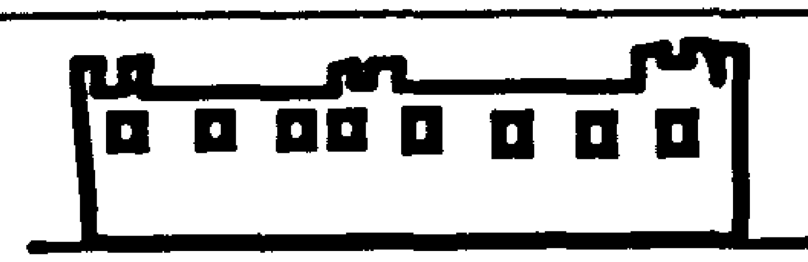
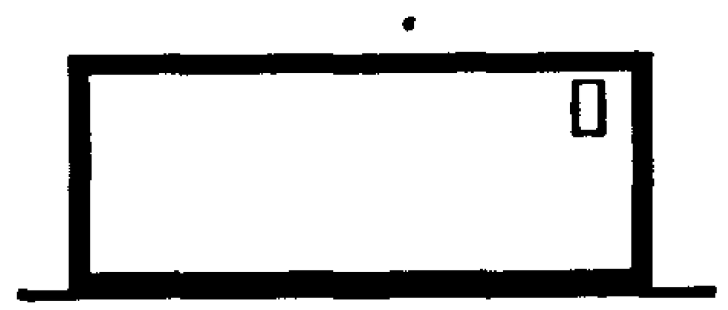
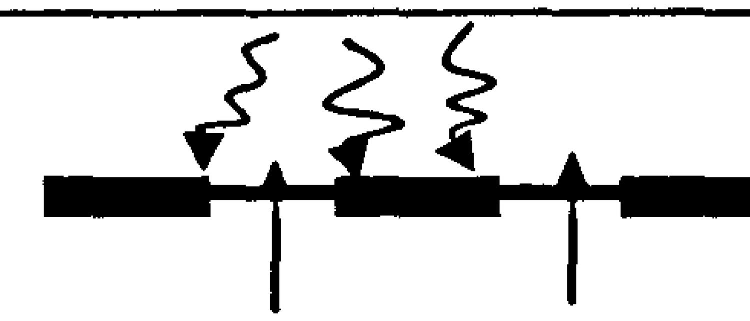
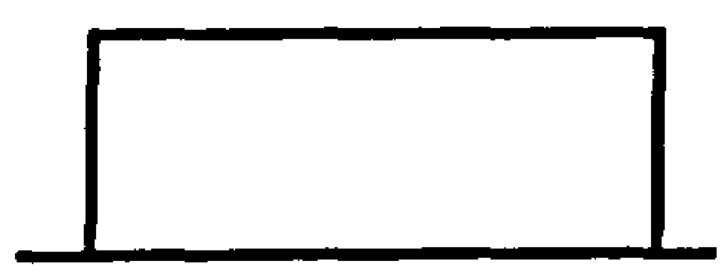
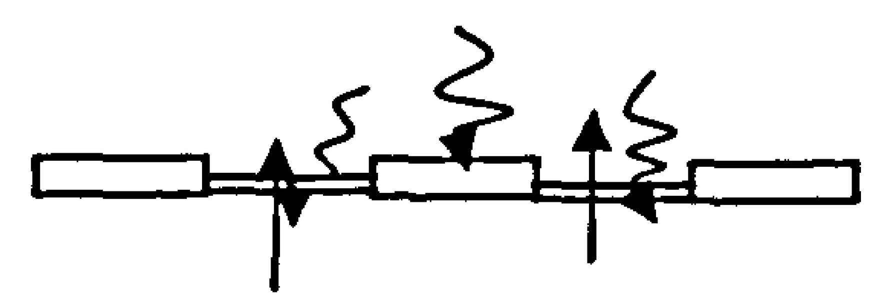
Period	Design movement		Façade role	
Before 1960		Traditional		Façade as a shield from natural forces
1960s		Structural shading devices		Façade to manipulate natural forces
1970s		Technology enabled architects to ignore natural forces		Façade as a sealed envelope
1980s		Façade related to building energy performance following the energy crises		Facades as energy systems
1990s-present		Development of technical fixes and integrate different energy measures		Theatre of interaction of different forces

Table 31: The development of prison façade design

Period	Design movement		Façade Role	
Pre-Historic prisons		No façade		Envelope as a Shield from human evil
12th-15th centuries		Fortified prisons		Façade as a deterrent tool
16th-18th centuries		House of correction		Façade as a sealed envelope
19th-early 20th century		Silence and Separation		Façade as a treatment facility
Late 20th Century- present		New generation prisons		Façade for rehabilitation: comfort and integration with society and nature

9.3.2 Orientation

The triangular shape of the housing unit, which has several advantages in minimising blind spots and providing good sightlines to the cells, tends to minimise the impact of orientation. The results showed very little sensitivity to changes in façade orientation with the base case configuration. The impact of orientation was increased slightly with the increase in window size. The base case did not provide the best orientation of the triangular housing units. Best orientation was achieved when one of the façades was facing north while the others faced south-west and south-east. Investigation of the solar and conduction thermal load of façades reveals a stronger relation to orientation. Different façades have different thermal load patterns that can be exploited to coincide with the inmates' activities throughout the day, in order to reduce the overall thermal load. It is important for any prison designer to look carefully into allocation of space to maximise the benefits of such different thermal load patterns. North and south facades should accommodate activities that are likely to extend for a long period throughout the day. Morning activities are better located away from the eastern side of the buildings, which can accommodate evening activities. The current configuration, of cells distributed in all directions, is therefore not advisable.

9.3.3 Impact of façade configuration

Investigation of the impact of façade configuration identified four areas that can affect the thermal performance of the facades. These areas are:

1. Window to Wall Ratio (WWR),
2. Fenestration Factors (FF), and
3. Selection of opaque and transparent materials (transmittance values, shading coefficient and shading devices).

A summary of results of the above variables and their implications on façade design is given below.

9.3.3.1 Window to Wall Ratio

The results showed that WWR has a major impact on the thermal performance of façades in the UAE environment, an increase as high as 25% in thermal load was obtained when large windows to the recommended UK standard were introduced. This large increase was however reduced to only 7% when the best orientation was applied. This is a relatively small increase given the benefits to the internal environment, and the social benefits of introducing relatively larger windows. The point that such increase actually shifted the peak time from August and September to October, the disadvantages of introducing larger windows become minimal. Much of the increase in the thermal load with larger windows is a result of the increase in solar radiation. This can be easily reduced by use of external shading devices. This again minimises further the impact of the introduction of the larger windows.

The analysis of the peak load in the cell zone provided further support for the application of the UK recommended WWR. The base case showed an increase in thermal load during the time that inmates remain in their cells. This is in contrast to the UK recommended scenario, where the load remains almost constant throughout the peak day. This can also be seen as further evidence of the importance of appropriate selection for the location of different activities.

9.3.3.2 Fenestration Factor

It was important to study the fenestration factor carefully, as it relates the volume of the cell to the façade configuration. Prison design guides and recommendations always refer to cell configuration. Adopting a certain recommendation will not only affect the thermal load within cells, but will change the whole envelope of the prison as the cells expand or contract. The results of simulating different scenarios highlighted the importance of the cell configuration on thermal performance of the envelope.

Results in Chapter 8 showed that cells with smaller sizes, but with larger windows can still reduce the thermal load by as much as 22% (Figure 143). The load per square metre was however slightly higher. The scenario with small size cells was based on the UK recommendation of the absolute minimum area for a single inmate. This however could be culturally unacceptable in a country with a large average house size. A more realistic scenario would be the UK recommended cell size with medium or large size windows (Scenario 5 and 6).

The above analysis, which favours the UK recommended cell with medium size windows (Scenario 5) is also supported by the analysis of the cell zone (Figure 149). Adoption of the UK minimum cell size with large windows will increase the total per square metre thermal load by approximately 25% over the base case. When scenario 5, the UK recommended cells with medium size windows, is simulated the results show only an increase of 11% per square metre while the overall consumption of the zone drops by as much as 25% (Figure 149). Very little difference is noted on analysis of peak day thermal performance.

9.3.3.3 Impact of selection of façade materials

Section 8.3.6 investigated the impact of a variety of transmittance factors for both opaque and transparent materials used in prison façades. The simulation of the prototype with the best developed orientation showed that conduction load, in general, has more impact than the solar thermal load. This led to the conclusion that the results of changing the Ug are very limited in the base case with the small size windows. The maximum difference between the lowest and highest Ug values remained under 6% for the annual thermal load, and only 2% in the peak day. As expected the difference in the cell zone is a little higher, and it requires as much as 11% change in the annual electric consumption to maintain the required comfort levels. It can be concluded that the transmittance factor of the transparent materials has very little impact on the overall thermal performance of the façade when compared to the influence of other factors. This reinforces the argument that the recommended UK cell configuration, with medium or large windows will not result in a major increase in thermal load.

Transmittance values of the opaque materials of the façade (Uo) have more impact on the total thermal load of prison buildings in UAE. Scenario 6, which is based on the UK recommended cell configuration with a medium window size, showed an actual decrease of the total annual thermal load by 5% (Figure 184). This again showed that walls with low transmittance values can compensate for the introduction of larger size windows in the UAE environment. If this is combined by external shaded devices, which are not attached to the building, such as landscape features, more savings can be achieved.

Investigation of changing the shading coefficient showed minor influence on the prison building cooling loads. The differences were however greater with larger windows. Again Scenarios 5 and 6, the UK recommended cells with medium and large size windows, provided good results; only 1% more thermal annual load than the base case.

Introduction of external shading devices also helped to reduce the gap between the UK recommended cells with medium and large windows, and the base case. The results showed a reduction in the UK recommended cells from 6% without shading devices, to 3% with external shading devices. This is despite the fact that conduction load has increased with the addition of materials to the façade in the form of those shading devices. If the structural shading devices can be separated from the structure of the building more savings may be achieved.

9.3.4 Impact of cell variables

The cell variables include the fenestration factor, area allocated per person in each cell, number of persons per cell and the elevation of cells. Impact of the fenestration factor on the thermal performance of prison façades is shown in section 9.3.3.2.

The results showed that the impact of density is very limited and negligible. No noticeable differences were obtained in different scenarios. It is interesting to note that during the peak day, the two cells showed similar thermal patterns in the peak hour(s) while the cells for four persons had better thermal profiles during all other periods. There was however noticeable variation in energy consumption between the ground and first floor cells. The differences were as much as 18% in the southwest elevations (Figure 99). Similar differences were observed under all the different scenarios, with more or less the same percentage. It was clear that changes in the reflectance factors might have some impact on the conduction load in outside cells. This was taken into consideration in the design of the new proposal.

9.3.5 Impact of activities

The results showed that the temporal profile and spatial distribution of activities can be key elements in the design of sustainable prison buildings. While different variables show different levels of contribution towards efficient thermal performance of façades, activities of inmates proved also to be rather important. Due to the harsh climatic environment in the UAE, migration within the prison throughout the day proved to be an important way to maintain required comfort levels with the least energy consumption. This is probably true for all other typologies as well. It is however necessary to look further into the allocation and spatio-temporal distribution of activities in prison due to the large volume occupied, the repetitive nature of activities, the strict profile that the system follows, and the large number of persons involved.

The results showed that morning activities that mainly take place in the association area should be located in the north facing façade. Cells which are normally occupied during the early morning, late evening and during the night should be allocated to the north and south facing façades, including the south east and south west orientation. Evening activities can be allocated to the east facing façade.

9.3.6 Building an alternative

Following the investigation in this thesis, it was important to build and test a model that comprised all the identified elements thought to produce more sustainable and energy efficient façade features. The following section provides an outline of the proposed design, and modifications made to the original prototype.

The prototype was modified to accommodate social as well as technical needs, for long term sustainability.

The best orientation result from the analysis of different scenarios in Chapter 8 has been adopted in the design for the proposal. Cells are located in the south east and south west orientation, while northerly orientation would suit all-day activities in the association areas.

Cells are designed according to the UK recommended cell sizes. The size of the cells (6.8m^2) is much smaller than the prototype (10.56m^2), but with larger windows 60x60 cm. This would meet the need for better day lighting and better views from within the cells. Smaller individual cells would improve the privacy and territorial requirements of the inmates. The smaller cell size enables the provision of extra cells. Such arrangement allowed the association area to be placed on the north façade where more windows are introduced to improve day lighting and view throughout the day. A new height of 2.4 metres is introduced, to improve the scale in individual cells. All these changes have impact on the configuration of the façades, and give a WWR of 0.067 and FF of 0.047.

A first floor association area is added, to double the number of association areas and decrease the population density in each. The reduction of the number of inmates in each association area would help to decrease the contact between inmates, enable more division by classification, improve communication with staff and improve privacy and territorial arrangements. The cost of constructing an extra level in such a large project is negligible. The new height of the association area will also give a sense of scale, and humanise this zone. Figure 210 shows the layout of the proposed scenario.

The façade materials for the proposal follow the recommendations obtained from previous analysis. The walls are constructed of brick air UF insulation l/w concrete block air gap and plaster. The overall Uo value is 0.722 W/m^2 °C. Windows are made of Low-e double glazing with an overall Ug of 1.733 W/m^2 °C and shading coefficient of 0.682.

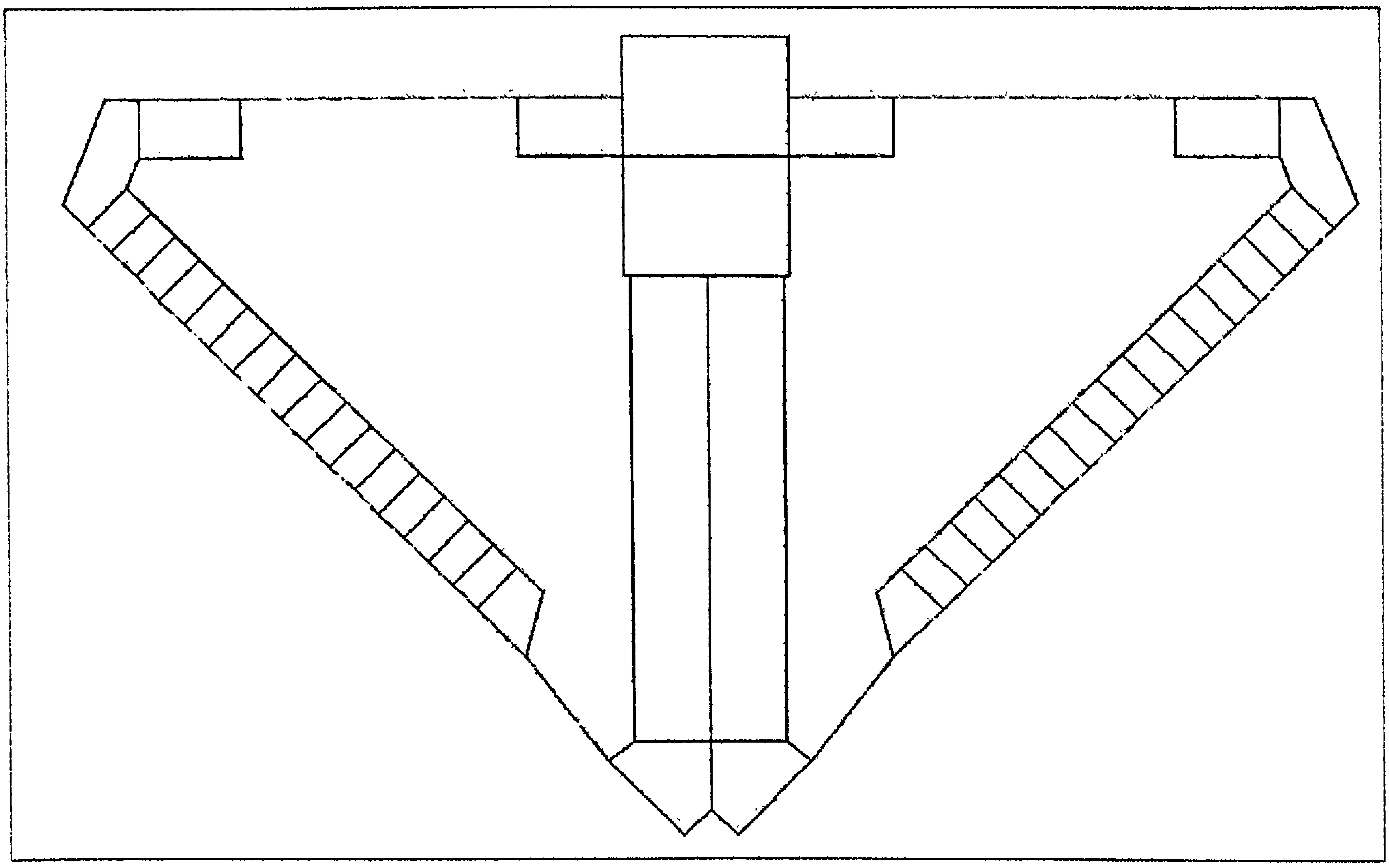


Figure 210: The proposed scenario layout

External shading devices are applied. It is recommended that the shading devices should be separate from the building structure to avoid extra conduction load on the building envelope. Previous analysis has shown that such measures can actually increase the total thermal load, due to conduction. Such measures were however difficult to implement in the software and could not be simulated.

The analysis of the selected cells in the previous chapter showed a large variation between cells on the ground floor, and those on the first floor. Changing the surrounding environment by providing grass areas can result in reduction of the thermal load. Reflectance value was therefore changed to relate to the introduction of grass around the building. The introduction of more soft landscape elements is important in increasing shading on buildings and reducing direct sunlight. Trees can also help the movement of air around the building, and thus reduce the conduction load. Again the simulation of the effects of trees around the building was not possible, and has been overlooked in this analysis. Emphasis on landscape elements with links to the interior of the prison is also important for providing a better visual and hence psychological environment.

Efforts have been made to keep the overall layout and volume of the proposal as similar as possible to the base case. Changes are made within the same 'shell' to allow meaningful comparative analysis of thermal performance. It is however believed that overall energy savings will be made with the slight reduction in the volume of the housing unit, through reduction of cell height.

Despite the introduction of large windows for rehabilitation purposes, the results show major energy savings in the proposal when compared to the base case (Figure 211). Solar gain has increased from 1.92 to 5.38 KWH/m^2 (Figure 212: A-B). This increase is very low when compared to the total reduction of conduction load from 43 to 24 KWH/m^2 (Figure 212: C-D). The total envelope load per square metre is therefore decreased by as much as 35%. This will lead to a total annual saving of 13% (Figure 212: E-F). Table 32 presents a summary of the building and the envelope annual cooling loads in the base case and the proposed scenario.

Analysis of the peak load shows interesting results. Not only did the proposal prove to be more energy efficient, it also provided a better load profile during the evening hours (Figure 211: D). The peak load per square metre is dropped from 106w/m^2 to 83 w/m^2 a reduction of 21.7%. The heavy load at 15:00 shown in the base case has almost disappeared in the new proposal. Only one peak, of 83w/m^2, appeared between 9:00 and 12:00 am. This will help with budgeting for the chillers and management of air-conditioning requirements in the prison.

Table 32: The building total and envelope loads in the base case and the proposed scenario

Load Type	Base case	Proposed scenario
Conduction gain KWH/m^2	43.15	24.09
Solar gain KWH/m^2	1.92	5.38
Total envelope heat gain KWH/m^2	45.08	29.48
Annual total cooling load KWH/m^2	143.68	124.78
Conduction load in relation to total cooling load %	30.03	19.31
Solar load in relation to total cooling load %	1.34	4.31
Envelope load in relation to total cooling load %	31.37	23.62
Relative envelope load %	100	65.39
Relative total cooling load %	100	86.84

The energy efficiency of the proposed design mentioned above, for the whole housing unit, is heightened when the cell zone is investigated separately. Figure 213: A-B shows an overall reduction of 92.4 KW in the peak day, a 50% reduction in the overall energy consumption. This is also shown in the total annual energy consumption in the cell zone. A reduction of 42.5% is achieved with the proposed design (Figure 213: E-F).

The price given of providing a more humane environment in the association areas was not as high as the savings gained in the cell zone. Annual energy consumption in the association areas is increased by 30% in the proposed design (Figure 214). This has to be seen within the context of the advantages gained for the rehabilitation programme, as well as the saving of 42.5% in the cell zone.

In summary the proposed design would provide a much better environment, accompanied by major energy savings. The envelope of the proposal offers an overall 35% reduction from the base case. It is important to note that all the analyses are based on the simulation of one housing unit. The prototype contains 12 housing units, and the energy savings can be of great importance. It is also important to note that this thesis has only dealt with variables that are façade related. More investigation of other aspects that constitute the thermal flow patterns within the building would be of great benefit.

