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Software framework for simulation of intelligent buildings integrated with GIS data

Semester Project

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1 Preface

This semester thesis is the result of a collaboration between the Geoinformation Technologies Group (GeoIT) led by Prof. Dr. Christine Giger and the Institute of Computer Engineering and Networks Laboratory (TIK) led by Prof. Dr. Lothar Thiele. It was written at the Swiss Federal Institute of Technology Zurich (ETHZ) during the summer term 2005.

We would like to thank all the people who helped us with this project:

- Valeria Agnolotti and Lennart Meier, our tutors, for their constant help during the whole work and their availability
- Hasse Kvist at the Lund Institute of Technology for his support with DEROB-LTH
- Prof. Dr. Maria Wall for providing us the test building

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2 Abstract

In this semester thesis three main topics are discussed.

At first, the possibility to couple GIS with software for the simulation of the thermal behaviour of an intelligent building has been examined. This would be helpful to provide a real environment around the test building analysed by the simulator. In fact, GIS is a tool able to supply spatial data such as quarters to import in the simulator.
One specific building dataset has been successfully imported in the simulator, but an automatic tool would be of great help.

Subsequently different scenarios have been simulated. Up to now all the simulations have been done not taking account of the environment surrounding the interested building, because it is not clear if existing simulators support multiple buildings. In this project a variable urban context for the test building is provided and simulation results are analysed and discussed.

At last, the capability of the software to simulate quick weather phenomena has been investigated. Intelligent buildings have the capability to respond to weather changes, but today's simulators cannot offer a proper simulation, because their climate input data, which holds parameters like solar radiation and temperature, are limited to a maximum of one entry pro hour. With this time resolution it is impossible to correctly simulate events that last less than an hour.
An easy solution would be the possibility to modify, as a parameter, the time-step. This is of major importance for a correct building simulation.

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4 Goals

Three main goals were defined at the beginning of this semester thesis:

- Integration of GIS data in a representative simulation software
- Simulation of thermal behaviour of intelligent buildings located in a variable urban context
- Simulation of sudden climate changes (summer storm, clouds, etc.) to verify the adaptability of the simulation software to quick dynamic environmental changes

To achieve these goals, these necessary steps were followed:

- Evaluation of existing simulation software
- Extension of the existing database of building with other buildings with different characteristics
- Comparison of the results of single and multiple buildings simulations in different scenarios:
    - Modifying the constructed environment
    - Modifying the properties of the constructed environment
- Analysis of quick climatic variation

In order to be useful to the main project, the results had to be analysed in terms of:

- Variation of the temperature inside the building
- Variation of the heating and cooling load
- Variation of the incident solar radiation
- Comfort

5 Intelligent buildings

5.1 Definition of intelligent buildings

There are many definitions in the scientific literature concerning this construction typology. The problem is that due to the complexity of the subject, it is not easy to condense in a few words the capabilities and the functionalities of intelligent buildings. The definition we like the most is simple: “An intelligent building is one that controls its own environment”.

In fact, intelligent buildings (IBs) have to suit a wide range of tasks concerning different aspects of the management of the building: from turning on the lights as soon as someone enters in a room, to automatically regulate the temperature in every space of the construction.
Different spaces, like offices, apartments and storage rooms, have different needs, forcing IBs to offer a large variety of features: from granting better comfort to reducing maintenance costs, from improving security to minimizing energy losses.

Nowadays, the main components of an IB are the so-called embedded systems. A large number of embedded systems like sensors and actuators are all connected to a central control unit whose task is to coordinate the management of the building.
The main goal of the sensor is, obviously, to sense changes that occur inside and outside the building environment. Typically, there are sensors for temperature, humidity, smoke, sunlight and alarms. The central unit can be considered as the brain of the building. It decides how to react to specific signals received from the sensors. It also sends instructions to the actuators whose task is to execute them. Examples for actuators are the devices that control the sunblinds or the cooling system.

To network the control unit and all the peripherals WLAN or Binary Unit System are often used. Networking the components is one of the last acknowledgement in the IB technology: it clearly offered a lot of benefits in term of ease of maintenance and resource saving. In the past, most of these embedded systems were independent, all working without being instructed by a central unit.

5.2 Features

One of the main advantages of IBs is that they greatly improve the comfort of the occupants. Modern IBs can learn from the occupant wishes. Everyone can preset in his space the ambient he prefers. It is clear that improving the quality of life (at work) of employees results in an increased productivity.

Another advantage of IBs is the better use of energy resources. Nowadays, 42% of the total energy is dissipated in the household. It is calculated that in long term, in an IB, an important decrease of energy consumption (especially useless losses) is granted.