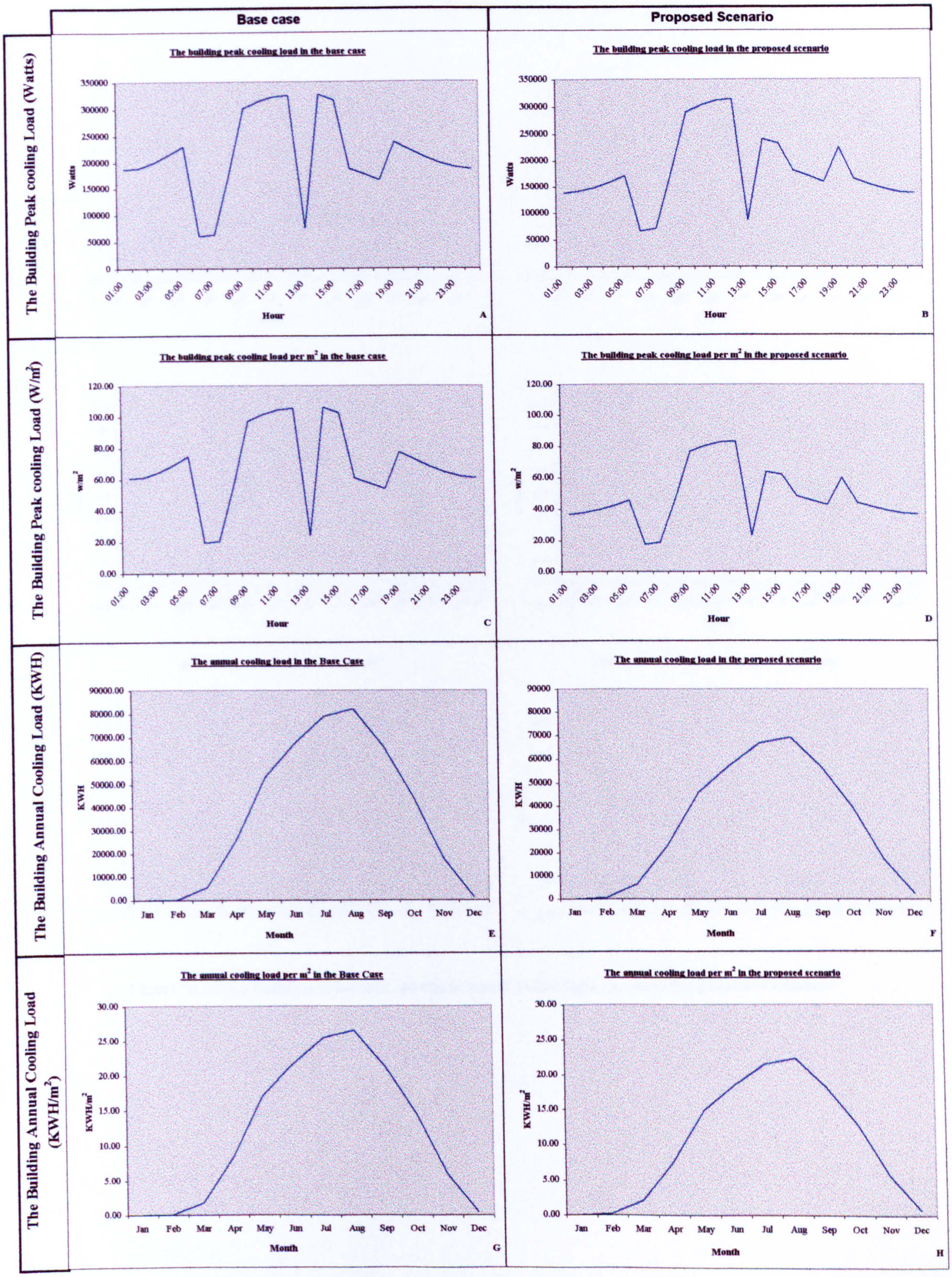


Figure 211: The building total and per square metre cooling loads in the base case and the proposed scenario

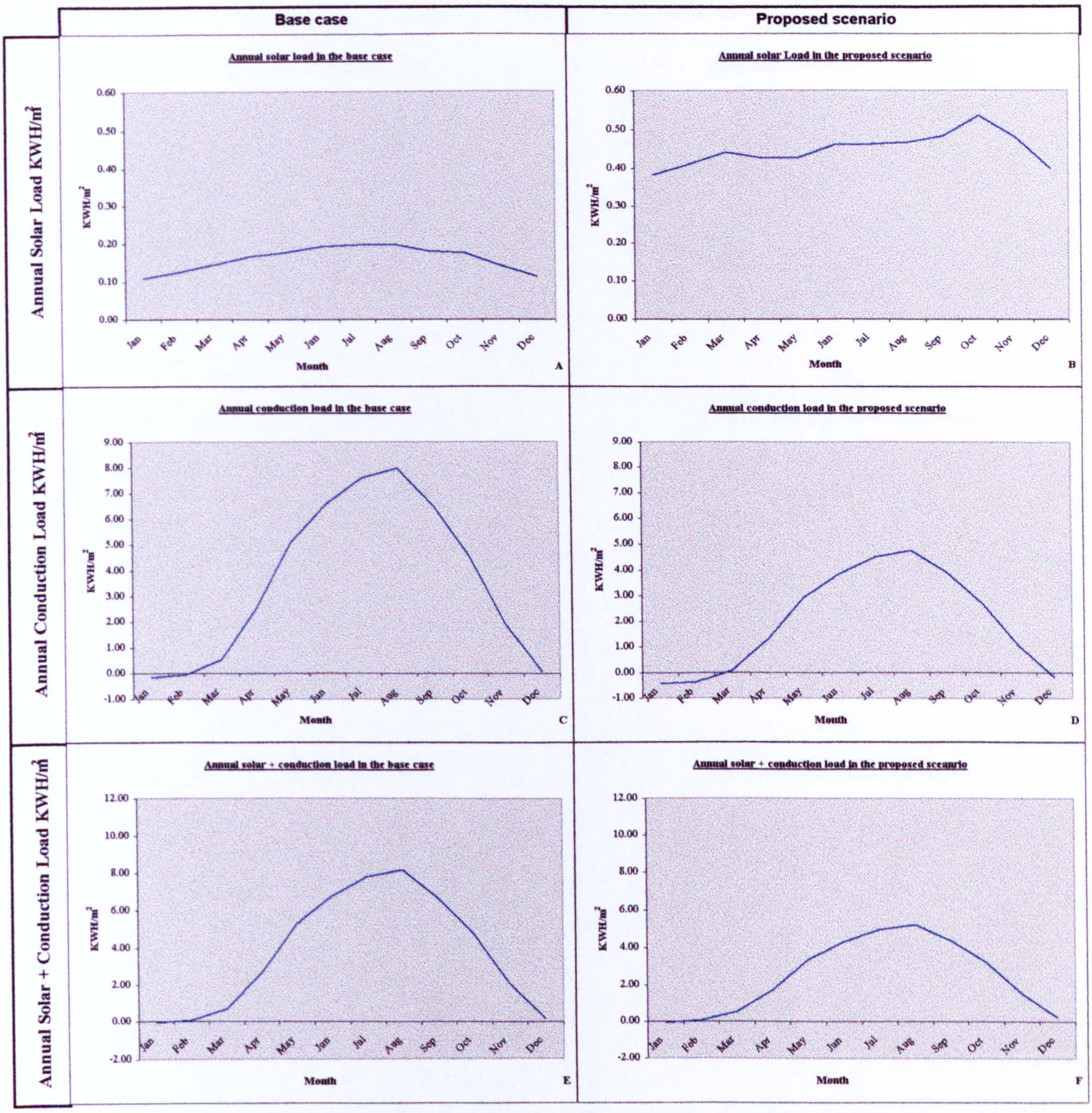


Figure 212: The building solar and conduction load in the base case and the proposed scenario

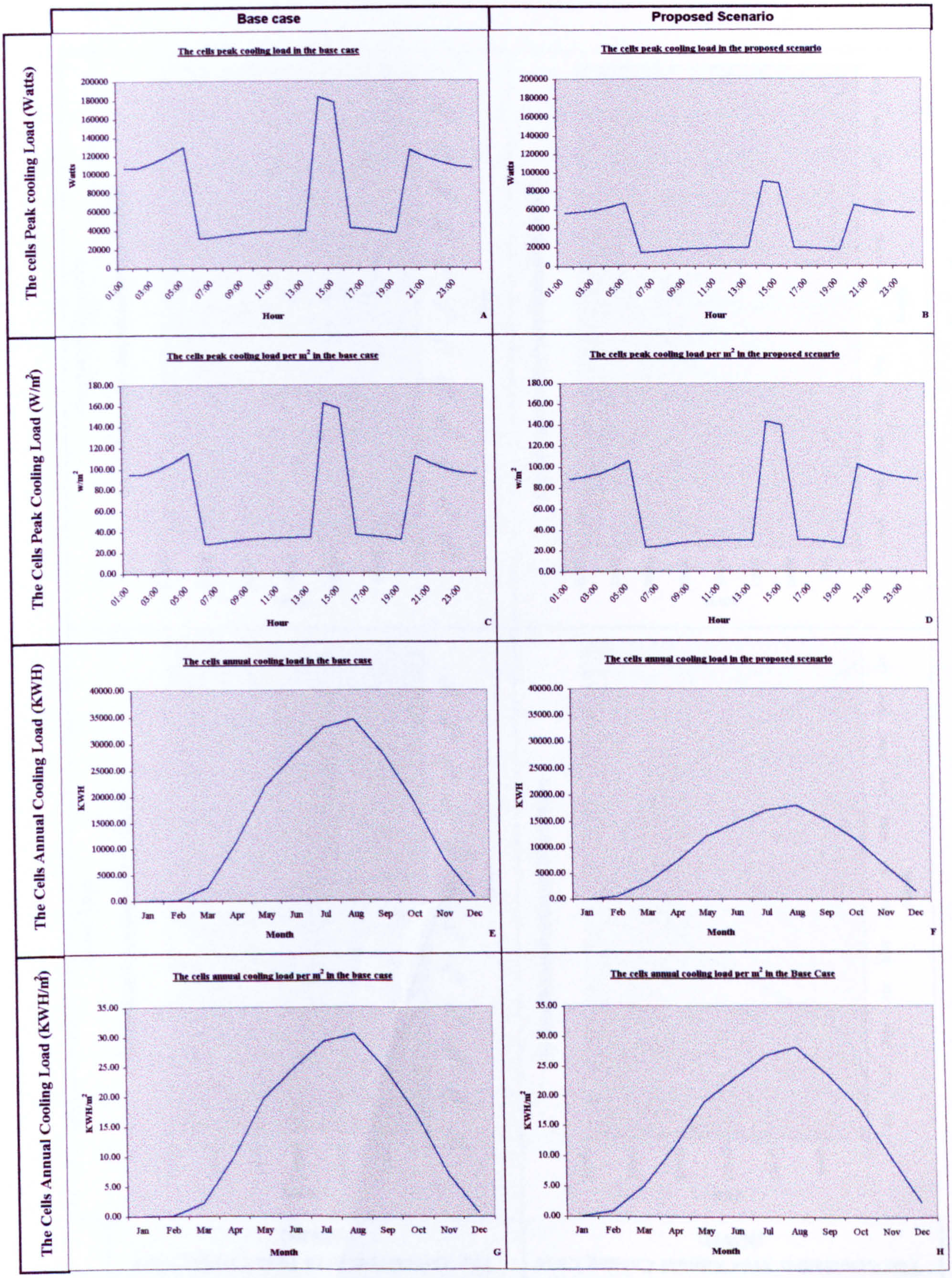


Figure 213: The cells total and per square metre cooling loads in the base case and the proposed scenario

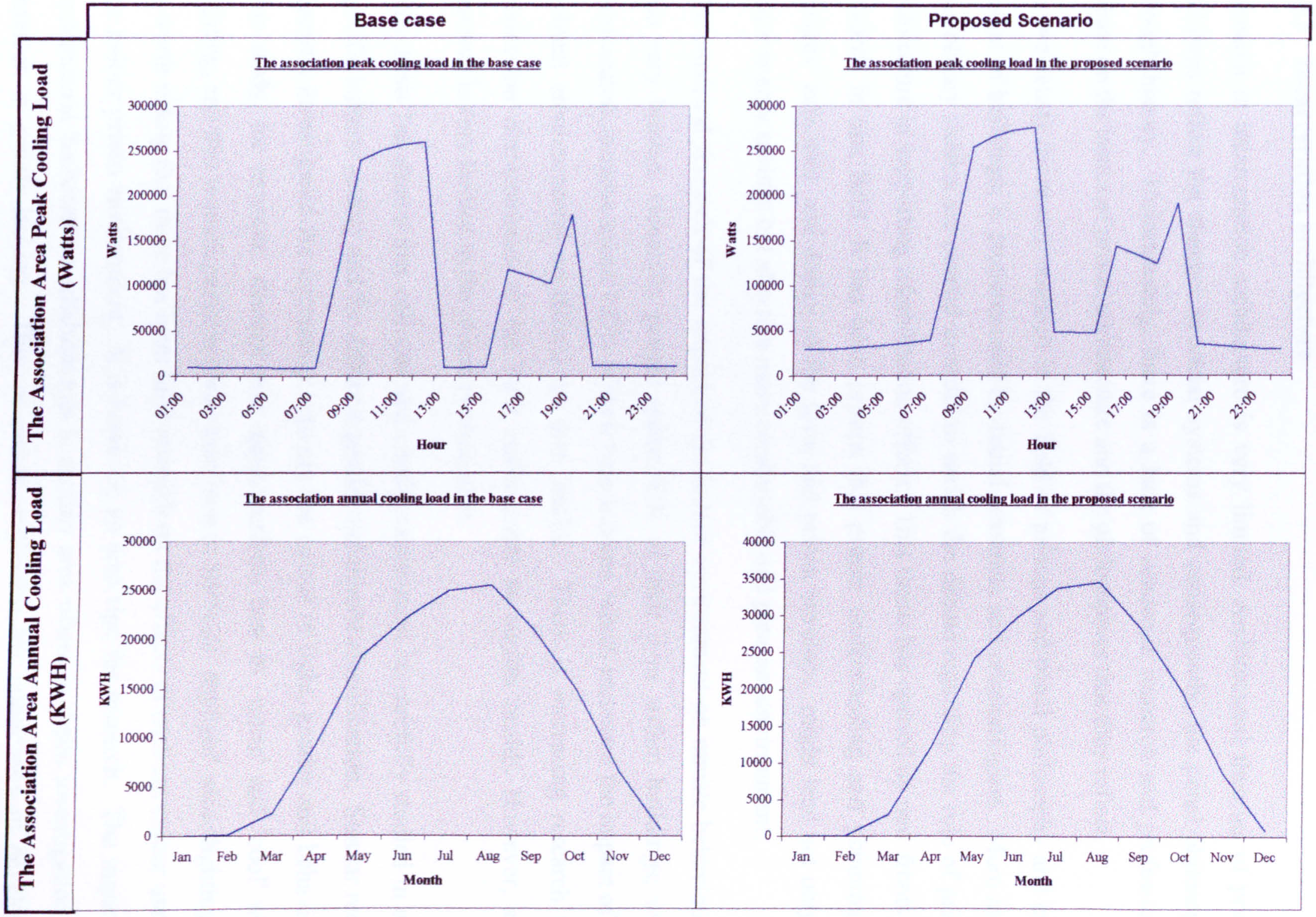


Figure 214: The association area peak and annual cooling loads in the base case and the proposed scenario

9.4 Recommendations for Future Research

9.4.1 Incarceration architecture

Research in incarceration architecture is very limited. Architectural theories of prison buildings reflect the changes in social systems and consequently, the penal philosophy through history. Unfortunately, there is a lack of academic research and professional debate on the issues of prison architecture and the philosophies that they reflect.

As previously discussed, research in the field of prisons and penal philosophy and even design of buildings, is predominated by social scientists and criminologists. More multi disciplinary studies are needed in order to enrich the debate regarding the role of prison architecture in supporting rehabilitation efforts. This thesis has opened up new fronts for research in this field. It has been proven that proper understanding and planning of inmates' activities, and design of the form and prison envelope, might lead not only to major energy savings but also to a more comfortable and pleasant environment.

The empirical research of the impact of the indoor environment on inmate behaviour is also very limited. Generally people spend 90% of their lives within buildings; when incarcerated, inmates spend 100% of their time indoors, which increases the impact of the ambient environmental conditions on their health. There is increasing research that relates the characteristics of the built environment to human health. However, such research is very limited in the prison environment.

This thesis has shown that cell size and configuration must be carefully studied in each specific cultural setting and for different gender and inmate classification. Similar recent research investigated the interaction between the colour of light, gender and behaviour. One study, for example, showed that males perform best in `warm' and `cool' white lighting, and that women perform better than men in artificial `daylight' white lighting. It is worth noting that there has been little research on the effects of ambient colour used in the indoor prison environment. It is however, an area ripe for research. The impact of architectural decisions on rehabilitation is another area where in-depth investigation and research is greatly lacking. This, of course, highlights the importance of developing appropriate indicators that measure the success of rehabilitation programmes. Unlike productivity as an indicator of the success of environmental conditions in office buildings, rehabilitation programmes have yet to produce some definite indicators.

9.4.2 Energy studies in prison buildings

Several types of building have been scrutinised for their thermal performance. This includes school, hospitals, office buildings and many others. Prison buildings have not received the same attention, despite their large population and continuous growth. The impact of daylight and windows in commercial and residential buildings has been studied extensively. It is very ironic that such an important element lacks any empirical research in an environment that is used to influence people and modify their behaviour, i.e. the prison environment. Several studies have related sensory deprivation resulting from the minimising of windows and access to a view, to high rates of stress and consequently cases of suicide among inmates. However, the recent emphasis on the importance of providing daylight in prison buildings is related to theoretical research founded upon general knowledge, with no significant empirical research which addresses the complicated prison environment.

9.4.3 Thermal performance of prison facades

Prisons have a very specific list of construction materials that can be used for the construction and finishing of the envelope. In general, such constraints limit the freedom of the designer of prison buildings. This thesis, however, has shown that reducing the overall thermal load might not be the answer to energy efficient design. Major factors such as spatial allocation of different activities and inmates' temporal programmes are also important. This thesis was however limited to testing the cell zone area. More overall research that would include all other activities would be most valuable.

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Appendix One: Prison life vs. a full-time Job

- In prison you spend the majority of your time in an 8' X 10' cell. At work you spend most of your time in a 6' X 8' cubicle.
- In prison you get three meals a day. At work you only get a break for one meal and you have to pay for that one.
- In prison you get time off for good behaviour. At work you get rewarded for good behaviour with more work.
- At work you must carry around a security card and unlock and open all the doors yourself. In prison a guard locks and unlocks all the doors for you.
- In prison you can watch TV and play games. At work you get fired for watching TV and playing games.
- In prison they ball-and-chain you when you go somewhere. At work you are just ball-and-chained.
- In prison you get your own room. At work you have to share.
- In prison they allow your family and friends to visit. At work you cannot even speak to your family and friends.
- In prison all expenses are paid by taxpayers, with no work required. At work you get to pay all the expenses to go to work and then they deduct taxes from your salary to pay for the prisoners.
- In prison you spend most of your life looking through bars from the inside wanting to get out. At work you spend most of your time wanting to get out and inside bars.
- In prison you can join many programs which you can leave at any time. At work there are some programs you can never get out of.
- In prison there are wardens who are often sadistic. At work we have managers.

Appendix Two: Sample of the analysis tables

Date	Building total	Total/ m²	solar gain	solar/m²	conduction gain	Conduction/m²	Solar+Conduction/m²	Association	OTHER	Cells	Cells / m²
	Base case										
Jan	1.00	0 00	337.8	0.11	-530 3	-0.17	-0 06	0	0	1.00	0 00
Feb	214 60	0 07	384	0.12	-125.3	-0.04	0 08	93 8	13 4	107.40	0.10
Mar	5523 60	1.79	445 4	0.14	1639 6	0 53	0 68	2321.7	591 6	2610.30	2 31
Apr	25947.00	8 41	516	0.17	7715	2.50	2 67	9504 6	5167.2	11275 20	9 99
May	53130.30	17.22	547.2	0.18	15744 4	5.10	5.28	18390 4	12658 4	22081 50	19 57
Jun	67189.10	21.77	597.2	0.19	20329 4	6 59	6 78	22230.6	16987.3	27971.20	24.79
Jul	78887.40	25.56	610	0 20	23478 8	7 61	7 81	25037.3	20749 8	33100 30	29 34
Aug	82030 00	26 58	612	0 20	24628 7	7 98	8 18	25617	21863 3	34549 70	30 62
Sep	66080 90	21.41	559 2	0.18	20110.5	6 52	6 70	21030 7	17159 8	27890 40	24 72
Oct	44814 10	14 52	543 8	0.18	14083.3	4 56	4 74	14942 4	10711 6	19160 10	16 98
Nov	18151.70	5 88	439 6	0.14	5874 8	1 90	2 05	6644 6	3452 6	8054 50	7 14
Dec	1420 80	0 46	346 4	0.11	216.8	0 07	0.18	635 4	121 7	663 70	0 59
Summed total	443390 6	143 68	5940.3	1 92	133162 9	43 15	45 08	146448 6	109477.3	187464 70	166 17
AREA	3085 9							1009 12	948 6	1128 18	
kwh/m²	143 68							145 13	115 41	166 17	

Date	Building total	Total/ m²	solar gain	solar/m²	conduction gain	Conduction/m²	Solar+Conduction/m²	Association	OTHER	Cells	Cells / m²
	Second Orientation										
Jan	2.2	0.00	364 8	0.12	-422 9	-0 14	-0.02	0	0	2 20	0 00
Feb	222.1	0.07	394 6	0.13	-26 8	-0 01	0 12	89 2	2 8	130.10	0.12
Mar	5404.3	1.75	405.2	0.13	1574.5	0.51	0 64	2323 8	566.7	2513 80	2 23
Apr	25510 2	8.27	417.8	0.14	7374 6	2.39	2 53	9505.2	5139 8	10865 20	9 63
May	52594 9	17.04	453	0.15	15300 6	4 96	5.11	18345 8	12651 4	21597.70	19.14
Jun	66612.4	21.59	511 4	0.17	19837.6	6.43	6 59	22166 9	16994	27451.50	24 33
Jul	78280.1	25 37	512.2	0.17	22966 8	7.44	7.61	24973.5	20751	32555 60	28 86
Aug	81413 2	26.38	487.2	0.16	24134 3	7.82	7.98	25580.3	21846	33986 90	30.13
Sep	65718.8	21.30	464.8	0.15	19842.3	6.43	6.58	21049.4	17137.8	27531.60	24.40
Oct	44753.3	14.50	516.2	0.17	14051.2	4.55	4.72	15028.9	10677.8	19046 60	16 88
Nov	18284.3	5.93	466.2	0.15	5989.2	1.94	2.09	6733 6	3417.7	8133.00	7.21
Dec	1503.1	0.49	382	0.12	356.3	0.12	0 24	640.8	106.1	756.20	0.67
Summed total	440298.9	142.68	5370 8	1.74	130978 8	42 44	44 18	146437.2	109291.5	184570.20	163 60
AREA	3085.9							1009.12	948.6	1128.18	
kwh/m²	142 68							145.11	115 21	163 60	

First Orientation										
Building total	Total/ m²	solar gain	solar/m2	conduction gain	Conduction/m2	Solar+Conduction/m²	Association	OTHER	Cells	Cells / m²
1.1	0.00	379.6	0.12	-375.3	-0.12	0.00	0.00	0	1.10	0.00
200.4	0.06	403.4	0.13	-25.8	-0.01	0.12	82.30	2.2	115.90	0.10
5343	1.73	415.4	0.13	1502.7	0.49	0.62	2303.60	565.4	2474.00	2.19
25231	8.18	382.4	0.12	7128.6	2.31	2.43	9512.70	5144.4	10573.90	9.37
52182.5	16.91	354.2	0.11	14986.6	4.86	4.97	18352.50	12655.6	21174.40	18.77
66108.1	21.42	356.8	0.12	19486.9	6.31	6.43	22161.80	17003.4	26942.90	23.88
77781	25.21	370.8	0.12	22606.3	7.33	7.45	24976.60	20757.4	32047.00	28.41
80988.2	26.24	412.2	0.13	23784.7	7.71	7.84	25598.60	21847	33542.60	29.73
65491.9	21.22	458.2	0.15	19622	6.36	6.51	21074.20	17132.9	27284.80	24.18
44688.7	14.48	532.2	0.17	13971.1	4.53	4.70	15053.10	10665.2	18970.40	16.82
18337.1	5.94	486.6	0.16	6027.3	1.95	2.11	6754.00	3401.4	8181.70	7.25
1481.8	0.48	402.2	0.13	407.7	0.13	0.26	636.8	101.6	743.40	0.66
437835.1	141.88	4961.2	1.61	129117.8	41.84	43.45	146506.10	109276.9	182052.10	161.37
3085.9							1009.12	948.6	1128.18	
141.88							145.18	115.20	161.37	

Third Orientation										
Building total	Total/ m²	solar gain	solar/m²	conduction gain	Conduction/m²	Solar+Conduction/m²	Association	OTHER	Cells	Cells / m²
2	0.00	362.80	0.12	-409.4	-0.13	-0.02	0	0	2.00	0.00
207.1	0.07	384.40	0.12	-39.9	-0.01	0.11	82.8	7.1	117.20	0.10
5393.8	1.75	405.00	0.13	1575.7	0.51	0.64	2314.1	577.1	2502.60	2.22
25512.5	8.27	418.40	0.14	7377.4	2.39	2.53	9495.9	5147.8	10868.80	9.63
52591.2	17.04	452.40	0.15	15296.7	4.96	5.10	18344	12652.1	21595.10	19.14
66614	21.59	514.00	0.17	19838.3	6.43	6.60	22165.7	16994.7	27453.60	24.33
78275.8	25.37	511.20	0.17	22963.9	7.44	7.61	24975.1	20750.5	32550.20	28.85
81410.3	26.38	486.60	0.16	24132.1	7.82	7.98	25581.9	21845.4	33983.00	30.12
65725.5	21.30	466.00	0.15	19847.5	6.43	6.58	21056.4	17134.3	27534.80	24.41
44754	14.50	516.00	0.17	14051.3	4.55	4.72	15030.1	10677.2	19046.70	16.88
18271	5.92	461.40	0.15	5979.8	1.94	2.09	6729.1	3421.7	8120.20	7.20
1475.2	0.48	382.00	0.12	359.1	0.12	0.24	626.1	111.3	737.80	0.65
440232.4	142.66	5362.00	1.74	130970.7	42.44	44.18	146401.1	109319.8	184511.50	163.55
3085.9							1009.12	948.6	1128.18	
142.66							145.08	115.24	163.55	

Peak Total Building Loads

Natural and Mechanical Ventilation On
Total Number of Rooms: 162
Total Floor Area: 3085.9 m^2
Total Volume: 12285.0 m^3

	Base case							
	Total building		Associations	OTHER	Cells		Total b
Load Type	Peak Cool (W/m^2)	Peak Cool (W/m^2)	Peak Cool (W/m^2)	Peak Cool (W/m^2)	Peak Cool (W/m^2)		Peak Cool (W/m^2)
Sensible	15.14	60.28					14.97
Latent	11.6	46.19					11.6
Total	26.68	106.2	257.33	141.66	162.81		26.51
Local Time Local Time	Total Cooling (Watts)	Total Cooling/ m^2 (Watts/ m^2)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Cell load/m^2 (Watts/ m^2)	Total Cooling (Watts)
01:00	187366	60.72	10054	70570	106742	94.61	185361
02:00	188869	61.20	9154	72534	107181	95.00	187875
03:00	199231	64.56	8994	77374	112863	100.04	198210
04:00	213337	69.13	8854	83908	120575	106.88	212300
05:00	230197	74.60	8736	91722	129739	115.00	229203
06:00	60782	19.70	8627	20755	31400	27.83	59801
07:00	63533	20.59	8540	21956	33037	29.28	62577
08:00	175239	56.79	116783	23214	35242	31.24	173919
09:00	300345	97.33	239044	24382	36919	32.72	298994
10:00	313634	101.63	250073	25373	38188	33.85	312389
11:00	322271	104.43	257137	26096	39038	34.60	321125
12:00	325727	105.55	259681	26511	39535	35.04	324762
13:00	75416	24.44	9157	26613	39646	35.14	74462
14:00	327711	106.20	9652	134382	183677	162.81	325626
15:00	317077	102.75	10143	129020	177914	157.70	314587
16:00	187930	60.90	118771	26696	42463	37.64	185431
17:00	178166	57.74	111147	25686	41333	36.64	175958
18:00	166511	53.96	103058	24304	39149	34.70	164782
19:00	238749	77.37	179007	22920	36822	32.64	237555
20:00	224642	72.80	11438	86895	126309	111.96	223624
21:00	210221	68.12	11442	80134	118645	105.16	208705
22:00	199059	64.51	11338	74984	112737	99.93	197027
23:00	191518	62.06	11068	71588	108862	96.49	189077

24:00	187696	60.82	10639	70157	106900	94.75	185263
MAX PEAK	327711		259681	134382	183677	162.81	325626
AREA	3085.9		1009.12	948.6	1128.18		3085.9
PEAK/M²	106.20		257.33	141.66	162.81		105.52

Load Type	Second Orientation						
	Total building		Associations	OTHER	Cells		Total b
	Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)		Peak Cool (W/m²)
Sensible	15.03	59.83					15.05
Latent	11.6	46.19					11.6
Total	26.56	105.74	257.29	141.42	161.50		26.58
Local Time Local Time	Total Cooling (Watts)	Total Cooling/ m² (Watts/ m²)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Cell load/m² (Watts/ m²)	Total Cooling (Watts)
01:00	186276	60.36	9531	70802	105943	93.91	186076
02:00	188294	61.02	9105	72540	106649	94.53	188300
03:00	198647	64.37	8938	77377	112332	99.57	198640
04:00	212753	68.94	8794	83900	120059	106.42	212732
05:00	229615	74.41	8676	91692	129247	114.56	229610
06:00	60212	19.51	8573	20726	30913	27.40	60199
07:00	62983	20.41	8500	21966	32517	28.82	62990
08:00	174499	56.55	116736	23239	34524	30.60	174542
09:00	299588	97.08	238997	24409	36182	32.07	299563
10:00	312914	101.40	250028	25399	37487	33.23	312810
11:00	321612	104.22	257093	26111	38408	34.04	321432
12:00	325176	105.37	259641	26513	39022	34.59	325046
13:00	74864	24.26	9116	26594	39154	34.71	74868
14:00	326315	105.74	9962	134154	182199	161.50	326580
15:00	315409	102.21	10505	128703	176201	156.18	315591
16:00	186394	60.40	119126	26358	40910	36.26	186362
17:00	176987	57.35	111469	25360	40158	35.60	176746
18:00	165792	53.73	103300	24050	38442	34.07	165365
19:00	238259	77.21	179097	22765	36397	32.26	237961
20:00	223825	72.53	11361	86873	125591	111.32	224299
21:00	209116	67.76	11176	80255	117685	104.31	209578
22:00	197713	64.07	10889	75177	111647	98.96	197998
23:00	189980	61.56	10477	71828	107675	95.44	190087
24:00	186276	60.36	10008	70426	105842	93.82	186180
MAX PEAK	326315		259641	134154	182199	161.50	326580
AREA	3085.9		1009.12	948.6	1128.18		3085.9
PEAK/M²	105.74		257.29	141.42	161.50		105.83

First Orientation				
uilding	Associations	OTHER	Cells	
Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	
59.61				
46.19				
105.52	257.30	141.54	160.91	
Total Cooling/ m^2 (Watts/ m^2)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Cell load/m^2 (Watts/ m^2)
60.07	9737	70741	104883	92.97
60.88	9115	72524	106236	94.17
64.23	8947	77364	111899	99.19
68.80	8802	83891	119607	106.02
74.27	8682	91688	128833	114.20
19.38	8578	20722	30501	27.04
20.28	8508	21952	32117	28.47
56.36	116742	23221	33956	30.10
96.89	239001	24391	35602	31.56
101.23	250035	25385	36969	32.77
104.06	257101	26102	37922	33.61
105.24	259650	26509	38603	34.22
24.13	9117	26590	38755	34.35
105.52	9819	134267	181540	160.91
101.94	10371	128839	175377	155.45
60.09	119011	26500	39920	35.38
57.02	111365	25511	39082	34.64
53.40	103219	24168	37395	33.15
76.98	179080	22782	35693	31.64
72.47	11412	86832	125380	111.13
67.63	11305	80191	117209	103.89
63.85	11098	75077	110852	98.26
61.27	10744	71709	106624	94.51

60.04	10278	70323	104662	92.77
	259650	134267	181540	160.91
	1009.12	948.6	1128.18	
	257.30	141.54	160.91	

Third Orientation				
uilding	Associations	OTHER	Cells	
Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	Peak Cool (W/m²)	
59.92				
46.19				
105.83	257.29	141.61	161.90	
Total Cooling/ m² (Watts/ m²)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Heat Gains: Net Plant Output (W)	Cell load/m² (Watts/ m²)
60.30	9875	70637	105564	93.57
61.02	9115	72521	106664	94.55
64.37	8949	77363	112328	99.57
68.94	8804	83889	120039	106.40
74.41	8685	91696	129229	114.55
19.51	8579	20730	30890	27.38
20.41	8503	21941	32546	28.85
56.56	116742	23197	34603	30.67
97.07	239000	24366	36197	32.08
101.37	250029	25359	37422	33.17
104.16	257092	26082	38258	33.91
105.33	259640	26501	38905	34.48
24.26	9114	26596	39158	34.71
105.83	9604	134329	182647	161.90
102.27	10090	128942	176559	156.50
60.39	118737	26614	41011	36.35
57.28	111158	25623	39965	35.42
53.59	103104	24266	37995	33.68
77.11	179032	22854	36075	31.98
72.69	11445	86841	126013	111.70
67.91	11391	80106	118081	104.67
64.16	11208	74974	111816	99.11
61.60	10866	71595	107626	95.40
60.33	10418	70196	105566	93.57
	259640	134329	182647	161.90
	1009.12	948.6	1128.18	
	257.29	141.61	161.90	

Room: SSST0000: Association (Peak=August)
Area: 504.56 m²
Volume: 3027.36 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)	
01.00	28.55	23	24.09	23.54	70	-5052	0	-5052	10054
02.00	29.27	23	23.99	23.5	70	-4561	0	-4561	9154
03.00	30.42	23	23.98	23.49	70	-4482	0	-4482	8994
04.00	31.92	23	23.96	23.48	70	-4414	0	-4414	8854
05.00	33.67	23	23.95	23.48	70	-4358	0	-4358	8736
06.00	35.55	23	23.94	23.47	70	-4305	0	-4305	8627
07.00	37.43	23	23.93	23.46	70	-4258	0	-4258	8540
08.00	39.17	23	24.03	23.52	70	-30937	-27443	-58380	116783
09.00	40.68	23	24.13	23.56	70	-62200	-57311	-119511	239044
10.00	41.83	23	24.14	23.57	70	-65751	-59274	-125025	250073
11.00	42.55	23	24.15	23.58	70	-68003	-60554	-128557	257137
12.00	42.8	23	24.16	23.58	70	-68829	-61000	-129829	259681
13.00	42.55	23	23.99	23.5	70	-4567	0	-4567	9157
14.00	41.83	23	24.04	23.52	70	-4814	0	-4814	9652
15.00	40.68	23	24.09	23.54	70	-5059	0	-5059	10143
16.00	39.17	23	24.22	23.61	70	-31930	-27443	-59373	118771
17.00	37.43	23	24.25	23.62	70	-29437	-26125	-55562	111147
18.00	35.55	23	24.27	23.64	70	-26699	-24819	-51518	103058
19.00	33.67	23	24.38	23.69	70	-42231	-47244	-89475	179007
20.00	31.92	23	24.2	23.6	70	-5637	0	-5637	11438
21.00	30.42	23	24.2	23.6	70	-5642	0	-5642	11442
22.00	29.27	23	24.19	23.6	70	-5615	0	-5615	11338
23.00	28.55	23	24.17	23.58	70	-5512	0	-5512	11068
24.00	28.3	23	24.14	23.57	70	-5329	0	-5329	10639

Room: CRRD0000: corridor (Peak=August)
Area: 65.80 m²
Volume: 197.40 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	24.46	23.73	70	-2175	-2947	-5122
02.00	29.27	23	24.38	23.69	70	-2284	-2999	-5283
03.00	30.42	23	24.34	23.67	70	-2522	-3086	-5608
04.00	31.92	23	24.31	23.66	70	-2845	-3209	-6054
05.00	33.67	23	24.28	23.64	70	-3227	-3364	-6591
06.00	35.55	23	24.26	23.63	70	-1159	-507	-1666
07.00	37.43	23	24.25	23.62	70	-1215	-535	-1750
08.00	39.17	23	24.25	23.62	70	-1273	-564	-1837
09.00	40.68	23	24.26	23.63	70	-1330	-590	-1920
10.00	41.83	23	24.28	23.64	70	-1382	-611	-1993
11.00	42.55	23	24.31	23.66	70	-1424	-625	-2049
12.00	42.8	23	24.34	23.67	70	-1456	-630	-2086
13.00	42.55	23	24.38	23.69	70	-1476	-625	-2101
14.00	41.83	23	24.77	23.88	70	-5468	-4279	-9747
15.00	40.68	23	24.86	23.93	70	-5269	-4129	-9398
16.00	39.17	23	24.88	23.94	70	-1728	-564	-2292
17.00	37.43	23	24.89	23.94	70	-1679	-535	-2214
18.00	35.55	23	24.84	23.92	70	-1575	-507	-2082
19.00	33.67	23	24.74	23.87	70	-1447	-481	-1928
20.00	31.92	23	24.69	23.84	70	-3122	-3209	-6331
21.00	30.42	23	24.66	23.83	70	-2755	-3086	-5841
22.00	29.27	23	24.62	23.81	70	-2456	-2999	-5455
23.00	28.55	23	24.56	23.78	70	-2248	-2947	-5195
24.00	28.3	23	24.52	23.76	70	-2156	-2930	-5086

Room: STR_0002: Store (Peak=August)
Area: 65.80 m²
Volume: 197.40 m³
Month: August (Peak)

Room: SSST0001: Association (Peak=August)
Area: 504.56 m²
Volume: 3027.36 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	24.07	23.54	70	-5002	0	-5002
02.00	29.27	23	24	23.5	70	-4593	0	-4593
03.00	30.42	23	23.98	23.49	70	-4512	0	-4512
04.00	31.92	23	23.97	23.48	70	-4440	0	-4440
05.00	33.67	23	23.95	23.48	70	-4378	0	-4378
06.00	35.55	23	23.94	23.47	70	-4322	0	-4322
07.00	37.43	23	23.94	23.47	70	-4282	0	-4282
08.00	39.17	23	24.03	23.52	70	-30960	-27443	-58403
09.00	40.68	23	24.13	23.56	70	-62222	-57311	-119533
10.00	41.83	23	24.14	23.57	70	-65774	-59274	-125048
11.00	42.55	23	24.15	23.58	70	-68026	-60554	-128580
12.00	42.8	23	24.16	23.58	70	-68852	-61000	-129852
13.00	42.55	23	23.99	23.5	70	-4590	0	-4590
14.00	41.83	23	24.04	23.52	70	-4838	0	-4838
15.00	40.68	23	24.09	23.54	70	-5084	0	-5084
16.00	39.17	23	24.22	23.61	70	-31955	-27443	-59398
17.00	37.43	23	24.25	23.62	70	-29460	-26125	-55585
18.00	35.55	23	24.27	23.64	70	-26721	-24819	-51540
19.00	33.67	23	24.39	23.7	70	-42288	-47244	-89532
20.00	31.92	23	24.23	23.62	70	-5801	0	-5801
21.00	30.42	23	24.22	23.61	70	-5800	0	-5800
22.00	29.27	23	24.21	23.6	70	-5723	0	-5723
23.00	28.55	23	24.18	23.59	70	-5556	0	-5556
24.00	28.3	23	24.13	23.56	70	-5310	0	-5310

Room: CRRD0001: corridor (Peak=August)
Area: 65.80 m²
Volume: 197.40 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	24.35	23.68	70	-2110	-2947	-5057
02.00	29.27	23	24.24	23.62	70	-2199	-2999	-5198
03.00	30.42	23	24.19	23.6	70	-2431	-3086	-5517
04.00	31.92	23	24.15	23.58	70	-2749	-3209	-5958
05.00	33.67	23	24.11	23.56	70	-3127	-3364	-6491
06.00	35.55	23	24.09	23.54	70	-1055	-507	-1562
07.00	37.43	23	24.08	23.54	70	-1110	-535	-1645
08.00	39.17	23	24.08	23.54	70	-1169	-564	-1733
09.00	40.68	23	24.1	23.55	70	-1230	-590	-1820
10.00	41.83	23	24.12	23.56	70	-1287	-611	-1898
11.00	42.55	23	24.16	23.58	70	-1335	-625	-1960
12.00	42.8	23	24.2	23.6	70	-1374	-630	-2004
13.00	42.55	23	24.25	23.62	70	-1402	-625	-2027
14.00	41.83	23	24.69	23.84	70	-5431	-4279	-9710
15.00	40.68	23	24.82	23.91	70	-5258	-4129	-9387
16.00	39.17	23	24.87	23.94	70	-1738	-564	-2302
17.00	37.43	23	24.9	23.95	70	-1703	-535	-2238
18.00	35.55	23	24.85	23.92	70	-1606	-507	-2113
19.00	33.67	23	24.76	23.88	70	-1478	-481	-1959
20.00	31.92	23	24.7	23.85	70	-3148	-3209	-6357
21.00	30.42	23	24.66	23.83	70	-2772	-3086	-5858
22.00	29.27	23	24.6	23.8	70	-2458	-2999	-5457
23.00	28.55	23	24.51	23.76	70	-2230	-2947	-5177
24.00	28.3	23	24.43	23.72	70	-2115	-2930	-5045

Room: STR_0013: Store (Peak=August)
Area: 30.00 m²
Volume: 90.00 m³
Month: August (Peak)

Room: STR_0027: Store (Peak=August)
Area: 30.00 m²
Volume: 90.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	24.89	23.94	70	-1269	-1344	-2613
02:00	29.27	23	24.71	23.86	70	-1272	-1367	-2639
03:00	30.42	23	24.65	23.82	70	-1370	-1407	-2777
04:00	31.92	23	24.6	23.8	70	-1507	-1463	-2970
05:00	33.67	23	24.55	23.78	70	-1672	-1534	-3206
06:00	35.55	23	24.52	23.76	70	-724	-231	-955
07:00	37.43	23	24.51	23.76	70	-746	-244	-990
08:00	39.17	23	24.52	23.76	70	-775	-257	-1032
09:00	40.68	23	24.54	23.77	70	-806	-269	-1075
10:00	41.83	23	24.57	23.78	70	-836	-279	-1115
11:00	42.55	23	24.61	23.8	70	-863	-285	-1148
12:00	42.8	23	24.66	23.83	70	-888	-287	-1175
13:00	42.55	23	24.72	23.86	70	-911	-285	-1196
14:00	41.83	23	25.09	24.04	70	-2754	-1951	-4705
15:00	40.68	23	25.28	24.14	70	-2710	-1883	-4593
16:00	39.17	23	25.39	24.2	70	-1133	-257	-1390
17:00	37.43	23	25.45	24.22	70	-1131	-244	-1375
18:00	35.55	23	25.43	24.22	70	-1094	-231	-1325
19:00	33.67	23	25.36	24.18	70	-1037	-219	-1256
20:00	31.92	23	25.28	24.14	70	-1785	-1463	-3248
21:00	30.42	23	25.18	24.09	70	-1589	-1407	-2996
22:00	29.27	23	25.15	24.08	70	-1454	-1367	-2821
23:00	28.55	23	25.09	24.04	70	-1353	-1344	-2697
24:00	28.3	23	25	24	70	-1290	-1336	-2626

Room: STR_0025: Store (Peak=August)
Area: 120.56 m²
Volume: 361.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	23.6	23.3	70	-2876	-5399	-8275
02:00	29.27	23	23.58	23.29	70	-3152	-5495	-8647
03:00	30.42	23	23.57	23.28	70	-3629	-5654	-9283
04:00	31.92	23	23.56	23.28	70	-4254	-5879	-10133
05:00	33.67	23	23.55	23.28	70	-4984	-6163	-11147
06:00	35.55	23	23.54	23.27	70	-1209	-928	-2137
07:00	37.43	23	23.54	23.27	70	-1314	-980	-2294
08:00	39.17	23	23.54	23.27	70	-1420	-1033	-2453
09:00	40.68	23	23.54	23.27	70	-1514	-1081	-2595
10:00	41.83	23	23.54	23.27	70	-1589	-1120	-2709
11:00	42.55	23	23.55	23.28	70	-1641	-1145	-2786
12:00	42.8	23	23.56	23.28	70	-1666	-1154	-2820
13:00	42.55	23	23.57	23.28	70	-1667	-1145	-2812
14:00	41.83	23	23.6	23.3	70	-8507	-7840	-16347
15:00	40.68	23	23.63	23.32	70	-8059	-7566	-15625
16:00	39.17	23	23.66	23.33	70	-1580	-1033	-2613
17:00	37.43	23	23.68	23.34	70	-1505	-980	-2485
18:00	35.55	23	23.69	23.34	70	-1406	-928	-2334
19:00	33.67	23	23.7	23.35	70	-1306	-880	-2186
20:00	31.92	23	23.7	23.35	70	-4446	-5879	-10325
21:00	30.42	23	23.7	23.35	70	-3802	-5654	-9456
22:00	29.27	23	23.68	23.34	70	-3292	-5495	-8787
23:00	28.55	23	23.66	23.33	70	-2955	-5399	-8354
24:00	28.3	23	23.63	23.32	70	-2817	-5368	-8185

Room: STR_0022: Store (Peak=August)
Area: 120.56 m²
Volume: 361.68 m³
Month: August (Peak)

Room: STR_0028: Store (Peak=August)
Area: 30.00 m²
Volume: 90.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	24.79	23.9	70	-1241	-1344	-2585
02:00	29.27	23	24.59	23.8	70	-1233	-1367	-2600
03:00	30.42	23	24.52	23.76	70	-1328	-1407	-2735
04:00	31.92	23	24.46	23.73	70	-1462	-1463	-2925
05:00	33.67	23	24.41	23.7	70	-1624	-1534	-3158
06:00	35.55	23	24.38	23.69	70	-674	-231	-905
07:00	37.43	23	24.36	23.68	70	-697	-244	-941
08:00	39.17	23	24.37	23.68	70	-726	-257	-983
09:00	40.68	23	24.39	23.7	70	-758	-269	-1027
10:00	41.83	23	24.43	23.72	70	-792	-279	-1071
11:00	42.55	23	24.48	23.74	70	-821	-285	-1106
12:00	42.8	23	24.54	23.77	70	-850	-287	-1137
13:00	42.55	23	24.62	23.81	70	-879	-285	-1164
14:00	41.83	23	25.03	24.02	70	-2741	-1951	-4692
15:00	40.68	23	25.25	24.12	70	-2710	-1883	-4593
16:00	39.17	23	25.39	24.2	70	-1142	-257	-1399
17:00	37.43	23	25.46	24.23	70	-1146	-244	-1390
18:00	35.55	23	25.44	24.22	70	-1109	-231	-1340
19:00	33.67	23	25.36	24.18	70	-1048	-219	-1267
20:00	31.92	23	25.29	24.14	70	-1803	-1463	-3266
21:00	30.42	23	25.19	24.1	70	-1602	-1407	-3009
22:00	29.27	23	25.14	24.07	70	-1461	-1367	-2828
23:00	28.55	23	25.06	24.03	70	-1349	-1344	-2693
24:00	28.3	23	24.94	23.97	70	-1274	-1336	-2610