If the IB technology would be applied more often in the construction industry, better efficiency could be achieved. A decrease of the management costs, a reduction of energy losses, an increase in productivity and a more comfortable working (and living) space are some of the long-term benefits that would be reached.

5.3 The importance of simulation

The importance of an accurate simulation of intelligent-building behaviour is of major concern for the building industry. There are at least three main reasons that have to be considered:

First, the construction industry slowly uptakes new technologies, especially those involving new materials (embedded systems' components, optic fiber, etc), probably depending of the sizable investment a building requires. The owners face a great economical risk. This results in a discouragement in the adopting of new technologies. Surely, this problem would be solved by proper simulations.

Another aspect is the lifetime of a building, which is limited. It requires a large investments to rebuild a traditional construction, taking account that it was not planned to support the needs of an IB. Probably in the next years many buildings will be completely redesigned to reap the benefits of this technology but this is only possible if in the phase of planning precise simulations will be done.

Last but not least, a proper simulation helps the maintenance of the building, supplying precious information used to prevent further problems.

6 Geographic Information System (GIS)

6.1 Definition of GIS

GIS is an acronym which stands for Geographic Information System.
A GIS is a computer system (software and hardware) which stores, displays, analyses and manipulates spatial data. In other words, with a GIS it is possible to visualise data related to their geographical position.
The database is composed of georeferenced coordinates, which are displayed according to a real-scaled projection system. The coordinates define an object to which attributes are assigned.
Important aspect of GIS is the huge database it has. In it has place information about roads, terrain morphology, population, economy, .. all linked to specific locations. In other words it makes thematic maps to help illustrate patterns.
Without a GIS we would be confronted with rows and columns of numbers and words: with a GIS it is possible to consult an easily understandable map with all the location information on hand.
As an example, the opportunity to easily find where to locate a retail businnes, taking into account the most important criteria (such as the population's age structures or other nearby stores), is simple to educe from a GIS map.
Today, a GIS is a key tool for using vast information sources, because often it is impossible to see the big picture without a visual map.

6.2 Coupling GIS with building simulation software

Up to now, simulation software only considers buildings as isolated objects in the middle of nowhere, but it is obvious that the environment (other buildings, hills, etc) has an important role in a proper simulation of the thermal behaviour of an IB. Demolition and redevelopment in urban onditions are often necessary, varying in a significant way the scene. A tool with the capabilities to supply and visualise various scenarios is of great importance.
With a GIS access to an enormous amount of possible real environments, such as cities and countrysides, where to simulate the construction planned to be built, is granted.

6.3 Useful GIS data

The project has as its first objective the simulation in an urban context, so the urban maps that a GIS provides are of primary concern. In ArcGIS (one of the GIS-packet applications), the data can be displayed as maps, but also exported as matrix (from coordinates of the building to its attributes, like the height). Such matrices are useful because they are simple text files which can be imported in simulators. Later, in the main project, also the form sturcture of the terrain will be considered, to have a more precise environment, but in this semester thesis it was impossible to deal with that due to the time limit.

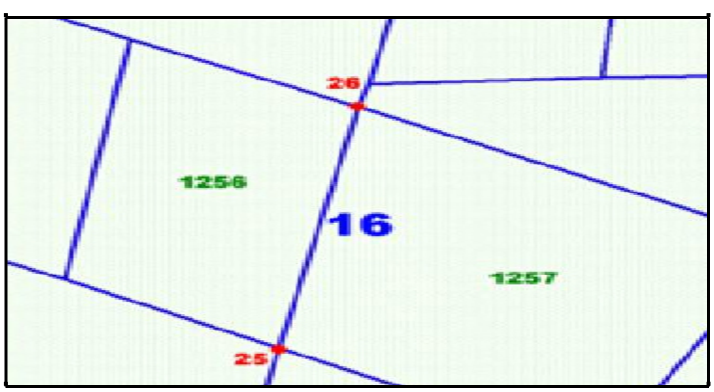

Fig. 6.1 GIS representation of space

Buildings are represented in GIS as nodes connected by segments delimiting the building space. Another useful feature of GIS is that the segments knows, as parameter, the space on the left side and on the right side of itself, which is of great practical help. Every construction (and the outdoor space, too) is characterised by a number, so it is easy to identify and isolate every structure, and also every element of the structure. In Fig. 6.1, nodes 25 and 26 are connected with edge 16 which divides two different zones.