Room: STR_0026: Store (Peak=August)
Area: 20.79 m²
Volume: 62.38 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	24.94	23.97	70	-938	-931	-1869
02:00	29.27	23	24.43	23.72	70	-835	-948	-1783
03:00	30.42	23	24.38	23.69	70	-904	-975	-1879
04:00	31.92	23	24.32	23.66	70	-997	-1014	-2011
05:00	33.67	23	24.25	23.62	70	-1104	-1063	-2167
06:00	35.55	23	24.23	23.62	70	-446	-160	-606
07:00	37.43	23	24.2	23.6	70	-459	-169	-628
08:00	39.17	23	24.2	23.6	70	-477	-178	-655
09:00	40.68	23	24.22	23.61	70	-498	-186	-684
10:00	41.83	23	24.25	23.62	70	-520	-193	-713
11:00	42.55	23	24.29	23.64	70	-540	-198	-738
12:00	42.8	23	24.35	23.68	70	-558	-199	-757
13:00	42.55	23	24.4	23.7	70	-572	-198	-770
14:00	41.83	23	24.52	23.76	70	-1780	-1352	-3132
15:00	40.68	23	24.62	23.81	70	-1726	-1305	-3031
16:00	39.17	23	24.7	23.85	70	-628	-178	-806
17:00	37.43	23	24.77	23.88	70	-631	-169	-800
18:00	35.55	23	24.82	23.91	70	-625	-160	-785
19:00	33.67	23	24.89	23.94	70	-627	-152	-779
20:00	31.92	23	25.02	24.01	70	-1209	-1014	-2223
21:00	30.42	23	25.15	24.08	70	-1138	-975	-2113
22:00	29.27	23	25.23	24.12	70	-1077	-948	-2025
23:00	28.55	23	25.24	24.12	70	-1027	-931	-1958
24:00	28.3	23	25.16	24.08	70	-985	-926	-1911

Room: STR_0023: Store (Peak=August)
Area: 20.79 m²
Volume: 62.38 m³
Month: August (Peak)

Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	23.74	23.37	70	-1649	-2947	-4596
02:00	29.27	23	23.74	23.37	70	-1815	-2999	-4814
03:00	30.42	23	23.74	23.37	70	-2079	-3086	-5165
04:00	31.92	23	23.73	23.36	70	-2423	-3209	-5632
05:00	33.67	23	23.73	23.36	70	-2825	-3364	-6189
06:00	35.55	23	23.73	23.36	70	-767	-507	-1274
07:00	37.43	23	23.72	23.36	70	-826	-535	-1361
08:00	39.17	23	23.72	23.36	70	-883	-564	-1447
09:00	40.68	23	23.72	23.36	70	-931	-590	-1521
10:00	41.83	23	23.72	23.36	70	-968	-611	-1579
11:00	42.55	23	23.72	23.36	70	-992	-625	-1617
12:00	42.8	23	23.72	23.36	70	-1000	-630	-1630
13:00	42.55	23	23.72	23.36	70	-994	-625	-1619
14:00	41.83	23	23.72	23.36	70	-4707	-4279	-8986
15:00	40.68	23	23.72	23.36	70	-4442	-4129	-8571
16:00	39.17	23	23.73	23.36	70	-886	-564	-1450
17:00	37.43	23	23.73	23.36	70	-831	-535	-1366
18:00	35.55	23	23.73	23.36	70	-768	-507	-1275
19:00	33.67	23	23.74	23.37	70	-714	-481	-1195
20:00	31.92	23	23.74	23.37	70	-2430	-3209	-5639
21:00	30.42	23	23.75	23.38	70	-2086	-3086	-5172
22:00	29.27	23	23.75	23.38	70	-1821	-2999	-4820
23:00	28.55	23	23.75	23.38	70	-1653	-2947	-4600
24:00	28.3	23	23.75	23.38	70	-1597	-2930	-4527

Room: STR_0014: Store (Peak=August)
Area: 120.56 m²
Volume: 361.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	23.71	23.36	70	-2992	-5399	-8391
02:00	29.27	23	23.71	23.36	70	-3297	-5495	-8792
03:00	30.42	23	23.71	23.36	70	-3783	-5654	-9437
04:00	31.92	23	23.71	23.36	70	-4416	-5879	-10295
05:00	33.67	23	23.7	23.35	70	-5154	-6163	-11317
06:00	35.55	23	23.7	23.35	70	-1384	-928	-2312
07:00	37.43	23	23.7	23.35	70	-1490	-980	-2470
08:00	39.17	23	23.69	23.34	70	-1595	-1033	-2628
09:00	40.68	23	23.69	23.34	70	-1684	-1081	-2765
10:00	41.83	23	23.69	23.34	70	-1752	-1120	-2872
11:00	42.55	23	23.69	23.34	70	-1795	-1145	-2940
12:00	42.8	23	23.69	23.34	70	-1810	-1154	-2964
13:00	42.55	23	23.69	23.34	70	-1799	-1145	-2944
14:00	41.83	23	23.7	23.35	70	-8603	-7840	-16443
15:00	40.68	23	23.7	23.35	70	-8115	-7566	-15681
16:00	39.17	23	23.7	23.35	70	-1601	-1033	-2634
17:00	37.43	23	23.7	23.35	70	-1499	-980	-2479
18:00	35.55	23	23.7	23.35	70	-1384	-928	-2312
19:00	33.67	23	23.71	23.36	70	-1276	-880	-2156
20:00	31.92	23	23.71	23.36	70	-4418	-5879	-10297
21:00	30.42	23	23.71	23.36	70	-3788	-5654	-9442
22:00	29.27	23	23.72	23.36	70	-3302	-5495	-8797
23:00	28.55	23	23.72	23.36	70	-2996	-5399	-8395
24:00	28.3	23	23.72	23.36	70	-2895	-5368	-8263

Room: STR_0017: Store (Peak=August)
Area: 65.80 m²
Volume: 197.40 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time	Outside Air	Inside Air	Inside	Comfort	Saturation	Heat Gains:	Heat Gains:	Heat Gains:

Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	24.87	23.94	70	-1264	-1344	-2608
02:00	29.27	23	24.67	23.84	70	-1255	-1367	-2622
03:00	30.42	23	24.61	23.8	70	-1354	-1407	-2761
04:00	31.92	23	24.56	23.78	70	-1492	-1463	-2955
05:00	33.67	23	24.51	23.76	70	-1656	-1534	-3190
06:00	35.55	23	24.49	23.74	70	-708	-231	-939
07:00	37.43	23	24.47	23.74	70	-730	-244	-974
08:00	39.17	23	24.48	23.74	70	-759	-257	-1016
09:00	40.68	23	24.5	23.75	70	-790	-269	-1059
10:00	41.83	23	24.53	23.76	70	-821	-279	-1100
11:00	42.55	23	24.57	23.78	70	-847	-285	-1132
12:00	42.8	23	24.62	23.81	70	-872	-287	-1159
13:00	42.55	23	24.66	23.84	70	-893	-285	-1178
14:00	41.83	23	25.18	24.09	70	-2790	-1951	-4741
15:00	40.68	23	25.28	24.14	70	-2710	-1883	-4593
16:00	39.17	23	25.28	24.14	70	-1090	-257	-1347
17:00	37.43	23	25.27	24.14	70	-1056	-244	-1300
18:00	35.55	23	25.19	24.1	70	-995	-231	-1226
19:00	33.67	23	25.15	24.08	70	-952	-219	-1171
20:00	31.92	23	25.09	24.04	70	-1708	-1463	-3171
21:00	30.42	23	25.08	24.04	70	-1547	-1407	-2954
22:00	29.27	23	25.07	24.04	70	-1420	-1367	-2787
23:00	28.55	23	25.03	24.02	70	-1329	-1344	-2673
24:00	28.3	23	24.97	23.98	70	-1278	-1336	-2614

Room: STR_0016: Store (Peak=August)
Area: 20.79 m²
Volume: 62.38 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01:00	28.55	23	25.07	24.04	70	-970	-931	-1901
02:00	29.27	23	24.53	23.76	70	-859	-948	-1807
03:00	30.42	23	24.49	23.74	70	-930	-975	-1905
04:00	31.92	23	24.44	23.72	70	-1026	-1014	-2040
05:00	33.67	23	24.38	23.69	70	-1133	-1063	-2196
06:00	35.55	23	24.35	23.68	70	-476	-160	-636
07:00	37.43	23	24.33	23.66	70	-490	-169	-659
08:00	39.17	23	24.33	23.66	70	-508	-178	-686
09:00	40.68	23	24.35	23.68	70	-528	-186	-714
10:00	41.83	23	24.37	23.68	70	-548	-193	-741
11:00	42.55	23	24.41	23.7	70	-566	-198	-764
12:00	42.8	23	24.45	23.72	70	-582	-199	-781
13:00	42.55	23	24.5	23.75	70	-593	-198	-791
14:00	41.83	23	24.59	23.8	70	-1794	-1352	-3146
15:00	40.68	23	24.66	23.83	70	-1731	-1305	-3036
16:00	39.17	23	24.72	23.86	70	-626	-178	-804
17:00	37.43	23	24.77	23.88	70	-624	-169	-793
18:00	35.55	23	24.81	23.9	70	-614	-160	-774
19:00	33.67	23	24.84	23.92	70	-605	-152	-757
20:00	31.92	23	24.89	23.94	70	-1161	-1014	-2175
21:00	30.42	23	25.02	24.01	70	-1092	-975	-2067
22:00	29.27	23	25.15	24.08	70	-1045	-948	-1993
23:00	28.55	23	25.22	24.11	70	-1013	-931	-1944
24:00	28.3	23	25.22	24.11	70	-995	-926	-1921

Room: STR_0018: Store (Peak=August)
Area: 30.00 m²
Volume: 90.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time	Outside Air	Inside Air	Inside	Comfort	Saturation	Heat Gains:	Heat Gains:	Heat Gains:

Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	23.71	23.36	70	-2996	-5399	-8395
02.00	29.27	23	23.71	23.36	70	-3302	-5495	-8797
03.00	30.42	23	23.71	23.36	70	-3788	-5654	-9442
04.00	31.92	23	23.7	23.35	70	-4420	-5879	-10299
05.00	33.67	23	23.7	23.35	70	-5157	-6163	-11320
06.00	35.55	23	23.7	23.35	70	-1386	-928	-2314
07.00	37.43	23	23.69	23.34	70	-1494	-980	-2474
08.00	39.17	23	23.69	23.34	70	-1598	-1033	-2631
09.00	40.68	23	23.69	23.34	70	-1687	-1081	-2768
10.00	41.83	23	23.69	23.34	70	-1755	-1120	-2875
11.00	42.55	23	23.69	23.34	70	-1799	-1145	-2944
12.00	42.8	23	23.69	23.34	70	-1813	-1154	-2967
13.00	42.55	23	23.69	23.34	70	-1802	-1145	-2947
14.00	41.83	23	23.69	23.34	70	-8606	-7840	-16446
15.00	40.68	23	23.7	23.35	70	-8119	-7566	-15685
16.00	39.17	23	23.7	23.35	70	-1604	-1033	-2637
17.00	37.43	23	23.7	23.35	70	-1503	-980	-2483
18.00	35.55	23	23.7	23.35	70	-1387	-928	-2315
19.00	33.67	23	23.7	23.35	70	-1279	-880	-2159
20.00	31.92	23	23.71	23.36	70	-4422	-5879	-10301
21.00	30.42	23	23.71	23.36	70	-3791	-5654	-9445
22.00	29.27	23	23.71	23.36	70	-3305	-5495	-8800
23.00	28.55	23	23.71	23.36	70	-2999	-5399	-8398
24.00	28.3	23	23.72	23.36	70	-2898	-5368	-8266

Room: STR_0019: Store (Peak=August)
Area: 120.56 m²
Volume: 361.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	23.6	23.3	70	-2875	-5399	-8274
02.00	29.27	23	23.58	23.29	70	-3150	-5495	-8645
03.00	30.42	23	23.57	23.28	70	-3628	-5654	-9282
04.00	31.92	23	23.56	23.28	70	-4253	-5879	-10132
05.00	33.67	23	23.55	23.28	70	-4985	-6163	-11148
06.00	35.55	23	23.55	23.28	70	-1210	-928	-2138
07.00	37.43	23	23.54	23.27	70	-1314	-980	-2294
08.00	39.17	23	23.54	23.27	70	-1420	-1033	-2453
09.00	40.68	23	23.54	23.27	70	-1514	-1081	-2595
10.00	41.83	23	23.54	23.27	70	-1589	-1120	-2709
11.00	42.55	23	23.55	23.28	70	-1641	-1145	-2786
12.00	42.8	23	23.56	23.28	70	-1667	-1154	-2821
13.00	42.55	23	23.57	23.28	70	-1667	-1145	-2812
14.00	41.83	23	23.6	23.3	70	-8507	-7840	-16347
15.00	40.68	23	23.63	23.32	70	-8059	-7566	-15625
16.00	39.17	23	23.66	23.33	70	-1580	-1033	-2613
17.00	37.43	23	23.68	23.34	70	-1505	-980	-2485
18.00	35.55	23	23.69	23.34	70	-1407	-928	-2335
19.00	33.67	23	23.7	23.35	70	-1306	-880	-2186
20.00	31.92	23	23.7	23.35	70	-4446	-5879	-10325
21.00	30.42	23	23.7	23.35	70	-3802	-5654	-9456
22.00	29.27	23	23.68	23.34	70	-3292	-5495	-8787
23.00	28.55	23	23.66	23.33	70	-2955	-5399	-8354
24.00	28.3	23	23.63	23.32	70	-2817	-5368	-8185

Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	25.02	24.01	70	-954	-931	-1885
02.00	29.27	23	24.54	23.77	70	-863	-948	-1811
03.00	30.42	23	24.5	23.75	70	-934	-975	-1909
04.00	31.92	23	24.45	23.72	70	-1029	-1014	-2043
05.00	33.67	23	24.39	23.7	70	-1137	-1063	-2200
06.00	35.55	23	24.36	23.68	70	-481	-160	-641
07.00	37.43	23	24.34	23.67	70	-494	-169	-663
08.00	39.17	23	24.34	23.67	70	-513	-178	-691
09.00	40.68	23	24.36	23.68	70	-533	-186	-719
10.00	41.83	23	24.38	23.69	70	-552	-193	-745
11.00	42.55	23	24.42	23.71	70	-571	-198	-769
12.00	42.8	23	24.46	23.73	70	-586	-199	-785
13.00	42.55	23	24.51	23.76	70	-598	-198	-796
14.00	41.83	23	24.6	23.8	70	-1798	-1352	-3150
15.00	40.68	23	24.67	23.84	70	-1736	-1305	-3041
16.00	39.17	23	24.73	23.86	70	-631	-178	-809
17.00	37.43	23	24.78	23.89	70	-628	-169	-797
18.00	35.55	23	24.82	23.91	70	-619	-160	-779
19.00	33.67	23	24.88	23.94	70	-618	-152	-770
20.00	31.92	23	25.01	24	70	-1199	-1014	-2213
21.00	30.42	23	25.14	24.07	70	-1129	-975	-2104
22.00	29.27	23	25.23	24.12	70	-1071	-948	-2019
23.00	28.55	23	25.25	24.12	70	-1026	-931	-1957
24.00	28.3	23	25.2	24.1	70	-992	-926	-1918

Room: STR_0020: Store (Peak=August)
Area: 20.79 m²
Volume: 62.38 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	Heat Gains: Net Plant Output (W)
01.00	28.55	23	25	24	70	-955	-931	-1886
02.00	29.27	23	24.42	23.71	70	-831	-948	-1779
03.00	30.42	23	24.37	23.68	70	-900	-975	-1875
04.00	31.92	23	24.32	23.66	70	-994	-1014	-2008
05.00	33.67	23	24.24	23.62	70	-1099	-1063	-2162
06.00	35.55	23	24.21	23.6	70	-441	-160	-601
07.00	37.43	23	24.19	23.6	70	-454	-169	-623
08.00	39.17	23	24.19	23.6	70	-473	-178	-651
09.00	40.68	23	24.21	23.6	70	-494	-186	-680
10.00	41.83	23	24.24	23.62	70	-515	-193	-708
11.00	42.55	23	24.28	23.64	70	-536	-198	-734
12.00	42.8	23	24.33	23.66	70	-554	-199	-753
13.00	42.55	23	24.39	23.7	70	-568	-198	-766
14:00	41.83	23	24.51	23.76	70	-1776	-1352	-3128
15.00	40.68	23	24.6	23.8	70	-1722	-1305	-3027
16.00	39.17	23	24.69	23.84	70	-624	-178	-802
17.00	37.43	23	24.76	23.88	70	-627	-169	-796
18.00	35.55	23	24.81	23.9	70	-621	-160	-781
19.00	33.67	23	24.85	23.92	70	-613	-152	-765
20.00	31.92	23	24.89	23.94	70	-1169	-1014	-2183
21.00	30.42	23	25.03	24.02	70	-1100	-975	-2075
22.00	29.27	23	25.14	24.07	70	-1051	-948	-1999
23.00	28.55	23	25.2	24.1	70	-1014	-931	-1945
24.00	28.3	23	25.18	24.09	70	-990	-926	-1916

(Hrs)	Temp (°C)	Temp (°C)	M.R.T. (°C)	(°C)	%	Sens. Plant Output (W)	Latent Plant Output (W)	Net Plant Output (W)
01.00	28.55	23	23.63	23.32	70	-1585	-2947	-4532
02.00	29.27	23	23.61	23.3	70	-1735	-2999	-4734
03.00	30.42	23	23.6	23.3	70	-1994	-3086	-5080
04.00	31.92	23	23.59	23.3	70	-2334	-3209	-5543
05.00	33.67	23	23.58	23.29	70	-2733	-3364	-6097
06.00	35.55	23	23.57	23.28	70	-672	-507	-1179
07.00	37.43	23	23.56	23.28	70	-730	-535	-1265
08.00	39.17	23	23.56	23.28	70	-787	-564	-1351
09.00	40.68	23	23.56	23.28	70	-838	-590	-1428
10.00	41.83	23	23.57	23.28	70	-879	-611	-1490
11.00	42.55	23	23.58	23.29	70	-908	-625	-1533
12.00	42.8	23	23.58	23.29	70	-921	-630	-1551
13.00	42.55	23	23.59	23.3	70	-921	-625	-1546
14.00	41.83	23	23.62	23.31	70	-4655	-4279	-8934
15.00	40.68	23	23.66	23.33	70	-4410	-4129	-8539
16.00	39.17	23	23.68	23.34	70	-875	-564	-1439
17.00	37.43	23	23.71	23.36	70	-834	-535	-1369
18.00	35.55	23	23.72	23.36	70	-781	-507	-1288
19.00	33.67	23	23.74	23.37	70	-731	-481	-1212
20.00	31.92	23	23.74	23.37	70	-2446	-3209	-5655
21.00	30.42	23	23.73	23.36	70	-2094	-3086	-5180
22.00	29.27	23	23.72	23.36	70	-1816	-2999	-4815
23.00	28.55	23	23.69	23.34	70	-1631	-2947	-4578
24.00	28.3	23	23.67	23.34	70	-1554	-2930	-4484

(Hrs)	Temp (°C)	Temp (°C)	M.R.T. (°C)	(°C)	%	Sens. Plant Output (W)	Latent Plant Output (W)	Net Plant Output (W)
01.00	28.55	23	24.78	23.89	70	-1237	-1344	-2581
02.00	29.27	23	24.54	23.77	70	-1216	-1367	-2583
03.00	30.42	23	24.48	23.74	70	-1312	-1407	-2719
04.00	31.92	23	24.42	23.71	70	-1447	-1463	-2910
05.00	33.67	23	24.37	23.68	70	-1609	-1534	-3143
06.00	35.55	23	24.34	23.67	70	-659	-231	-890
07.00	37.43	23	24.32	23.66	70	-681	-244	-925
08.00	39.17	23	24.33	23.66	70	-710	-257	-967
09.00	40.68	23	24.35	23.68	70	-743	-269	-1012
10.00	41.83	23	24.39	23.7	70	-776	-279	-1055
11.00	42.55	23	24.44	23.72	70	-805	-285	-1090
12.00	42.8	23	24.5	23.75	70	-834	-287	-1121
13.00	42.55	23	24.57	23.78	70	-859	-285	-1144
14.00	41.83	23	25.12	24.06	70	-2777	-1951	-4728
15.00	40.68	23	25.26	24.13	70	-2712	-1883	-4595
16.00	39.17	23	25.29	24.14	70	-1102	-257	-1359
17.00	37.43	23	25.28	24.14	70	-1072	-244	-1316
18.00	35.55	23	25.19	24.1	70	-1009	-231	-1240
19.00	33.67	23	25.13	24.06	70	-955	-219	-1174
20.00	31.92	23	25.1	24.05	70	-1723	-1463	-3186
21.00	30.42	23	25.08	24.04	70	-1559	-1407	-2966
22.00	29.27	23	25.06	24.03	70	-1427	-1367	-2794
23.00	28.55	23	25	24	70	-1326	-1344	-2670
24.00	28.3	23	24.91	23.95	70	-1264	-1336	-2600

Room: CELL0091: cell (Peak=August)
Area: 10.56 m²
Volume: 31.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01.00	28.55	23	24.16	23.58	70	0	0	90	60	206	473	154	-450	-533	983	93.09	0.00	14.58
02.00	29.27	23	24.12	23.56	70	0	0	90	60	233	481	147	-470	-541	1011	95.74	0.00	13.92
03.00	30.42	23	24.1	23.55	70	0	0	90	60	276	495	143	-508	-555	1063	100.66	0.00	13.54
04.00	31.92	23	24.08	23.54	70	0	0	90	60	332	515	139	-560	-575	1135	107.48	0.00	13.16
05.00	33.67	23	24.06	23.53	70	0	0	90	60	396	540	136	-622	-600	1222	115.72	0.00	12.88
06.00	35.55	23	23.97	23.48	70	0	0	0	0	67	81	146	-212	-81	293	27.75	0.00	13.83
07.00	37.43	23	23.99	23.5	70	51	8	0	0	77	86	141	-226	-86	312	29.55	4.83	13.35
08.00	39.17	23	24.08	23.54	70	59	52	0	0	86	90	114	-252	-90	342	32.39	5.59	10.80
09.00	40.68	23	24.09	23.54	70	56	59	0	0	94	95	110	-263	-95	358	33.90	5.30	10.42
10.00	41.83	23	24.1	23.55	70	44	54	0	0	100	98	115	-270	-98	368	34.85	4.17	10.89
11.00	42.55	23	24.09	23.54	70	26	41	0	0	104	100	128	-273	-100	373	35.32	2.46	12.12
12.00	42.8	23	24.08	23.54	70	10	22	0	0	105	101	144	-271	-101	372	35.23	0.95	13.64
13.00	42.55	23	24.07	23.54	70	8	9	0	0	104	100	157	-270	-100	370	35.04	0.76	14.87
14.00	41.83	23	24.47	23.74	70	7	8	90	60	699	687	208	-1005	-747	1752	165.91	0.66	19.70
15.00	40.68	23	24.54	23.77	70	7	7	90	60	657	663	222	-976	-723	1699	160.89	0.66	21.02
16.00	39.17	23	24.46	23.73	70	6	6	0	0	86	90	234	-326	-90	416	39.39	0.57	22.16
17.00	37.43	23	24.43	23.72	70	4	5	0	0	77	86	230	-312	-86	398	37.69	0.38	21.78
18.00	35.55	23	24.35	23.68	70	2	4	0	0	67	81	216	-287	-81	368	34.85	0.19	20.45
19.00	33.67	23	24.26	23.63	70	0	2	0	0	57	77	201	-260	-77	337	31.91	0.00	19.03
20.00	31.92	23	24.29	23.64	70	0	0	90	60	332	515	181	-602	-575	1177	111.46	0.00	17.14
21.00	30.42	23	24.28	23.64	70	0	0	90	60	276	495	177	-543	-555	1098	103.98	0.00	16.76
22.00	29.27	23	24.25	23.62	70	0	0	90	60	233	481	173	-496	-541	1037	98.20	0.00	16.38
23.00	28.55	23	24.23	23.62	70	0	0	90	60	206	473	168	-464	-533	997	94.41	0.00	15.91
24.00	28.3	23	24.19	23.6	70	0	0	90	60	197	470	161	-448	-530	978	92.61	0.00	15.25