7 Simulation software

7.1 Simulation software analysis

There is a huge catalogue of simulation software which analyse the behaviour of IBs. Most of these simulators were developed in the 60's or in the 70's and are quite out of date, but still provide a good solution for a stand-alone building simulation. In this project, only the simulation of the thermal behaviour of an IB was to be considered. Useful for this work are the simulators that consider the whole thermal balance of the construction, taking into account external temperature and weather condition, solar radiation, and the heating and cooling system. There is a lot of software which focuses on different aspects of the simulation. A first evaluation of many simulators was necessary to decide which program could be used for this project.
In the interest of this project, which has as its goal the simulation of buildings integrated in the environment, many essential features are missing in all the simulators. As an example, most of the simulators do not allow the user to consider a scenario with more than one building. Also the integration of a building in a natural environment is not considered in most of the software.
All the software assume the building to be stand-alone. As showed in the following, for a correct simulation it is imperative to have the possibility to simulate taking account of the scenario in which the construction will be located.
Another useful peculiarity would be the possibility to simulate sudden climate changes, which is still not possible. In fact, in most of the simulators no more than one entry pro hour is possible. With this temporal resolution is impossible to accurately simulate weather changes which last less than an hour.

In the past winter term many simulators has been evaluated by two students of the Department of Civil Engineering of the Swiss Federal Institute of Technology Zurich. This assignment was part of their semester thesis.
Due to lack of time, their software analysis was used as starting point.
DEROB-LTH was the final choice because of the simple input file system. It is very simple to modify the input parameters such as the building description and the climatic conditions.

7.2 DEROB-LTH

DEROB, an acronym that stands for Dynamic Energy Response of Buildings, has been developed at the Numerical Simulation Laboratory at the School of Architecture of the University of Texas and has been constantly improved at the Department of Building Science of the Lund University's.

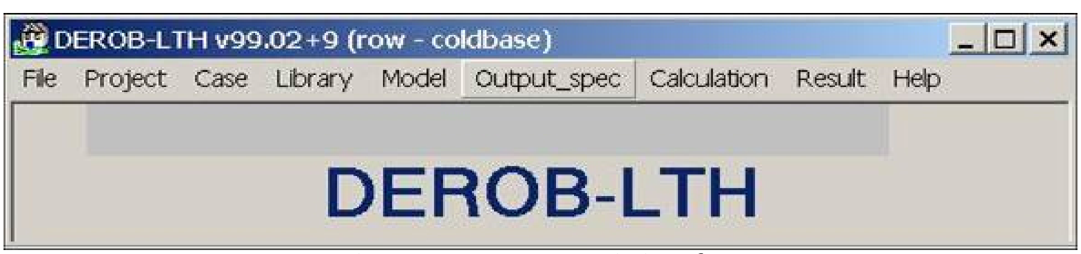

Fig. 7.1 DEROB-LTH main interface

This software allows the thermal simulation of buildings, taking account of the parameters described above. Besides, it considers also the internal load (the heat produced by devices) in each volume: it is possible to simulate the presence of home appliances which surely influence the temperature inside the rooms.

The input data are of two types: the building description (shape, internal environment, position, etc.) and the climatic conditions.

The first is composed of the construction geometry and the parameters for each wall and window, the other of the geographical location of the building, like the time zone and the climate.

7.2.1 Building description

The libraries which hold the parameters of walls, windows, curtains, HVAC schedules and some environmental constants are easily accessible to the user who has the opportunity to change the characteristics for each element of the building.

The geometrical part needs some practice to be mastered, for essentially two reasons. The former is the reference system (which is a local coordinate system), the latter is relative to the design of elements: Every form is defined by its lower left corner, its dimension and its orientation in three-dimensional space. At the beginning, this characterisation was not very understandable.

DEROB can simulate buildings of arbitrary geometries but building elements can be described by only five available shapes.

7.2.2 Climatic description

Hourly data for the external temperature, sky temperature, humidity and the solar radiation intensity are necessary to perform a simulation. These parameters are stored in a text file that is read by DEROB.

Other environmental attributes, such as ground reflectivity and soil resistance can be set from an appropriate form directly using the program interface.

7.2.3 Features

DEROB handles energy transmission across the building envelope by taking account of thermal properties of building materials. Each wall can be divided into layers and, one internal node is assigned to each layer. A maximum of 7 nodes can be assigned inside each wall. Thermal properties for the walls are assigned by input or by a material library. Windows are modelled with one node for each pane. The transmission of heat through windows is handled considering the first principles of the thermodynamics, while the absorption of solar radiation is calculated taking account of incident angle and all reflections between panes.