Room: CELL0126: cell (Peak=August)
Area: 10.56 m²
Volume: 31.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01.00	28.55	23	24.34	23.67	70	0	0	90	60	206	473	190	-486	-533	1019	96.50	0.00	17.99
02.00	29.27	23	24.09	23.54	70	0	0	90	60	233	481	142	-465	-541	1006	95.27	0.00	13.45

-5122	-5057	-2608	-4596	-8391	-1901	-2581	-4532	-8274	-1886	-1885	-8395	-8275	-1869	-2585	-2613	-70570	70570
-5283	-5198	-2622	-4814	-8792	-1807	-2583	-4734	-8645	-1779	-1811	-8797	-8647	-1783	-2600	-2639	-72534	72534
-5608	-5517	-2761	-5165	-9437	-1905	-2719	-5080	-9282	-1875	-1909	-9442	-9283	-1879	-2735	-2777	-77374	77374
-6054	-5958	-2955	-5632	-10295	-2040	-2910	-5543	-10132	-2008	-2043	-10299	-10133	-2011	-2925	-2970	-83908	83908
-6591	-6491	-3190	-6189	-11317	-2196	-3143	-6097	-11148	-2162	-2200	-11320	-11147	-2167	-3158	-3206	-91722	91722
-1666	-1562	-939	-1274	-2312	-636	-890	-1179	-2138	-601	-641	-2314	-2137	-606	-905	-955	-20755	20755
-1750	-1645	-974	-1361	-2470	-659	-925	-1265	-2294	-623	-663	-2474	-2294	-628	-941	-990	-21946	21946
-1837	-1733	-1016	-1447	-2628	-686	-967	-1351	-2453	-651	-691	-2631	-2453	-655	-983	-1032	-23214	23214
-1920	-1820	-1059	-1521	-2765	-714	-1012	-1428	-2595	-680	-719	-2768	-2595	-684	-1027	-1075	-24382	24382
-1993	-1898	-1100	-1579	-2872	-741	-1055	-1490	-2709	-708	-745	-2875	-2709	-713	-1071	-1115	-25373	25373
-2049	-1960	-1132	-1617	-2940	-764	-1090	-1533	-2786	-734	-769	-2944	-2786	-738	-1106	-1148	-25096	25096
-2086	-2004	-1159	-1630	-2964	-781	-1121	-1551	-2821	-753	-785	-2967	-2820	-757	-1137	-1175	-26511	26511
-2101	-2027	-1178	-1619	-2944	-791	-1144	-1546	-2812	-766	-796	-2947	-2812	-770	-1164	-1196	-26613	26613
-9747	-9710	-4741	-8966	-16443	-3146	-4728	-8934	-16347	-3128	-3150	-16446	-16347	-3132	-4692	-4705	-134382	134382
-9398	-9387	-4593	-8571	-15681	-3036	-4595	-8539	-15625	-3027	-3041	-15685	-15625	-3031	-4593	-4593	-129020	129020
-2292	-2302	-1347	-1450	-2634	-804	-1359	-1439	-2613	-802	-809	-2637	-2613	-806	-1399	-1390	-26656	26656
-2214	-2238	-1300	-1366	-2479	-793	-1316	-1369	-2485	-796	-797	-2483	-2485	-800	-1390	-1375	-25686	25686
-2082	-2113	-1226	-1275	-2312	-774	-1240	-1288	-2335	-781	-779	-2315	-2334	-785	-1340	-1325	-24304	24304
-1928	-1959	-1171	-1195	-2156	-757	-1174	-1212	-2186	-765	-770	-2159	-2186	-779	-1267	-1256	-22920	22920
-6331	-6357	-3171	-5639	-10297	-2175	-3186	-5655	-10325	-2183	-2213	-10301	-10325	-2223	-3266	-3248	-86895	86895
-5841	-5858	-2954	-5172	-9442	-2067	-2966	-5180	-9456	-2075	-2104	-9445	-9456	-2113	-3009	-2996	-80134	80134
-5455	-5457	-2787	-4820	-8797	-1993	-2794	-4815	-8787	-1999	-2019	-8800	-8787	-2025	-2828	-2821	-74984	74984
-5195	-5177	-2673	-4600	-8395	-1944	-2670	-4578	-8354	-1945	-1957	-8398	-8354	-1958	-2693	-2697	-71588	71588
-5086	-5045	-2614	-4527	-8263	-1921	-2600	-4484	-8185	-1916	-1918	-8266	-8185	-1911	-2610	-2626	-70157	70157

Room: CELL0063: cell (Peak=August)
Area: 10.56 m^2
Volume: 31.68 m^3
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01.00	28.55	23	24.08	23.54	70	0	0	90	60	206	473	139	-435	-533	968	91.67	0.00	13.16
02.00	29.27	23	24.03	23.52	70	0	0	90	60	233	481	128	-451	-541	992	93.94	0.00	12.12
03.00	30.42	23	24	23.5	70	0	0	90	60	276	495	123	-489	-555	1044	98.86	0.00	11.65
04.00	31.92	23	23.98	23.49	70	0	0	90	60	332	515	118	-540	-575	1115	105.59	0.00	11.17
05.00	33.67	23	23.96	23.48	70	0	0	90	60	396	540	115	-601	-600	1201	113.73	0.00	10.89
06.00	35.55	23	23.86	23.43	70	0	0	0	0	67	81	123	-190	-81	271	25.66	0.00	11.65
07.00	37.43	23	23.88	23.44	70	51	8	0	0	77	86	119	-204	-86	290	27.46	4.83	11.27
08.00	39.17	23	23.98	23.49	70	59	52	0	0	86	90	93	-231	-90	321	30.40	5.59	8.81
09.00	40.68	23	24	23.5	70	56	59	0	0	94	95	90	-243	-95	338	32.01	5.30	8.52
10.00	41.83	23	24	23.5	70	44	54	0	0	100	98	96	-250	-98	348	32.95	4.17	9.09
11.00	42.55	23	24	23.5	70	26	41	0	0	104	100	109	-254	-100	354	33.52	2.46	10.32
12.00	42.8	23	23.98	23.49	70	10	22	0	0	105	101	125	-252	-101	353	33.43	0.95	11.84
13.00	42.55	23	23.98	23.49	70	8	9	0	0	104	100	138	-251	-100	351	33.24	0.76	13.07
14.00	41.83	23	24.42	23.71	70	7	8	90	60	699	687	197	-994	-747	1741	164.87	0.66	18.66
15.00	40.68	23	24.51	23.76	70	7	7	90	60	657	663	215	-969	-723	1692	160.23	0.66	20.36
16.00	39.17	23	24.44	23.72	70	6	6	0	0	86	90	229	-322	-90	412	39.02	0.57	21.69
17.00	37.43	23	24.42	23.71	70	4	5	0	0	77	86	228	-309	-86	395	37.41	0.38	21.59
18.00	35.55	23	24.35	23.68	70	2	4	0	0	67	81	215	-285	-81	366	34.66	0.19	20.36
19.00	33.67	23	24.26	23.63	70	0	2	0	0	57	77	199	-258	-77	335	31.72	0.00	18.84
20.00	31.92	23	24.29	23.64	70	0	0	90	60	332	515	179	-601	-575	1176	111.36	0.00	16.95
21.00	30.42	23	24.27	23.64	70	0	0	90	60	276	495	175	-540	-555	1095	103.69	0.00	16.57
22.00	29.27	23	24.23	23.62	70	0	0	90	60	233	481	168	-491	-541	1032	97.73	0.00	15.91
23.00	28.55	23	24.19	23.6	70	0	0	90	60	206	473	159	-455	-533	988	93.56	0.00	15.06
24.00	28.3	23	24.14	23.57	70	0	0	90	60	197	470	149	-436	-530	966	91.48	0.00	14.11

Room: CELL0118: cell (Peak=August)
Area: 10.56 m^2
Volume: 31.68 m^3
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01.00	28.55	23	24.28	23.64	70	0	0	90	60	206	473	177	-473	-533	1006	95.27	0.00	16.76
02.00	29.27	23	24	23.5	70	0	0	90	60	233	481	123	-446	-541	987	93.47	0.00	11.65

03 00	30 42	23	24 08	23 54	70	0	0	90	60	276	495	139	-505	-555	1060	100 38	0 00	13 16
04 00	31 92	23	24 06	23 53	70	0	0	90	60	332	515	136	-557	-575	1132	107 20	0 00	12 88
05 00	33 67	23	24 03	23 52	70	0	0	90	60	396	540	131	-617	-600	1217	115 25	0 00	12 41
06 00	35 55	23	23 94	23 47	70	0	0	0	0	87	81	141	-207	-81	288	27 27	0 00	13 35
07 00	37 43	23	23 93	23 46	70	3	1	0	0	77	86	137	-214	-86	300	28 41	0 28	12 97
08 00	39 17	23	23 94	23 47	70	4	3	0	0	86	90	136	-225	-90	315	29 83	0 38	12 88
09 00	40 68	23	23 94	23 47	70	6	5	0	0	94	95	136	-235	-95	330	31 25	0 57	12 88
10 00	41 83	23	23 96	23 48	70	7	6	0	0	100	98	137	-243	-98	341	32 29	0 66	12 97
11 00	42 55	23	23 97	23 48	70	7	7	0	0	104	100	140	-250	-100	350	33 14	0 66	13 26
12 00	42 8	23	23 99	23 5	70	8	8	0	0	105	101	143	-255	-101	356	33 71	0 76	13 54
13 00	42 55	23	24 01	23 5	70	8	8	0	0	104	100	147	-258	-100	358	33 90	0 76	13 92
14 00	41 83	23	24 14	23 57	70	11	9	90	60	699	687	142	-941	-747	1688	159 85	1 04	13 45
15 00	40 68	23	24 18	23 59	70	24	14	90	60	657	663	146	-906	-723	1629	154 26	2 27	13 83
16 00	39 17	23	24 15	23 58	70	37	26	0	0	86	90	155	-267	-90	357	33 81	3 50	14 68
17 00	37 43	23	24 2	23 6	70	44	38	0	0	77	86	153	-267	-86	353	33 43	4 17	14 49
18 00	35 55	23	24 22	23 61	70	39	43	0	0	67	81	152	-261	-81	342	32 39	3 69	14 39
19 00	33 67	23	24 2	23 6	70	0	32	0	0	57	77	159	-248	-77	325	30 78	0 00	15 06
20 00	31 92	23	24 23	23 62	70	0	0	90	60	332	515	169	-590	-575	1165	110 32	0 00	16 00
21 00	30 42	23	24 29	23 64	70	0	0	90	60	276	495	180	-546	-555	1101	104 26	0 00	17 05
22 00	29 27	23	24 35	23 66	70	0	0	90	60	233	481	192	-515	-541	1056	100 00	0 00	18 18
23 00	28 55	23	24 39	23 7	70	0	0	90	60	206	473	200	-496	-533	1029	97 44	0 00	18 94
24 00	28 3	23	24 4	23 7	70	0	0	90	60	197	470	202	-489	-530	1019	96 50	0 00	19 13
															0	0 00	0 00	0 00

Room: CELL0161: cell (Peak=August)
Area: 10 56 m²
Volume: 31.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains. Sens. Plant Output (W)	Heat Gains. Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01 00	28 55	23	24 3	23 65	70	0	0	90	60	206	473	184	-480	-533	1013	95 93	0 00	17 42
02 00	29 27	23	24 11	23 56	70	0	0	90	60	233	481	147	-470	-541	1011	95 74	0 00	13 97
03 00	30 42	23	24 09	23 54	70	0	0	90	60	276	495	143	-509	-555	1064	100 76	0 00	13 54
04 00	31 92	23	24 07	23 54	70	0	0	90	60	332	515	139	-561	-575	1136	107 58	0 00	13 16
05 00	33 67	23	24 04	23 52	70	0	0	90	60	396	540	134	-621	-600	1221	115 63	0 00	12 69
06 00	35 55	23	23 95	23 48	70	0	0	0	0	87	81	144	-211	-81	292	27 65	0 00	13 64
07 00	37 43	23	23 94	23 47	70	3	1	0	0	77	86	141	-219	-86	305	28 88	0 28	13 35
08 00	39 17	23	23 95	23 48	70	4	3	0	0	86	90	140	-229	-90	319	30 21	0 38	13 26
09 00	40 68	23	23 96	23 48	70	6	5	0	0	94	95	140	-239	-95	334	31 63	0 57	13 26
10 00	41 83	23	23 97	23 48	70	7	6	0	0	100	98	142	-248	-98	346	32 77	0 66	13 45
11 00	42 55	23	23 99	23 5	70	7	7	0	0	104	100	144	-255	-100	355	33 62	0 66	13 64
12 00	42 8	23	24 01	23 5	70	8	8	0	0	105	101	147	-260	-101	361	34 19	0 76	13 92
13 00	42 55	23	24 04	23 52	70	16	11	0	0	104	100	150	-264	-100	364	34 47	1 52	14 20
14 00	41 83	23	24 17	23 58	70	28	19	90	60	699	687	141	-949	-747	1696	160 61	2 65	13 35
15 00	40 68	23	24 23	23 62	70	38	30	90	60	657	663	140	-917	-723	1640	155 30	3 60	13 26
16 00	39 17	23	24.19	23 6	70	41	38	0	0	86	90	152	-276	-90	366	34 66	3 88	14 39
17 00	37 43	23	24 22	23 61	70	38	40	0	0	77	86	156	-273	-86	359	34 00	3 60	14 77
18 00	35 55	23	24 23	23 62	70	26	35	0	0	67	81	162	-264	-81	345	32 67	2 46	15 34
19 00	33 67	23	24 23	23 62	70	0	21	0	0	57	77	177	-254	-77	331	31 34	0 00	16 76
20 00	31.92	23	24 35	23 68	70	0	0	90	60	332	515	194	-615	-575	1190	112 69	0 00	18 37
21 00	30 42	23	24 4	23 7	70	0	0	90	60	276	495	204	-570	-555	1125	106 53	0 00	19 32
22 00	29 27	23	24 43	23.72	70	0	0	90	60	233	481	209	-532	-541	1073	101 61	0 00	19 79
23 00	28 55	23	24 43	23.72	70	0	0	90	60	206	473	209	-505	-533	1038	98 30	0 00	19 79
24 00	28 3	23	24 39	23 7	70	0	0	90	60	197	470	202	-488	-530	1018	96 40	0 00	19 13

Room: CELL0089: cell (Peak=August)
Area: 22.00 m²
Volume: 66 00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01 00	28 55	23	24 53	23 76	70	0	0	360	240	429	985	305	-1095	-1225	2320	105 45	0 00	13 86
02 00	29 27	23	24 48	23 74	70	0	0	360	240	485	1003	290	-1135	-1243	2378	108 09	0 00	13 18
03 00	30 42	23	24 45	23.72	70	0	0	360	240	574	1032	281	-1215	-1272	2487	113 05	0 00	12 77
04 00	31 92	23	24 43	23.72	70	0	0	360	240	691	1073	273	-1324	-1313	2637	119 86	0 00	12 41
05 00	33 67	23	24 41	23 7	70	0	0	360	240	826	1125	266	-1452	-1365	2817	128 05	0 00	12 09
06 00	35.55	23	24 19	23 6	70	0	0	0	0	139	169	308	-447	-169	616	28 00	0 00	14 00

03 00	30 42	23	23 98	23 49	70	0	0	90	60	276	495	120	-485	-555	1040	98 48	0 00	11 36
04 00	31 92	23	23 96	23 48	70	0	0	90	60	332	515	116	-537	-575	1112	105 30	0 00	10 98
05 00	33 67	23	23 93	23 46	70	0	0	90	60	396	540	110	-597	-600	1197	113 35	0 00	10 42
06 00	35 55	23	23 83	23 42	70	0	0	0	0	67	81	119	-185	-81	266	25 19	0 00	11 27
07 00	37 43	23	23 82	23 41	70	3	1	0	0	77	86	115	-192	-86	278	26 33	0 28	10 89
08 00	39 17	23	23 83	23 42	70	4	3	0	0	86	90	114	-203	-90	293	27 75	0 38	10 80
09 00	40 68	23	23 84	23 42	70	6	5	0	0	94	95	114	-213	-95	308	29 17	0 57	10 80
10 00	41 83	23	23 85	23 42	70	7	6	0	0	100	98	116	-222	-98	320	30 30	0 66	10 98
11 00	42 55	23	23 87	23 44	70	7	7	0	0	104	100	119	-230	-100	330	31 25	0 66	11 27
12 00	42 8	23	23 9	23 45	70	8	8	0	0	105	101	123	-236	-101	337	31 91	0 76	11 65
13 00	42 55	23	23 92	23 46	70	8	8	0	0	104	100	128	-240	-100	340	32 20	0 76	12 12
14 00	41 83	23	24 07	23 54	70	11	9	90	60	699	687	128	-927	-747	1674	158 52	1 04	12 12
15 00	40 68	23	24 14	23 57	70	24	14	90	60	657	663	136	-896	-723	1619	153 31	2 27	12 88
16 00	39 17	23	24 12	23 56	70	37	26	0	0	86	90	148	-260	-90	350	33 14	3 50	14 02
17 00	37 43	23	24 19	23 6	70	44	38	0	0	77	86	149	-264	-86	350	33 14	4 17	14 11
18 00	35 55	23	24 22	23 61	70	39	43	0	0	67	81	150	-260	-81	341	32 29	3 69	14 20
19 00	33 67	23	24 21	23 6	70	0	32	0	0	57	77	154	-247	-77	324	30 68	0 00	14 96
20 00	31 92	23	24 23	23 62	70	0	0	90	60	332	515	167	-598	-575	1163	110 13	0 00	15 81
21 00	30 42	23	24 28	23 64	70	0	0	90	60	276	495	178	-544	-555	1099	104 07	0 00	16 86
22 00	29 27	23	24 34	23 67	70	0	0	90	60	233	481	189	-512	-541	1053	99 72	0 00	17 90
23 00	28 55	23	24 36	23 68	70	0	0	90	60	206	473	194	-490	-533	1023	96 88	0 00	18 37
24 00	28 3	23	24 36	23 68	70	0	0	90	60	197	470	193	-480	-530	1010	95 64	0 00	18 28
															0	0 00	0 00	0 00

Room: CELL0153: cell (Peak=August)
Area: 10.56 m²
Volume: 31.68 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains. Sens. Plant Output (W)	Heat Gains. Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01 00	28 55	23	24 24	23 62	70	0	0	90	60	206	473	170	-466	-533	999	94 60	0 00	16 10
02 00	29 27	23	24 02	23 51	70	0	0	90	60	233	481	128	-451	-541	992	93 94	0 00	12 12
03 00	30 42	23	24	23 5	70	0	0	90	60	276	495	124	-490	-555	1045	98 96	0 00	11 74
04 00	31 92	23	23 97	23 48	70	0	0	90	60	332	515	119	-540	-575	1115	105 59	0 00	11 27
05 00	33 67	23	23 94	23 47	70	0	0	90	60	396	540	114	-600	-600	1200	113 64	0 00	10 80
06 00	35 55	23	23 84	23 42	70	0	0	0	0	67	81	122	-188	-81	269	25 47	0 00	11 55
07 00	37 43	23	23 83	23 42	70	3	1	0	0	77	86	119	-196	-86	282	26 70	0 28	11 27
08 00	39 17	23	23 84	23 42	70	4	3	0	0	86	90	118	-207	-90	297	28 13	0 38	11 17
09 00	40 68	23	23 85	23 42	70	6	5	0	0	94	95	118	-217	-95	312	29 55	0 57	11 17
10 00	41 83	23	23 87	23 44	70	7	6	0	0	100	98	120	-226	-98	324	30 68	0 66	11 36
11 00	42 55	23	23 89	23 44	70	7	7	0	0	104	100	123	-234	-100	334	31 63	0 66	11 65
12 00	42 8	23	23 91	23 46	70	8	8	0	0	105	101	127	-240	-101	341	32 29	0 76	12 03
13 00	42 55	23	23 95	23 48	70	16	11	0	0	104	100	131	-246	-100	346	32 77	1 52	12 41
14 00	41 83	23	24 11	23 56	70	28	19	90	60	699	687	127	-935	-747	1682	159 28	2 65	12 03
15 00	40 68	23	24 19	23 6	70	38	30	90	60	657	663	131	-907	-723	1630	154 36	3 60	12 41
16 00	39 17	23	24 17	23 58	70	41	38	0	0	86	90	146	-270	-90	360	34 09	3 88	13 83
17 00	37 43	23	24 21	23 6	70	38	40	0	0	77	86	153	-269	-86	355	33 62	3 60	14 49
18 00	35 55	23	24 22	23 61	70	26	35	0	0	67	81	160	-262	-81	343	32 48	2 46	15 15
19 00	33 67	23	24 23	23 62	70	0	21	0	0	57	77	175	-253	-77	330	31 25	0 00	16 57
20 00	31.92	23	24 35	23 68	70	0	0	90	60	332	515	193	-615	-575	1190	112 69	0 00	18 28
21 00	30 42	23	24 41	23 7	70	0	0	90	60	276	495	203	-569	-555	1124	106 44	0 00	19 22
22 00	29 27	23	24 42	23.71	70	0	0	90	60	233	481	206	-529	-541	1070	101 33	0 00	19 51
23 00	28 55	23	24 41	23 7	70	0	0	90	60	206	473	203	-499	-533	1032	97 73	0 00	19 22
24 00	28 3	23	24 35	23 68	70	0	0	90	60	197	470	192	-479	-530	1009	95 55	0 00	18 18

Room: CELL0071: cell (Peak=August)
Area: 22.00 m²
Volume: 66.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01 00	28 55	23	24 47	23.74	70	0	0	360	240	429	985	280	-1069	-1225	2294	104 27	0 00	12 73
02.00	29.27	23	24 4	23 7	70	0	0	360	240	485	1003	258	-1103	-1243	2346	106 64	0 00	11.73
03 00	30 42	23	24 36	23 68	70	0	0	360	240	574	1032	247	-1181	-1272	2453	111 50	0 00	11 23
04 00	31 92	23	24 33	23 66	70	0	0	360	240	691	1073	237	-1288	-1313	2601	118 23	0 00	10.77
05 00	33 67	23	24 31	23 66	70	0	0	360	240	826	1125	229	-1415	-1365	2780	126 36	0 00	10 41
06 00	35 55	23	24 07	23 54	70	0	0	0	0	139	169	266	-405	-169	574	26 09	0 00	12 09

07.00	37.43	23	24.21	23.8	70	101	17	0	0	159	179	298	-474	-179	653	29.68	4.59	13.55
08.00	39.17	23	24.32	23.86	70	119	105	0	0	179	188	244	-527	-188	715	32.50	5.41	11.09
09.00	40.68	23	24.33	23.86	70	112	118	0	0	195	197	234	-547	-197	744	33.82	5.09	10.64
10.00	41.83	23	24.34	23.87	70	88	109	0	0	208	204	245	-562	-204	766	34.82	4.00	11.14
11.00	42.55	23	24.34	23.87	70	52	82	0	0	216	209	273	-571	-209	780	35.45	2.36	12.41
12.00	42.8	23	24.32	23.86	70	19	44	0	0	219	211	303	-567	-211	778	35.36	0.86	13.77
13.00	42.55	23	24.31	23.86	70	16	18	0	0	216	209	328	-563	-209	772	35.09	0.73	14.91
14.00	41.83	23	24.93	23.96	70	15	15	360	240	1457	1431	416	-2248	-1671	3919	178.14	0.68	18.91
15.00	40.68	23	25.02	24.01	70	13	14	360	240	1368	1381	445	-2187	-1621	3808	173.09	0.59	20.23
16.00	39.17	23	24.81	23.9	70	11	13	0	0	179	188	491	-683	-188	871	39.59	0.50	22.32
17.00	37.43	23	24.8	23.9	70	8	11	0	0	159	179	489	-660	-179	839	38.14	0.36	22.23
18.00	35.55	23	24.7	23.85	70	5	8	0	0	139	169	461	-607	-169	776	35.27	0.23	20.95
19.00	33.67	23	24.56	23.78	70	0	4	0	0	118	161	422	-543	-161	704	32.00	0.00	19.18
20.00	31.92	23	24.7	23.85	70	0	0	360	240	691	1073	358	-1409	-1313	2722	123.73	0.00	16.27
21.00	30.42	23	24.68	23.84	70	0	0	360	240	574	1032	352	-1286	-1272	2558	116.27	0.00	16.00
22.00	29.27	23	24.64	23.82	70	0	0	360	240	485	1003	341	-1186	-1243	2429	110.41	0.00	15.50
23.00	28.55	23	24.62	23.81	70	0	0	360	240	429	985	334	-1123	-1225	2348	106.73	0.00	15.18
24.00	28.3	23	24.58	23.79	70	0	0	360	240	410	980	321	-1092	-1220	2312	105.09	0.00	14.59

Room: CELL0124: cell (Peak=August)
Area: 22.00 m²
Volume: 66.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01.00	28.55	23	24.76	23.89	70	0	0	360	240	429	985	386	-1175	-1225	2400	109.09	0.00	17.55
02.00	29.27	23	24.45	23.72	70	0	0	360	240	485	1003	282	-1127	-1243	2370	107.73	0.00	12.82
03.00	30.42	23	24.43	23.72	70	0	0	360	240	574	1032	274	-1209	-1272	2481	112.77	0.00	12.45
04.00	31.92	23	24.4	23.7	70	0	0	360	240	691	1073	266	-1317	-1313	2630	119.55	0.00	12.09
05.00	33.67	23	24.36	23.68	70	0	0	360	240	826	1125	253	-1439	-1365	2804	127.45	0.00	11.50
06.00	35.55	23	24.14	23.57	70	0	0	0	0	139	169	295	-434	-169	603	27.41	0.00	13.41
07.00	37.43	23	24.13	23.56	70	5	1	0	0	159	179	291	-451	-179	630	28.64	0.23	13.23
08.00	39.17	23	24.14	23.57	70	9	6	0	0	179	188	288	-473	-188	661	30.05	0.41	13.09
09.00	40.68	23	24.14	23.57	70	12	9	0	0	195	197	285	-489	-197	686	31.18	0.55	12.95
10.00	41.83	23	24.16	23.58	70	14	12	0	0	208	204	288	-508	-204	712	32.36	0.64	13.09
11.00	42.55	23	24.18	23.59	70	15	14	0	0	216	209	294	-524	-209	733	33.32	0.68	13.36
12.00	42.8	23	24.21	23.6	70	16	15	0	0	219	211	301	-534	-211	745	33.86	0.73	13.68
13.00	42.55	23	24.24	23.62	70	16	16	0	0	216	209	309	-541	-209	750	34.09	0.73	14.05
14.00	41.83	23	24.5	23.75	70	23	18	360	240	1457	1431	279	-2114	-1671	3785	172.05	1.05	12.68
15.00	40.68	23	24.56	23.78	70	49	28	360	240	1368	1381	287	-2043	-1621	3664	166.55	2.23	13.05
16.00	39.17	23	24.42	23.71	70	74	52	0	0	179	188	329	-560	-188	748	34.00	3.36	14.95
17.00	37.43	23	24.49	23.74	70	88	76	0	0	159	179	329	-564	-179	743	33.77	4.00	14.95
18.00	35.55	23	24.52	23.76	70	78	85	0	0	139	169	328	-552	-169	721	32.77	3.55	14.91
19.00	33.67	23	24.5	23.75	70	0	64	0	0	118	161	341	-523	-161	684	31.09	0.00	15.50
20.00	31.92	23	24.63	23.82	70	0	0	360	240	691	1073	338	-1389	-1313	2702	122.82	0.00	15.36
21.00	30.42	23	24.71	23.86	70	0	0	360	240	574	1032	364	-1298	-1272	2570	116.82	0.00	16.55
22.00	29.27	23	24.79	23.9	70	0	0	360	240	485	1003	388	-1233	-1243	2476	112.55	0.00	17.64
23.00	28.55	23	24.84	23.92	70	0	0	360	240	429	985	405	-1194	-1225	2419	109.95	0.00	18.41
24.00	28.3	23	24.86	23.93	70	0	0	360	240	410	980	410	-1180	-1220	2400	109.09	0.00	18.64

Room: CELL0160: cell (Peak=August)
Area: 22.00 m²
Volume: 66.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01:00	28.55	23	24.73	23.86	70	0	0	360	240	429	985	370	-1159	-1225	2384	108.36	0.00	16.82
02.00	29.27	23	24.48	23.74	70	0	0	360	240	485	1003	290	-1136	-1243	2379	108.14	0.00	13.18
03.00	30.42	23	24.45	23.72	70	0	0	360	240	574	1032	281	-1216	-1272	2488	113.09	0.00	12.77
04.00	31.92	23	24.42	23.71	70	0	0	360	240	691	1073	272	-1322	-1313	2635	119.77	0.00	12.36
05.00	33.67	23	24.39	23.7	70	0	0	360	240	826	1125	260	-1446	-1365	2811	127.77	0.00	11.82
06.00	35.55	23	24.16	23.58	70	0	0	0	0	139	169	301	-440	-169	609	27.68	0.00	13.68
07:00	37.43	23	24.16	23.58	70	5	1	0	0	159	179	298	-458	-179	637	28.95	0.23	13.55
08.00	39.17	23	24.16	23.58	70	9	6	0	0	179	188	295	-480	-188	668	30.36	0.41	13.41
09:00	40.68	23	24.16	23.58	70	12	9	0	0	195	197	291	-496	-197	693	31.50	0.55	13.23
10.00	41.83	23	24.18	23.59	70	14	12	0	0	208	204	295	-515	-204	719	32.68	0.64	13.41

07 00	37 43	23	24 09	23 54	70	101	17	0	0	159	179	258	-433	-179	812	27 82	4 59	11 64
08 00	39 17	23	24 22	23 61	70	119	105	0	0	179	188	206	-490	-188	678	30 82	5 41	9 36
09 00	40 68	23	24 24	23 62	70	112	118	0	0	195	197	198	-511	-197	708	32 18	5 09	9 00
10 00	41 83	23	24 24	23 62	70	88	109	0	0	208	204	210	-527	-204	731	33 23	4 00	9 55
11 00	42 55	23	24 25	23 62	70	52	82	0	0	216	209	239	-537	-209	746	33 91	2 36	10 86
12 00	42 8	23	24 23	23 62	70	19	44	0	0	219	211	270	-534	-211	745	33 86	0 86	12 27
13 00	42 55	23	24 23	23 62	70	16	18	0	0	216	209	297	-531	-209	740	33 64	0 73	13 50
14 00	41 83	23	24 9	23 95	70	15	15	360	240	1457	1431	400	-2232	-1671	3903	177 41	0 68	18 18
15 00	40 68	23	25 01	24	70	13	14	360	240	1368	1381	438	-2180	-1621	3801	172 77	0 59	19 91
16 00	39 17	23	24 82	23 91	70	11	13	0	0	179	188	488	-660	-188	848	38 45	0 50	22 18
17 00	37 43	23	24 82	23 91	70	8	11	0	0	159	179	490	-660	-179	839	38 14	0 36	22 27
18 00	35 55	23	24 72	23 86	70	5	8	0	0	139	169	463	-610	-169	779	35 41	0 23	21 05
19 00	33 67	23	24 58	23 79	70	0	4	0	0	118	161	424	-546	-161	707	32 14	0 00	19 27
20 00	31 92	23	24 73	23 86	70	0	0	360	240	691	1073	362	-1413	-1313	2726	123 91	0 00	16 45
21 00	30 42	23	24 7	23 85	70	0	0	360	240	574	1032	353	-1287	-1272	2559	116 32	0 00	16 05
22 00	29 27	23	24 65	23 82	70	0	0	360	240	485	1003	337	-1182	-1243	2425	110 23	0 00	15 32
23 00	28 55	23	24 6	23 8	70	0	0	360	240	429	985	323	-1112	-1225	2337	106 23	0 00	14 68
24 00	28 3	23	24 54	23 77	70	0	0	360	240	410	980	303	-1073	-1220	2293	104 23	0 00	13 77

Room: CELL0116. cell (Peak=August)
Area: 22 00 m²
Volume: 66 00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains. Sens. Plant Output (W)	Heat Gains. Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01 00	28 55	23	24 73	23 86	70	0	0	360	240	429	985	365	-1154	-1225	2379	108 14	0 00	16 59
02 00	29 27	23	24 37	23 68	70	0	0	360	240	485	1003	250	-1096	-1243	2339	106 32	0 00	11 36
03 00	30 42	23	24 34	23 67	70	0	0	360	240	574	1032	241	-1176	-1272	2448	111 27	0 00	10 95
04 00	31 92	23	24 31	23 66	70	0	0	360	240	691	1073	231	-1282	-1313	2595	117 95	0 00	10 50
05 00	33 67	23	24 26	23 63	70	0	0	360	240	826	1125	217	-1403	-1365	2768	125 82	0 00	9 86
06 00	35 55	23	24 03	23 52	70	0	0	0	0	139	169	255	-393	-169	562	25 55	0 00	11 59
07 00	37 43	23	24 02	23 51	70	5	1	0	0	159	179	250	-410	-179	589	26 77	0 23	11 36
08 00	39 17	23	24 02	23 51	70	9	6	0	0	179	188	248	-432	-188	620	28 18	0 41	11 27
09 00	40 68	23	24 03	23 52	70	12	9	0	0	195	197	245	-450	-197	647	29 41	0 55	11 14
10 00	41 83	23	24 05	23 52	70	14	12	0	0	208	204	250	-470	-204	674	30 64	0 64	11 36
11 00	42 55	23	24 08	23 54	70	15	14	0	0	216	209	258	-488	-209	697	31 68	0 68	11 73
12 00	42 8	23	24 12	23 56	70	16	15	0	0	219	211	267	-501	-211	712	32 36	0 73	12 14
13 00	42 55	23	24 15	23 58	70	16	16	0	0	216	209	279	-510	-209	719	32 68	0 73	12 68
14 00	41 83	23	24 45	23 72	70	23	18	360	240	1457	1431	259	-2094	-1671	3765	171.14	1 05	11 77
15 00	40 68	23	24 53	23 76	70	49	28	360	240	1368	1381	275	-2031	-1621	3652	166 00	2 23	12 50
16 00	39 17	23	24 41	23 7	70	74	52	0	0	179	188	322	-554	-188	742	33 73	3 36	14 64
17 00	37 43	23	24 51	23 76	70	88	76	0	0	159	179	328	-564	-179	743	33 77	4 00	14 91
18 00	35 55	23	24 55	23 78	70	78	85	0	0	139	169	332	-556	-169	725	32 95	3 55	15 09
19 00	33 67	23	24 52	23 76	70	0	64	0	0	118	161	346	-528	-161	689	31 32	0 00	15 73
20 00	31 92	23	24 66	23 83	70	0	0	360	240	691	1073	343	-1394	-1313	2707	123 05	0 00	15 59
21 00	30 42	23	24 74	23 87	70	0	0	360	240	574	1032	367	-1302	-1272	2574	117 00	0 00	16 68
22 00	29 27	23	24 8	23 9	70	0	0	360	240	485	1003	388	-1233	-1243	2476	112 55	0 00	17.64
23 00	28 55	23	24 84	23 92	70	0	0	360	240	429	985	399	-1188	-1225	2413	109 68	0 00	18 14
24 00	28 3	23	24 83	23 92	70	0	0	360	240	410	980	397	-1167	-1220	2387	108 50	0 00	18 05

Room: CELL0152: cell (Peak=August)
Area: 22.00 m²
Volume: 66.00 m³
Month: August (Peak)
Design day: Monday
Natural and Mechanical Ventilation On

Local Time (Hrs)	Outside Air Temp (°C)	Inside Air Temp (°C)	Inside M.R.T. (°C)	Comfort (°C)	Saturation %	Window Solar Inst. (Watts)	Window Solar Lag (Watts)	Sensible Cas. Gains (Watts)	Latent Cas. Gains (Watts)	Sensible Vent. Gains (Watts)	Latent Vent. Gains (Watts)	Conduction & Storage (Watts)	Heat Gains: Sens. Plant Output (W)	Heat Gains: Latent Plant Output (W)	total gain	total/m2	solar/m2	conduction/ m2
01:00	28 55	23	24 68	23 84	70	0	0	360	240	429	985	348	-1137	-1225	2362	107.36	0 00	15 82
02 00	29 27	23	24 39	23 7	70	0	0	360	240	485	1003	259	-1104	-1243	2347	106 68	0 00	11 77
03 00	30 42	23	24 36	23.68	70	0	0	360	240	574	1032	248	-1183	-1272	2455	111 59	0 00	11 27
04 00	31.92	23	24 32	23 66	70	0	0	360	240	691	1073	237	-1287	-1313	2600	118 18	0 00	10 77
05 00	33 67	23	24 28	23 64	70	0	0	360	240	826	1125	224	-1410	-1365	2775	126 14	0 00	10 18
06 00	35 55	23	24 05	23 52	70	0	0	0	0	139	169	261	-400	-169	569	25 86	0 00	11 86
07 00	37.43	23	24 04	23 52	70	5	1	0	0	159	179	256	-417	-179	596	27 09	0 23	11 64
08:00	39 17	23	24 05	23 52	70	9	6	0	0	179	188	254	-439	-188	627	28.50	0 41	11 55
09 00	40 68	23	24 05	23 52	70	12	9	0	0	195	197	252	-457	-197	654	29 73	0 55	11 45
10 00	41 83	23	24 07	23 54	70	14	12	0	0	208	204	257	-477	-204	681	30 95	0 64	11 68

11.00	42.55	23	24.21	23.6	70	15	14	0	0	216	209	301	-531	-209	740	33.84	0.68	13.68
12.00	42.8	23	24.23	23.62	70	17	18	0	0	219	211	307	-542	-211	753	34.23	0.77	13.95
13.00	42.55	23	24.27	23.64	70	33	21	0	0	218	209	314	-551	-209	760	34.55	1.50	14.27
14.00	41.83	23	24.55	23.78	70	57	37	360	240	1457	1431	276	-2130	-1671	3801	172.77	2.59	12.55
15.00	40.88	23	24.62	23.81	70	75	60	360	240	1368	1381	275	-2062	-1621	3683	167.41	3.41	12.50
16.00	39.17	23	24.47	23.74	70	81	76	0	0	179	188	322	-576	-188	764	34.73	3.88	14.84
17.00	37.43	23	24.52	23.76	70	75	80	0	0	159	179	334	-573	-179	752	34.18	3.41	15.18
18.00	35.55	23	24.53	23.76	70	93	71	0	0	139	189	345	-555	-189	724	32.91	2.41	15.88
19.00	33.67	23	24.53	23.76	70	0	42	0	0	118	181	373	-534	-181	695	31.59	0.00	16.95
20.00	31.92	23	24.79	23.9	70	0	0	360	240	891	1073	388	-1439	-1313	2752	125.09	0.00	17.64
21.00	30.42	23	24.86	23.93	70	0	0	360	240	874	1032	411	-1345	-1272	2617	118.95	0.00	18.68
22.00	29.27	23	24.89	23.94	70	0	0	360	240	485	1003	421	-1264	-1243	2509	114.05	0.00	19.14
23.00	28.55	23	24.9	23.95	70	0	0	360	240	429	985	473	-1212	-1225	2437	110.77	0.00	19.23
24.00	29.3	23	24.85	23.92	70	0	0	360	240	410	960	408	-1178	-1220	2398	109.00	0.00	19.55

Total Peak Load in different rooms (W/m²)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161	Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Hr	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0	Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
01.00	93.09	91.87	96.50	95.27	95.93	94.60	105.45	104.27	109.09	108.14	108.30	107.30
02.00	95.74	93.94	95.27	93.47	95.74	93.94	108.09	106.64	107.73	106.32	108.14	108.64
03.00	100.86	98.89	100.38	98.48	100.76	98.89	113.05	111.50	112.77	111.27	113.09	111.59
04.00	107.44	105.59	107.20	105.30	107.58	105.59	119.86	118.23	119.55	117.95	119.77	118.18
05.00	115.72	113.73	115.25	113.35	115.83	113.84	128.05	126.36	127.45	125.82	127.77	126.14
06.00	27.75	25.86	27.27	25.19	27.85	25.47	28.00	26.09	27.41	25.59	27.86	25.86
07.00	29.55	27.46	28.41	26.33	28.88	26.70	29.89	27.82	28.64	26.77	28.95	27.09
08.00	32.39	30.40	29.83	27.75	30.21	28.13	32.50	30.82	30.05	28.18	30.36	28.55
09.00	33.96	32.01	31.25	29.17	31.63	29.55	33.82	32.18	31.18	29.41	31.50	29.73
10.00	34.85	32.97	32.29	30.30	32.77	30.68	34.82	33.23	32.36	30.64	32.86	30.91
11.00	35.32	33.57	33.14	31.25	33.62	31.83	35.45	33.91	33.32	31.68	33.64	32.00
12.00	35.23	33.43	33.71	31.91	34.19	32.29	35.36	33.86	33.86	32.36	34.23	32.64
13.00	35.04	33.24	33.90	32.20	34.47	32.77	35.09	33.64	34.09	32.68	34.55	33.18
14.00	165.91	164.87	159.85	158.52	160.81	159.28	178.14	177.41	172.05	171.14	172.77	171.86
15.00	160.89	160.23	154.26	153.31	155.30	154.36	173.09	172.77	166.55	166.00	167.41	166.95
16.00	39.39	39.02	33.81	33.14	34.66	34.09	39.59	39.45	34.00	33.73	34.73	34.45
17.00	37.69	37.41	33.43	33.14	34.00	33.62	38.14	38.14	33.77	33.77	34.18	34.18
18.00	34.85	34.66	32.39	32.29	32.87	32.48	35.27	35.41	32.77	32.95	32.91	33.05
19.00	31.91	31.72	30.78	30.68	31.34	31.25	32.00	32.14	31.09	31.32	31.59	31.77
20.00	111.46	111.36	110.32	110.13	112.69	112.69	123.73	123.91	122.82	123.05	125.09	125.36
21.00	103.98	103.69	104.26	104.07	106.53	108.44	116.27	118.32	116.82	117.00	118.95	119.18
22.00	98.20	97.73	100.00	99.72	101.61	101.33	110.41	110.23	112.55	112.55	114.05	114.09
23.00	94.41	93.56	97.44	96.88	98.30	97.73	106.73	108.23	109.95	109.68	110.77	110.55
24.00	92.61	91.48	96.50	95.64	95.40	95.55	105.09	104.23	109.09	108.50	109.00	108.41

Solar Peak Load in different rooms (W/m²)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161
Hr	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0
01.00	0.00	0.00	0.00	0.00	0.00
02.00	0.00	0.00	0.00	0.00	0.00
03.00	0.00	0.00	0.00	0.00	0.00
04.00	0.00	0.00	0.00	0.00	0.00
05.00	0.00	0.00	0.00	0.00	0.00
06.00	0.00	0.00	0.00	0.00	0.00
07.00	4.83	4.83	0.28	0.28	0.28
08.00	5.39	5.39	0.38	0.38	0.38
09.00	5.30	5.30	0.57	0.57	0.57
10.00	4.17	4.17	0.66	0.66	0.66
11.00	2.46	2.46	0.66	0.66	0.66
12.00	0.95	0.95	0.76	0.76	0.76
13.00	0.76	0.75	0.76	0.76	1.52
14.00	0.66	0.66	1.04	1.04	2.85
15.00	0.66	0.66	2.27	2.27	3.80
16.00	0.57	0.57	3.50	3.50	3.88
17.00	0.38	0.38	4.17	4.17	3.80
18.00	0.19	0.19	3.69	3.69	2.46
19.00	0.00	0.00	0.00	0.00	0.00
20.00	0.00	0.00	0.00	0.00	0.00
21.00	0.00	0.00	0.00	0.00	0.00
22.00	0.00	0.00	0.00	0.00	0.00
23.00	0.00	0.00	0.00	0.00	0.00
24.00	0.00	0.00	0.00	0.00	0.00

Conduction Peak Load in different rooms (W/m²)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161	Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Hr	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0	Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
01.00	14.58	13.16	17.99	16.76	17.42	16.10	13.86	12.73	17.55	16.59	16.82	15.82
02.00	13.92	12.12	13.45	11.65	13.92	12.12	13.18	11.73	12.82	11.36	13.18	11.77
03.00	13.54	11.65	13.16	11.36	13.54	11.74	12.77	11.23	12.45	10.95	12.77	11.27
04.00	13.16	11.17	12.88	10.98	13.16	11.27	12.41	10.77	12.09	10.50	12.36	10.77
05.00	12.88	10.89	12.41	10.42	12.69	10.80	12.09	10.41	11.50	9.86	11.82	10.18
06.00	13.83	11.65	13.35	11.27	13.64	11.55	14.00	12.09	13.41	11.59	13.68	11.86
07.00	13.35	11.27	12.97	10.89	13.35	11.27	13.55	11.64	13.23	11.36	13.55	11.64
08.00	10.80	8.81	12.88	10.80	13.26	11.17	11.09	9.36	13.09	11.27	13.41	11.55
09.00	10.42	8.52	12.88	10.80	13.26	11.17	10.64	9.00	12.95	11.14	13.23	11.45
10.00	10.89	9.09	12.97	10.98	13.45	11.36	11.14	9.55	13.09	11.36	13.41	11.68
11.00	12.12	10.32	13.26	11.27	13.64	11.65	12.41	10.86	13.36	11.73	13.68	12.05
12.00	13.64	11.84	13.54	11.65	13.92	12.03	13.77	12.27	13.68	12.14	13.95	12.45
13.00	14.87	13.07	13.92	12.12	14.20	12.41	14.91	13.50	14.05	12.68	14.27	12.86
14.00	19.70	18.66	13.45	12.12	13.35	12.03	18.91	18.18	12.68	11.77	12.55	11.64
15.00	21.02	20.36	13.83	12.88	13.26	12.41	20.23	19.91	13.05	12.50	12.50	12.00
16.00	22.16	21.69	14.68	14.02	14.39	13.83	22.32	22.18	14.95	14.64	14.64	14.36
17:00	21.78	21.59	14.49	14.11	14.77	14.49	22.23	22.27	14.95	14.91	15.18	15.18
18.00	20.45	20.36	14.39	14.20	15.34	15.15	20.95	21.05	14.91	15.09	15.68	15.82
19.00	19.03	18.84	15.06	14.96	16.76	16.57	19.18	19.27	15.50	15.73	16.95	17.18
20.00	17.14	16.95	16.00	15.81	18.37	18.28	16.27	16.45	15.36	15.59	17.64	17.91
21:00	16.76	16.57	17.05	16.86	19.32	19.22	16.00	16.05	16.55	16.68	18.68	18.86

Conduction and Solar Peak Load in different rooms (W/m²)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161
Hr	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0
01.00	14.58	13.16	17.99	16.76	17.42
02.00	13.92	12.12	13.45	11.65	13.92
03.00	13.54	11.65	13.16	11.36	13.54
04.00	13.16	11.17	12.88	10.98	13.16
05.00	12.88	10.89	12.41	10.42	12.69
06.00	13.83	11.65	13.35	11.27	13.64
07.00	18.18	16.10	13.26	11.17	13.64
08.00	16.38	14.39	13.26	11.17	13.64
09.00	15.72	13.83	13.45	11.36	13.83
10.00	15.06	13.26	13.64	11.65	14.11
11:00	14.58	12.78	13.92	11.93	14.30
12.00	14.58	12.78	14.30	12.41	14.68
13.00	15.63	13.83	14.68	12.88	15.72
14.00	20.36	19.32	14.49	13.16	16.00
15.00	21.69	21.02	16.10	15.15	16.86
16.00	22.73	22.25	18.18	17.52	18.28
17.00	22.16	21.97	18.66	18.28	18.37
18.00	20.64	20.55	18.09	17.90	17.80
19.00	19.03	18.84	15.06	14.96	16.76
20.00	17.14	16.95	16.00	15.81	18.37
21.00	16.76	16.57	17.05	16.86	19.32

11.00	42.55	23	24.1	23.55	70	15	14	0	0	210	209	203	-499	-210	204	32.00	0.88	12.05
12.00	42.8	23	24.14	23.57	70	17	16	0	0	219	211	274	-508	-211	119	32.68	0.77	12.43
13.00	42.55	23	24.19	23.8	70	33	21	0	0	216	209	281	-521	-209	130	31.18	1.50	12.86
14.00	41.83	23	24.5	23.75	70	87	37	360	240	1457	1431	256	-2110	-1671	3781	171.86	2.59	11.64
15.00	40.68	23	24.6	23.8	70	75	80	360	240	1368	1381	294	-2092	-1621	3673	168.95	3.41	12.00
16.00	39.17	23	24.47	23.74	70	81	78	0	0	179	188	316	-870	-188	758	34.45	3.68	14.36
17.00	37.43	23	24.54	23.77	70	75	80	0	0	159	179	334	-873	-179	752	34.18	3.41	15.18
18.00	35.55	23	24.55	23.78	70	53	71	0	0	139	169	348	-858	-169	727	33.05	2.41	15.82
19.00	33.67	23	24.35	23.78	70	0	42	0	0	118	161	378	-538	-161	699	31.77	0.00	17.18
20.00	31.92	23	24.82	23.91	70	0	0	360	240	891	1073	384	-1445	-1313	2758	125.36	0.00	17.91
21.00	30.42	23	24.89	23.94	70	0	0	360	240	874	1032	415	-1390	-1277	2622	119.18	0.00	18.86
22.00	29.27	23	24.91	23.96	70	0	0	360	240	485	1003	422	-1267	-1243	2510	114.09	0.00	19.18
23.00	28.55	23	24.9	23.95	70	0	0	360	240	426	985	418	-1207	-1275	2432	110.55	0.00	19.05
24.00	28.3	23	24.82	23.91	70	0	0	360	240	410	980	395	-1165	-1270	2385	108.41	0.00	17.86

Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.29	4.59	4.59	0.23	0.23	0.23	0.23
0.38	5.41	5.41	0.41	0.41	0.41	0.41
0.57	5.09	5.09	0.55	0.55	0.55	0.55
0.66	4.00	4.00	0.64	0.64	0.64	0.64
0.66	2.36	2.36	0.68	0.68	0.68	0.68
0.76	0.86	0.86	0.73	0.73	0.77	0.77
1.52	0.73	0.73	0.73	0.73	1.50	1.50
2.65	0.68	0.68	1.05	1.05	2.59	2.59
3.60	0.59	0.59	2.23	2.23	3.41	3.41
3.84	0.50	0.50	3.36	3.36	3.68	3.68
3.90	0.36	0.36	4.00	4.00	3.41	3.41
2.46	0.23	0.23	3.55	3.55	2.41	2.41
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00

Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
16.10	13.86	12.73	17.55	16.59	16.82	15.82
12.12	13.18	11.73	12.82	11.36	13.18	11.77
11.74	12.77	11.23	12.45	10.95	12.77	11.27
11.27	12.41	10.77	12.09	10.50	12.36	10.77
10.80	12.09	10.41	11.50	9.86	11.82	10.18
11.55	14.00	12.09	13.41	11.59	13.68	11.86
11.55	18.14	16.23	13.45	11.59	13.77	11.86
11.55	16.50	14.77	13.50	11.68	13.82	11.95
11.74	15.73	14.09	13.50	11.68	13.77	12.00
12.03	15.14	13.55	13.73	12.00	14.05	12.32
12.31	14.77	13.23	14.05	12.41	14.36	12.73
12.78	14.64	13.14	14.41	12.86	14.73	13.23
13.92	15.64	14.23	14.77	13.41	15.77	14.36
14.68	19.59	18.86	13.73	12.82	15.14	14.23
16.00	20.82	20.50	15.27	14.73	15.91	15.41
17.71	22.82	22.68	18.32	18.00	18.32	18.05
18.09	22.59	22.64	18.95	18.91	18.59	18.59
17.61	21.18	21.27	18.45	18.64	18.09	18.23
16.57	19.18	19.27	15.50	15.73	16.95	17.18
18.28	16.27	16.45	15.36	15.59	17.64	17.91
19.22	16.00	16.05	16.55	16.68	18.68	18.86

22 00	16 38	15 91	18.18	17 90	19 79	19 51	15 50	15 32	17 64	17 64	19 14	19 18
23 00	15 91	15 06	18 94	18 37	19.79	19 22	15.18	14 68	18 41	18.14	19.23	19.00
24.00	15 25	14.11	19 13	18.28	19.13	18.18	14.59	13.77	18 64	18 05	18.55	17.95

Total Annual Load in different rooms (KWH/m^2)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161	Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Month	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0	Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
Jan	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 00	0 01	0 02
Feb	0 04	0 08	0 00	0 01	0 06	0 11	0.28	0 36	0 12	0 17	0 50	0 68
Mar	2.14	2 55	1 43	1 76	2 52	2 99	3 99	4 38	3 21	3 56	4 69	5 10
Apr	10 18	10 56	9 08	9 45	9 88	10 26	12 70	13 00	11 66	11 96	12 48	12 78
May	19 85	19 68	19 23	19 04	19.13	18 95	22 53	22 41	21 94	21 82	21 82	21 70
Jun	25 18	24 69	24.71	24 21	24 07	23 57	27.77	27 42	27.33	26 97	26 66	26 29
Jul	29 72	29 01	29 19	28 47	28.78	28 06	32 39	31 87	31 89	31 38	31 45	30 93
Aug	31 07	30 11	30.14	29 17	30 63	29 67	33 71	32 97	32 84	32 10	33 30	32 56
Sep	25 05	24 19	23 88	23 01	25 49	24 63	27 59	26 89	26 49	25 78	28 07	27 38
Oct	17.27	16 65	15 76	15 13	18.38	17 77	19 88	19 32	18 46	17 89	21 07	20 52
Nov	7 19	6 99	5 96	5 77	8.52	8 33	9 56	9 28	8 38	8 12	11 06	10 79
Dec	0 46	0 49	0 24	0 26	0 79	0 86	1 23	1 25	0 87	0 88	2 04	2 11
Total	168 15	164 99	159 61	156 29	168.24	165 20	191 62	189 16	183 21	180 63	193 16	190 85

Conduction Annual Load in different rooms (KWH/m^2)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161	Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Month	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0	Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
Jan	-0 15	0 02	-0 70	-0 58	0 47	0 71	-0 51	-0 48	-1 09	-1.10	0 02	0 11
Feb	0 02	0 67	-0 68	-0 10	0 49	1 19	-0 28	0 22	-1.05	-0 59	0.11	0 67
Mar	0 79	1 52	-0 01	0 69	1.21	1.95	0 66	1 20	-0 17	0 35	1 08	1 62
Apr	3 76	4 26	2 83	3 32	3 51	4 00	3 66	4 08	2 73	3 14	3 41	3 82
May	7 29	7 05	6 76	6 52	6 69	6 44	7.15	6 98	6 62	6 45	6 55	6 38
Jun	9 38	8 73	8 98	8 33	8 45	7 80	9.20	8 71	8 81	8 32	8.29	7.79
Jul	10 75	9 82	10 30	9 37	9 97	9 03	10 56	9 84	10 12	9 40	9 79	9 07
Aug	11 28	10 02	10.50	9 24	10 91	9 65	11 09	10 07	10 32	9 29	10 72	9 70
Sep	9 17	8 04	8 19	7 04	9 52	8 40	9 01	8 04	8 04	7 06	9 35	8 39
Oct	6 49	5 69	5 21	4 39	7 40	6 61	6 37	5 60	5 10	4 31	7.26	6 50
Nov	2 75	2 43	1 67	1 33	3 86	3 55	2 66	2 23	1.58	1.14	3 76	3 34
Dec	0 16	0 14	-0 48	-0 55	0 96	1 02	-0 09	-0 26	-0 78	-0 98	0 69	0 59
Total	61.70	58 41	52 58	49 00	63 43	60 34	59 49	56 24	50 23	46 78	61.02	57 97

R oom type CE LL0071 - cell

I Month	Windo Sola	H w Interna r Casual	EAT I EXTERNA Conduct	GAINS L ELEMENTS n. Ventiltn	(MJ) OTHER Conductn.	ELEMEN Ventil	TS	Plant In.
JAN	26.3	482.1	-38	-314.6	-155 6		0	-0.1
FEB	33.3	435.5	17.3	-279.6	-177.5		0	-28.7
MAR	39 7	482.1	94.8	-163	-106.2		0	-347.1
APR	51	466 6	322.8	237.6	-48		0	-1029.6
MAY	53.2	482.1	552.8	719	-32		0	-1774.9
JUN	59.2	466.6	690.2	983	-27.4		0	-2171.3
JUL	59.3	482.1	779.7	1229 5	-25.9		0	-2524.4
AUG	58.9	482.1	797.7	1297	-23.9		0	-2611.6
SEP	50.8	466.6	637	997.9	-22.4		0	-2129.5
OCT	47.2	482.1	443.3	583.1	-25.3		0	-1530.2
NOV	35.6	466.6	176 8	95.3	-38.9		0	-735.2
DEC	26 6	482.1	-20.2	-275 8	-113.7		0	-99

R oom type CE LL0083 - cell

I Month	Windo Sola	H w Interna r Casual	EAT I EXTERNA Conduct	GAINS L ELEMENTS n. Ventiltn	(MJ) OTHER Conductn.	ELEMEN Ventil	TS	Plant In.
JAN	13.2	120.5	0.8	-113.2	-21.1		0	0
FEB	16.7	108.9	25.6	-103.1	-44.7		0	-3
MAR	19.9	120.5	57.9	-68.1	-33		0	-96.8
APR	25.6	116.6	162	114.7	-17.2		0	-401.3
MAY	26.7	120.5	268.2	345.1	-12.2		0	-748

22:00	16 38	15 91	18 18	17 90	19 79
23:00	15 91	15.06	18 94	18.37	19.79
24:00	15 25	14.11	19 13	18 28	19 13

Solar Annual Load in different rooms (KWH/m^2)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161
Month	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0
Jan	0 35	0 35	0 14	0 14	0 61
Feb	0 44	0 44	0 17	0 17	0 63
Mar	0 52	0 52	0 27	0 27	0 64
Apr	0 67	0 67	0 39	0 39	0 56
May	0 70	0 70	0 54	0 54	0 48
Jun	0 78	0 78	0 66	0 66	0 45
Jul	0 78	0 78	0 64	0 64	0 49
Aug	0 78	0 78	0 53	0 53	0 62
Sep	0 67	0 67	0 37	0 37	0 74
Oct	0 62	0 62	0 24	0 24	0 88
Nov	0 47	0 47	0 16	0 16	0 79
Dec	0 35	0 35	0 13	0 13	0 65
Total	7 14	7 14	4 23	4 23	7 54

Conduction and solar Annual Load in different rooms (KWH/m^2)

	Cell 91	Cell 83	Cell 126	Cell 118	Cell 161
Month	Single East 0	Single East 1	Single NW 0	Single NW 1	Single SW0
Jan	0 19	0 37	-0 56	-0 44	1 08
Feb	0 46	1 11	-0 52	0 07	1 11
Mar	1.32	2 05	0 26	0 96	1 85
Apr	4 43	4 93	3 22	3 71	4 07
May	7 99	7 76	7 31	7 07	7 17
Jun	10 16	9 51	9 64	8 99	8 90
Jul	11 53	10 60	10 94	10 01	10 46
Aug	12 06	10 80	11 03	9 77	11 53
Sep	9 84	8 71	8 55	7 41	10 26
Oct	7.12	6 31	5 45	4 63	8 28
Nov	3 22	2 89	1 83	1 49	4 65
Dec	0 51	0 49	-0 35	-0 43	1 62
Total	68 84	65 55	56 81	53 23	70 96

Cell 71 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m^2	Conduction Load KWH/m^2	Solar Load KWH/m^2
Jan	7.31	133 92	-10 56	-87 39	-43 22	-0 03	0 03	0 00	-0 48	0 33
Feb	9.25	120 97	4 81	-77.67	-49 31	-7 97	7 97	0 36	0.22	0 42
Mar	11 03	133 92	26.33	-45 28	-29 50	-96 42	96 42	4.38	1.20	0 50
Apr	14.17	129 61	89 67	66 00	-13 33	-286 00	286 00	13 00	4 08	0 64
May	14 78	133 92	153 56	199 72	-8 89	-493 03	493 03	22 41	6 98	0 67
Jun	16 44	129 61	191.72	273.06	-7 61	-603 14	603 14	27.42	8 71	0 75
Jul	16 47	133 92	216 58	341 53	-7 19	-701.22	701 22	31 87	9 84	0 75
Aug	16 36	133 92	221 58	360.28	-6 64	-725 44	725 44	32 97	10 07	0.74
Sep	14 11	129 61	176 94	277.19	-6.22	-591 53	591.53	26 89	8 04	0 64
Oct	13.11	133 92	123.14	161 97	-7.03	-425 06	425 06	19.32	5 60	0 60
Nov	9 89	129 61	49 11	26 47	-10 81	-204 22	204.22	9 28	2 23	0 45
Dec	7 39	133 92	-5 61	-76 61	-31 58	-27 50	27 50	1 25	-0 26	0 34

Cell 83 annual load KWH

I	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m^2	Conduction Load KWH/m^2	solar Load KWH/m^3
Jan	3 67	33 47	0.22	-31 44	-5 86	0 00	0 00	0 00	0 02	0 35
Feb	4 64	30 25	7.11	-28 64	-12 42	-0 83	0 83	0 08	0 67	0 44
Mar	5 53	33 47	16 08	-18 92	-9 17	-26 89	26 89	2 55	1.52	0 52
Apr	7.11	32.39	45 00	31.86	-4 78	-111 47	111 47	10 56	4.26	0 67
May	7 42	33 47	74.50	95 86	-3 39	-207.78	207.78	19 68	7 05	0 70

19.51	15.50	15.32	17.64	17.64	19.14	19.18
19.22	15.18	14.68	18.41	18.14	19.23	19.00
18.18	14.59	13.77	18.64	18.05	18.55	17.95

Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
0.61	0.33	0.33	0.13	0.13	0.58	0.58
0.63	0.42	0.42	0.16	0.16	0.60	0.60
0.64	0.50	0.50	0.25	0.25	0.61	0.61
0.56	0.64	0.64	0.37	0.37	0.54	0.54
0.48	0.67	0.67	0.52	0.52	0.46	0.46
0.45	0.75	0.75	0.63	0.63	0.43	0.43
0.49	0.75	0.75	0.61	0.61	0.47	0.47
0.62	0.74	0.74	0.51	0.51	0.60	0.60
0.74	0.64	0.64	0.35	0.35	0.71	0.71
0.88	0.60	0.60	0.23	0.23	0.84	0.84
0.79	0.45	0.45	0.15	0.15	0.75	0.75
0.65	0.34	0.34	0.12	0.12	0.63	0.63
7.54	6.83	6.83	4.05	4.05	7.22	7.22

Cell 153	Cell 89	Cell 71	Cell 124	Cell 116	Cell 160	Cell 152
Single SW 1	Multi East 0	Multi East 1	Multi NW 0	Multi NW 1	Multi SW 0	Multi SW 1
1.32	-0.18	-0.15	-0.96	-0.97	0.60	0.69
1.82	0.14	0.64	-0.89	-0.44	0.71	1.27
2.59	1.16	1.70	0.08	0.60	1.69	2.23
4.56	4.31	4.72	3.11	3.51	3.95	4.36
6.92	7.82	7.65	7.14	6.97	7.01	6.83
8.25	9.95	9.46	9.44	8.95	8.72	8.22
9.52	11.30	10.59	10.73	10.01	10.26	9.54
10.27	11.83	10.82	10.83	9.80	11.31	10.30
9.14	9.65	8.68	8.39	7.41	10.06	9.10
7.48	6.96	6.19	5.33	4.55	8.09	7.34
4.34	3.11	2.68	1.74	1.29	4.51	4.09
1.68	0.25	0.06	-0.66	-0.86	1.32	1.22
67.88	66.32	63.07	54.27	50.83	68.23	65.18

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JUN	29.7	116.6	332	471.9	-11.2		0	-938.5
JUL	29.7	120.5	373.2	590.2	-10.4		0	-1102.7
AUG	29.5	120.5	381.1	622.6	-8.6		0	-1144.6
SEP	25.5	116.6	305.8	479	-6.8		0	-919.6
OCT	23.7	120.5	216.3	279.9	-6.8		0	-633.1
NOV	17.8	116.6	92.2	48	-8.6		0	-265.9
DEC	13.3	120.5	5.5	-108	-12.5		0	-18.6

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Jun	8.25	32.39	92.22	131.08	-3.11	-260.69	260.69	24.69	8.73	0.78
Jul	8.25	33.47	103.67	163.94	-2.89	-306.31	306.31	29.01	9.82	0.78
Aug	8.19	33.47	105.86	172.94	-2.39	-317.94	317.94	30.11	10.02	0.78
Sep	7.08	32.39	84.94	133.06	-1.89	-255.44	255.44	24.19	8.04	0.67
Oct	6.58	33.47	60.08	77.75	-1.89	-175.86	175.86	16.65	5.69	0.62
Nov	4.94	32.39	25.61	13.33	-2.39	-73.86	73.86	6.99	2.43	0.47
Dec	3.69	33.47	1.53	-30.00	-3.47	-5.17	5.17	0.49	0.14	0.35

R oom type CE LL0089 - cell

HEAT GAINS (MJ)

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	26.3	482.1	-40.2	-312.1	-156		0	0
FEB	33.3	435.5	-22.3	-272.7	-151.5		0	-21.9
MAR	39.7	482.1	52.5	-162.1	-95.7		0	-316.2
APR	51	466.6	290	237.5	-39.2		0	-1005.6
MAY	53.2	482.1	565.9	719	-35.5		0	-1784.4
JUN	59.2	466.6	729	983	-38		0	-2199.5
JUL	59.3	482.1	836	1229.5	-41.3		0	-2565.2
AUG	58.9	482.1	878.1	1297	-45.9		0	-2669.9
SEP	50.8	466.6	713.7	997.9	-43.5		0	-2185.1
OCT	47.2	482.1	504.4	583.1	-42.2		0	-1574.4
NOV	35.6	466.6	211	94.9	-50.8		0	-757.1
DEC	26.6	482.1	-6.8	-276.8	-128		0	-97.2

Cell 89 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Jan	7.31	133.92	-11.17	-86.69	-43.33	0.00	0.00	0.00	-0.51	0.33
Feb	9.25	120.97	-6.19	-75.75	-42.08	-6.08	6.08	0.28	-0.28	0.42
Mar	11.03	133.92	14.58	-45.03	-26.58	-87.83	87.83	3.99	0.66	0.50
Apr	14.17	129.61	80.56	65.97	-10.89	-279.33	279.33	12.70	3.66	0.64
May	14.78	133.92	157.19	199.72	-9.86	-495.67	495.67	22.53	7.15	0.67
Jun	16.44	129.61	202.50	273.06	-10.56	-610.97	610.97	27.77	9.20	0.75
Jul	16.47	133.92	232.22	341.53	-11.47	-712.56	712.56	32.39	10.56	0.75
Aug	16.36	133.92	243.92	360.28	-12.75	-741.64	741.64	33.71	11.09	0.74
Sep	14.11	129.61	198.25	277.19	-12.08	-606.97	606.97	27.59	9.01	0.64
Oct	13.11	133.92	140.11	161.97	-11.72	-437.33	437.33	19.88	6.37	0.60
Nov	9.89	129.61	58.61	26.36	-14.11	-210.31	210.31	9.56	2.66	0.45
Dec	7.39	133.92	-1.89	-76.89	-35.56	-27.00	27.00	1.23	-0.09	0.34

R oom type CE LL0091 - cell

HEAT GAINS (MJ)

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	13.2	120.5	-5.8	-111.5	-16.2		0	0
FEB	16.7	108.9	0.8	-98.5	-25.7		0	-1.7
MAR	19.9	120.5	30.2	-66.6	-22.4		0	-81.3
APR	25.6	116.6	143	114.7	-12.7		0	-386.9
MAY	26.7	120.5	277.2	345.1	-14.3		0	-754.8
JUN	29.7	116.6	356.4	471.9	-17		0	-957.2
JUL	29.7	120.5	408.5	590.2	-18.8		0	-1129.7
AUG	29.5	120.5	428.9	622.6	-19.9		0	-1181.1
SEP	25.5	116.6	348.7	479	-17		0	-952.4
OCT	23.7	120.5	246.8	279.9	-14		0	-656.5
NOV	17.8	116.6	104.7	47.6	-13.1		0	-273.4
DEC	13.3	120.5	6.2	-108	-14.6		0	-17.3

Cell 91 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	3.67	33.47	-1.61	-30.97	-4.50	0.00	0.00	0.00	-0.15	0.35
Feb	4.64	30.25	0.22	-27.36	-7.14	-0.47	0.47	0.04	0.02	0.44
Mar	5.53	33.47	8.39	-18.50	-6.22	-22.58	22.58	2.14	0.79	0.52
Apr	7.11	32.39	39.72	31.86	-3.53	-107.47	107.47	10.18	3.76	0.67
May	7.42	33.47	77.00	95.86	-3.97	-209.67	209.67	19.85	7.29	0.70
Jun	8.25	32.39	99.00	131.08	-4.72	-265.89	265.89	25.18	9.38	0.78
Jul	8.25	33.47	113.47	163.94	-5.22	-313.81	313.81	29.72	10.75	0.78
Aug	8.19	33.47	119.14	172.94	-5.53	-328.08	328.08	31.07	11.28	0.78
Sep	7.08	32.39	96.86	133.06	-4.72	-264.56	264.56	25.05	9.17	0.67
Oct	6.58	33.47	68.56	77.75	-3.89	-182.36	182.36	17.27	6.49	0.62
Nov	4.94	32.39	29.08	13.22	-3.64	-75.94	75.94	7.19	2.75	0.47
Dec	3.69	33.47	1.72	-30.00	-4.06	-4.81	4.81	0.46	0.16	0.35

R oom type CE LL0116 - cell

HEAT GAINS (MJ)

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	10.4	482.1	-87	-287.9	-117.6		0	0
FEB	12.6	435.5	-47.1	-252.5	-135.1		0	-13.1
MAR	20.1	482.1	27.6	-158.8	-89		0	-281.9
APR	29.6	466.6	248.6	237.7	-34.7		0	-947.6
MAY	41.2	482.1	511.1	719	-25.1		0	-1728
JUN	49.9	466.6	659	983	-22		0	-2136.2
JUL	48.5	482.1	744.6	1229.5	-19.6		0	-2484.9
AUG	40.3	482.1	735.9	1297	-13		0	-2542.2
SEP	27.7	466.6	558.8	997.9	-8.7		0	-2042.1
OCT	18.5	482.1	341.5	583.1	-8		0	-1417.1
NOV	12.1	466.6	90.2	96.1	-21.7		0	-643.1
DEC	9.5	482.1	-77.9	-259.9	-83.8		0	-70

Cell 116 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Jan	2.89	133.92	-24.17	-79.97	-32.67	0.00	0.00	0.00	-1.10	0.13
Feb	3.50	120.97	-13.08	-70.14	-37.53	-3.64	3.64	0.17	-0.59	0.16
Mar	5.58	133.92	7.67	-44.11	-24.72	-78.31	78.31	3.56	0.35	0.25
Apr	8.22	129.61	69.06	66.03	-9.64	-263.22	263.22	11.96	3.14	0.37
May	11.44	133.92	141.97	199.72	-6.97	-480.00	480.00	21.82	6.45	0.52
Jun	13.86	129.61	183.06	273.06	-6.11	-593.39	593.39	26.97	8.32	0.63
Jul	13.47	133.92	206.83	341.53	-5.44	-690.25	690.25	31.38	9.40	0.61
Aug	11.19	133.92	204.42	360.28	-3.61	-706.17	706.17	32.10	9.29	0.51
Sep	7.69	129.61	155.22	277.19	-2.42	-567.25	567.25	25.78	7.06	0.35
Oct	5.14	133.92	94.86	161.97	-2.22	-393.64	393.64	17.89	4.31	0.23
Nov	3.36	129.61	25.06	26.69	-6.03	-178.64	178.64	8.12	1.14	0.15
Dec	2.64	133.92	-21.64	-72.19	-23.28	-19.44	19.44	0.88	-0.98	0.12

R oom type CE LL0118 - cell

HEAT GAINS (MJ)

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	5.2	120.5	-22	-97.2	-6.5		0	0
FEB	6.3	108.9	-3.8	-84.2	-26.6		0	-0.3
MAR	10.1	120.5	26.3	-63.1	-26.9		0	-66.8
APR	14.8	116.6	126.1	114.8	-12.9		0	-359.2
MAY	20.7	120.5	248	345.1	-10.1		0	-723.9
JUN	25	116.6	316.8	471.9	-9.4		0	-920.5
JUL	24.3	120.5	356.2	590.2	-8.4		0	-1082.4
AUG	20.2	120.5	351.1	622.6	-5.1		0	-1109.1
SEP	13.9	116.6	267.8	479	-2.3		0	-874.8
OCT	9.3	120.5	166.9	279.9	-1.2		0	-575.2
NOV	6.1	116.6	50.5	48.9	-2.8		0	-219.4

Cell 118 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	1.44	33.47	-6.11	-27.00	-1.81	0.00	0.00	0.00	-0.58	0.14
Feb	1.75	30.25	-1.06	-23.39	-7.39	-0.08	0.08	0.01	-0.10	0.17
Mar	2.81	33.47	7.31	-17.53	-7.47	-18.56	18.56	1.76	0.69	0.27
Apr	4.11	32.39	35.03	31.89	-3.58	-99.78	99.78	9.45	3.32	0.39
May	5.75	33.47	68.89	95.86	-2.81	-201.08	201.08	19.04	6.52	0.54
Jun	6.94	32.39	88.00	131.08	-2.61	-255.69	255.69	24.21	8.33	0.66
Jul	6.75	33.47	98.94	163.94	-2.33	-300.67	300.67	28.47	9.37	0.64
Aug	5.61	33.47	97.53	172.94	-1.42	-308.08	308.08	29.17	9.24	0.53
Sep	3.86	32.39	74.39	133.06	-0.64	-243.00	243.00	23.01	7.04	0.37
Oct	2.58	33.47	46.36	77.75	-0.33	-159.78	159.78	15.13	4.39	0.24
Nov	1.69	32.39	14.03	13.58	-0.72	-60.94	60.94	5.77	1.33	0.16

Month	Window Solar	Internal Casual	External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
DEC	4.8	120.5	-21	-95.2	0.8		0	-9.9

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Dec	1.33	33.47	-5.83	-26.44	0.22	-2.75	2.75	0.26	-0.55	0.13

Room type CELL0124 - cell

Month	Window Solar	Internal Casual	EAT GAINS (MJ) External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	10.4	482.1	-86.5	-285.6	-120.4		0	0
FEB	12.6	435.5	-83.2	-244.8	-110.1		0	-9.7
MAR	20.1	482.1	-13.5	-157.3	-77.1		0	-254.2
APR	29.6	466.6	216.6	237.6	-26.6		0	-923.7
MAY	41.2	482.1	524.4	719	-28.8		0	-1737.7
JUN	49.9	466.6	698.1	983	-32.7		0	-2164.6
JUL	48.5	482.1	801.3	1229.5	-35.2		0	-2526
AUG	40.3	482.1	817.1	1297	-35.3		0	-2601
SEP	27.7	466.6	636.4	997.9	-30.1		0	-2098.3
OCT	18.5	482.1	403.6	583.1	-25.2		0	-1462.1
NOV	12.1	466.6	125.4	95.5	-36		0	-663.5
DEC	9.5	482.1	-61.8	-260.8	-100.1		0	-69.1

Cell 124 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Jan	2.89	133.92	-24.03	-79.33	-33.44	0.00	0.00	0.00	-1.09	0.13
Feb	3.50	120.97	-23.11	-68.00	-30.58	-2.69	2.69	0.12	-1.05	0.16
Mar	5.58	133.92	-3.75	-43.69	-21.42	-70.61	70.61	3.21	-0.17	0.25
Apr	8.22	129.61	60.17	66.00	-7.39	-256.58	256.58	11.66	2.73	0.37
May	11.44	133.92	145.67	199.72	-8.00	-482.69	482.69	21.94	6.62	0.52
Jun	13.86	129.61	193.92	273.06	-9.08	-601.28	601.28	27.33	8.81	0.63
Jul	13.47	133.92	222.58	341.53	-9.78	-701.67	701.67	31.89	10.12	0.61
Aug	11.19	133.92	226.97	360.28	-9.81	-722.50	722.50	32.84	10.32	0.51
Sep	7.69	129.61	176.78	277.19	-8.36	-582.86	582.86	26.49	8.04	0.35
Oct	5.14	133.92	112.11	161.97	-7.00	-406.14	406.14	18.46	5.10	0.23
Nov	3.36	129.61	34.83	26.53	-10.00	-184.31	184.31	8.38	1.58	0.15
Dec	2.64	133.92	-17.17	-72.44	-27.81	-19.19	19.19	0.87	-0.78	0.12

Room type CELL0126 - cell

Month	Window Solar	Internal Casual	EAT GAINS (MJ) External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	5.2	120.5	-26.5	-95.7	-3.4		0	0
FEB	6.3	108.9	-26	-79.6	-9.2		0	-0.1
MAR	10.1	120.5	-0.3	-60.9	-14.8		0	-54.3
APR	14.8	116.6	107.5	114.8	-8.6		0	-345
MAY	20.7	120.5	257.1	345.1	-12.2		0	-730.9
JUN	25	116.6	341.5	471.9	-15.3		0	-939.3
JUL	24.3	120.5	391.7	590.2	-16.8		0	-1109.5
AUG	20.2	120.5	399.3	622.6	-16.5		0	-1145.8
SEP	13.9	116.6	311.2	479	-12.6		0	-907.9
OCT	9.3	120.5	198	279.9	-8.6		0	-599
NOV	6.1	116.6	63.5	48.4	-8		0	-226.6
DEC	4.8	120.5	-18.2	-95.4	-2.6		0	-9.2

Cell 126 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	1.44	33.47	-7.36	-26.58	-0.94	0.00	0.00	0.00	-0.70	0.14
Feb	1.75	30.25	-7.22	-22.11	-2.56	-0.03	0.03	0.00	-0.68	0.17
Mar	2.81	33.47	-0.08	-16.92	-4.11	-15.08	15.08	1.43	-0.01	0.27
Apr	4.11	32.39	29.86	31.89	-2.39	-95.83	95.83	9.08	2.83	0.39
May	5.75	33.47	71.42	95.86	-3.39	-203.03	203.03	19.23	6.76	0.54
Jun	6.94	32.39	94.86	131.08	-4.25	-260.92	260.92	24.71	8.98	0.66
Jul	6.75	33.47	108.81	163.94	-4.67	-308.19	308.19	29.19	10.30	0.64
Aug	5.61	33.47	110.92	172.94	-4.58	-318.28	318.28	30.14	10.50	0.53
Sep	3.86	32.39	86.44	133.06	-3.50	-252.19	252.19	23.88	8.19	0.37
Oct	2.58	33.47	55.00	77.75	-2.39	-166.39	166.39	15.76	5.21	0.24
Nov	1.69	32.39	17.64	13.44	-2.22	-62.94	62.94	5.96	1.67	0.16
Dec	1.33	33.47	-5.06	-26.50	-0.72	-2.56	2.56	0.24	-0.48	0.13

Room type CELL0152 - cell

Month	Window Solar	Internal Casual	EAT GAINS (MJ) External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	46.1	482.1	8.8	-374.9	-160.3		0	-1.5
FEB	47.4	435.5	52.8	-320.5	-161.3		0	-53.5
MAR	48.4	482.1	128.1	-169.4	-84.8		0	-404.2
APR	42.7	466.6	302.4	237.5	-36.4		0	-1012.4
MAY	36.3	482.1	505	719	-23.7		0	-1718.5
JUN	34	466.6	617.2	983	-18.2		0	-2082.4
JUL	37.5	482.1	718.1	1229.5	-17.3		0	-2449.7
AUG	47.2	482.1	768.2	1297	-15.4		0	-2578.9
SEP	56.3	466.6	664.5	997.9	-16.7		0	-2168.1
OCT	66.3	482.1	514.7	583.1	-20.8		0	-1625.1
NOV	59.7	466.6	264.3	94.7	-30.8		0	-854.2
DEC	49.6	482.1	46.9	-308.7	-102.9		0	-166.8

Cell 152 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²
Jan	12.81	133.92	2.44	-104.14	-44.53	-0.42	0.42	0.02	0.11	0.58
Feb	13.17	120.97	14.67	-89.03	-44.81	-14.86	14.86	0.68	0.67	0.60
Mar	13.44	133.92	35.58	-47.06	-23.56	-112.28	112.28	5.10	1.62	0.61
Apr	11.86	129.61	84.00	65.97	-10.11	-281.22	281.22	12.78	3.82	0.54
May	10.08	133.92	140.28	199.72	-6.58	-477.36	477.36	21.70	6.38	0.46
Jun	9.44	129.61	171.44	273.06	-5.06	-578.44	578.44	26.29	-7.79	0.43
Jul	10.42	133.92	199.47	341.53	-4.81	-680.47	680.47	30.93	9.07	0.47
Aug	13.11	133.92	213.39	360.28	-4.28	-716.36	716.36	32.56	9.70	0.60
Sep	15.64	129.61	184.58	277.19	-4.64	-602.25	602.25	27.38	8.39	0.71
Oct	18.42	133.92	142.97	161.97	-5.78	-451.42	451.42	20.52	6.50	0.84
Nov	16.58	129.61	73.42	26.31	-8.56	-237.28	237.28	10.79	3.34	0.75
Dec	13.78	133.92	13.03	-85.75	-28.58	-46.33	46.33	2.11	0.59	0.63

Room type CELL0153 - cell

Month	Window Solar	Internal Casual	EAT GAINS (MJ) External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant
JAN	23.1	120.5	26.9	-136.6	-33.6		0	0
FEB	23.8	108.9	45.2	-120.7	-52.8		0	-4
MAR	24.3	120.5	74.1	-73.1	-31.8		0	-113.5
APR	21.4	116.6	152.1	114.4	-14.2		0	-390.1
MAY	18.2	120.5	245	345.1	-8.2		0	-720.3
JUN	17	116.6	296.5	471.9	-5.8		0	-895.9
JUL	18.8	120.5	343.2	590.2	-5.5		0	-1066.9
AUG	23.6	120.5	366.8	622.6	-5.1		0	-1128
SEP	28.2	116.6	319.2	479	-6.2		0	-936.4
OCT	33.3	120.5	251.2	279.9	-8.7		0	-675.6
NOV	29.9	116.6	134.9	46.9	-11.3		0	-318.7
DEC	24.9	120.5	38.8	-126.6	-24.6		0	-32.8

Cell 153 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	6.42	33.47	7.47	-37.94	-9.33	0.00	0.00	0.00	0.71	0.61
Feb	6.61	30.25	12.56	-33.53	-14.61	-1.11	1.11	0.11	1.19	0.63
Mar	6.75	33.47	20.58	-20.31	-8.83	-31.53	31.53	2.99	1.95	0.64
Apr	5.94	32.39	42.25	31.78	-3.94	-108.36	108.36	10.26	4.00	0.56
May	5.06	33.47	68.06	95.86	-2.28	-200.08	200.08	18.95	6.44	0.48
Jun	4.72	32.39	82.36	131.08	-1.61	-248.86	248.86	23.57	7.80	0.45
Jul	5.22	33.47	95.33	163.94	-1.53	-296.36	296.36	28.06	9.03	0.49
Aug	6.56	33.47	101.89	172.94	-1.42	-313.33	313.33	29.67	9.65	0.62
Sep	7.83	32.39	88.67	133.06	-1.72	-260.11	260.11	24.63	8.40	0.74
Oct	9.25	33.47	69.78	77.75	-2.42	-187.67	187.67	17.77	6.61	0.88
Nov	8.31	32.39	37.47	13.03	-3.14	-87.97	87.97	8.33	3.55	0.79
Dec	6.92	33.47	10.78	-35.17	-6.83	-9.11	9.11	0.86	1.02	0.65

Room type CELL0160 - cell

Month	Window Solar	Internal Casual	EAT GAINS (MJ) External Conduct	Elements Ventiltn	Other Conductn.	Elemen Ventil	TS	Plant

Cell 160 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	Solar Load KWH/m²

JAN	46.1	482.1	1.4	-371.2	-157.2	0	-0.9
FEB	47.4	435.5	9	-314.5	-137.5	0	-39.4
MAR	48.4	482.1	85.2	-168.8	-75	0	-371.6
APR	42.7	466.6	270	237.5	-28	0	-988.6
MAY	36.3	482.1	518 6	719	-27.4	0	-1728.4
JUN	34	466.6	656.9	983	-29.1	0	-2111.2
JUL	37.5	482.1	775	1229.5	-32.9	0	-2491
AUG	47.2	482.1	848 8	1297	-37.5	0	-2637.3
SEP	56 3	466 6	740.7	997.9	-37.8	0	-2223 3
OCT	66.3	482.1	574 8	583.1	-37.5	0	-1668.5
NOV	59.7	466.6	297.4	94.4	-41.8	0	-876
DEC	49.6	482.1	54.8	-309.5	-115	0	-161.7

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	12 81	133 92	0.39	-103.11	-43 67	-0.25	0 25	0 01	0 02	0 58
Feb	13 17	120 97	2 50	-87.36	-38 19	-10 94	10 94	0 50	0 11	0 60
Mar	13 44	133 92	23 67	-46 89	-20 83	-103 22	103 22	4 69	1 08	0 61
Apr	11 86	129 61	75.00	65 97	-7 78	-274 61	274 61	12 48	3 41	0 54
May	10 08	133 92	144.06	199 72	-7 61	-480 11	480.11	21 82	6 55	0 46
Jun	9 44	129 61	182.47	273 06	-8 08	-586 44	586 44	26 66	8 29	0 43
Jul	10 42	133 92	215 28	341 53	-9 14	-691.94	691 94	31 45	9 79	0 47
Aug	13 11	133 92	235.78	360.28	-10 42	-732.58	732 58	33 30	10.72	0 60
Sep	15 64	129 61	205 75	277 19	-10 50	-617 58	617.58	28 07	9 35	0 71
Oct	18 42	133 92	159 67	161 97	-10 42	-463.47	463 47	21 07	7 26	0 84
Nov	16 58	129 61	82 61	26 22	-11 61	-243 33	243.33	11 06	3 76	0 75
Dec	13 78	133 92	15 22	-85 97	-31 94	-44 92	44 92	2 04	0 69	0 63

R oom type CE LL0161 - cell

Month	Window Solar	Internal Casual	EXTERNAL Conduct	ELEMENTS Ventiltn	OTHER Conductn.	ELEMEN Ventil	TS | Plant
	HEAT GAINS (MJ)						
JAN	23.1	120.5	17.8	-134.3	-26.8	0	0
FEB	23.8	108.9	18 5	-115.9	-32.7	0	-2.1
MAR	24.3	120.5	45 9	-71.9	-22.6	0	-95.7
APR	21.4	116 6	133 4	114 5	-9.9	0	-375.7
MAY	18.2	120.5	254.2	345.1	-10.5	0	-727.3
JUN	17	116.6	321.3	471.9	-11.7	0	-914.9
JUL	18.8	120.5	378.9	590.2	-14	0	-1094.1
AUG	23 6	120.5	414.7	622 6	-16.5	0	-1164.6
SEP	28 2	116.6	361.9	479	-16.4	0	-969
OCT	33.3	120 5	281.3	279.9	-15 8	0	-698.6
NOV	29 9	116 6	146.7	46 6	-15.5	0	-324
DEC	24 9	120.5	36.6	-126.3	-25.3	0	-30

Cell 161 annual load KWH

	window Solar	Internal Casual	External Conduction	Ventilation	Other Conduction	Plant	Cooling Load KWH	Cooling Load KWH/m²	Conduction Load KWH/m²	solar Load KWH/m³
Jan	6 42	33 47	4 94	-37.31	-7.44	0 00	0 00	0 00	0 47	0 61
Feb	6 61	30 25	5 14	-32.19	-9 08	-0 58	0 58	0 06	0 49	0 63
Mar	6.75	33 47	12.75	-19 97	-6 28	-26 58	26 58	2 52	1 21	0 64
Apr	5 94	32 39	37 06	31 81	-2 75	-104.36	104 36	9 88	3 51	0 56
May	5 06	33 47	70 61	95 86	-2 92	-202 03	202 03	19 13	6 69	0 48
Jun	4 72	32.39	89.25	131 08	-3 25	-254.14	254 14	24 07	8 45	0 45
Jul	5.22	33 47	105 25	163 94	-3 89	-303 92	303 92	28 78	9 97	0 49
Aug	6 56	33 47	115 19	172 94	-4 58	-323 50	323 50	30 63	10 91	0 62
Sep	7.83	32 39	100 53	133 06	-4.56	-269 17	269 17	25 49	9.52	0 74
Oct	9 25	33 47	78.14	77 75	-4 39	-194 06	194.06	18 38	7 40	0 88
Nov	8 31	32.39	40 75	12 94	-4 31	-90 00	90 00	8 52	3 86	0 79
Dec	6 92	33 47	10 17	-35 08	-7 03	-8 33	8 33	0 79	0 96	0 65

Appendix Three: List of publications

Refereed Journals

1. Al-Hosany, N. and Elkadi, H. (2000) Energy Management and Façade design in Prison Buildings in Hot Climates, In Renewable Energy Congress - VI, Vol. 3, Brighton, UK, 1-7 July, 2000. Pergamon, pp. 1808-1811.
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THESIS CONTAINS

VIDEO CD DVD TAPE CASSETTE

Appendix Four: CD of Chapter 8 figures