In addition to the thermal loads from direct and diffused solar radiation, DEROB considers solar radiation reflected from the ground and shading devices. To handle the shading process of each wall on another, the program uses view factors from the outer surfaces to the sky and ground to determine primary incident diffuse sky and ground reflected radiation to these surfaces. The view factors are also used when incident long wave radiation from the sky and the ground is estimated. Furthermore, view factors between surfaces are used to calculate the radiation reflected from one surface onto another. An approximate method based on a 8 by 8 grid representing each surface is used to calculate direct solar radiation on each surface. This method can give some over- or underestimation due to factors such as the geometry of the building and obstructing shading screens. Direct solar radiation reflected from a surface is treated as a source of diffuse radiation. Diffuse solar radiation transmitted through a transparent building element is treated as a source of diffuse radiation. Diffuse and direct solar radiation can be transmitted into adjacent volumes through transparent building elements.

DEROB takes account of infiltration and forced ventilation. It can also take account of static pressure-driven air exchanges between volumes that take place across openings at different levels (advection connection). It can also calculate the air-conditioning loads and required plant capacities.

8 Urban context

In order to simulate a real environment, a set of buildings were extracted from the GIS database and used as an urban context where to locate the test house. Nevertheless it was necessary to modify the GIS data because of the different format between the GIS output and the DEROB input.

8.1 Test house

Albeit it was possible to design the test construction ourselves, the chance to import an already developed test house was of great help, taking account that modelling a building is outside our specific competence, and that the necessary reading up would have required a considerable amount of time. Prof. Dr. Maria Wall kindly provided us an already developed building, designed for testing purposes.

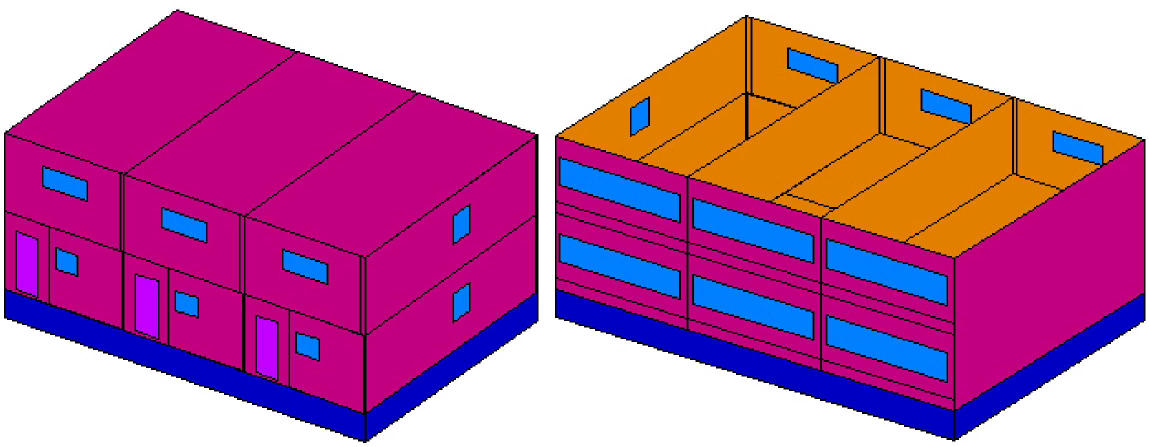

Fig. 8.1 North and south façade of the test house

The test house has a so-called light structure, which means that the buildings elements do not have a heavy isolation towards the external environment. Even the smallest variation in the outside climate influences the inside conditions.

This test house is a row house formed of 5 apartments but actually divided in 6 volumes. The central unit consists of three volumes: one on the first floor, two on the ground floor. Volume 4 is the end unit of the row house. Volume 5 is limited to the outside with an adiabatic (no heat transfer) wall, to pretend that there are other volume attached. This expedient is needed because of DEROB's limitation to a maximum of 8 volumes. Volume 6 is defined as the ground, to simulate different ground proprieties under the construction.

8.1.1 HVAC schedules

HVAC stands for Heat, Ventilation and Air Conditioning system.

Every volume has a corresponding HVAC schedule which sets when and how the heating and cooling system works. The schedule divides the year into periods in which different workloads for the heating and cooling system are used. Up to 5 periods are supported in DEROB. Different time frames, like workdays or weekends, can be set for each period to simulate the different behaviour of the HVAC system.

A schedule set points for the start of heating and cooling and the maximum available power that can be used to control the inside temperature. Also the internal load (due to heat-generating objects, like PC, lights, etc.) of each volume can be adjusted.

8.2 The GIS dataset

In Fig. 8.1 the dataset is shown as seen in ArcGIS, the software used to visualise the GIS database. The first step to import this dataset in DEROB was extracting the text file containing the information of the dataset from ArcGIS and analysing it to understand how data are stored in a GIS.

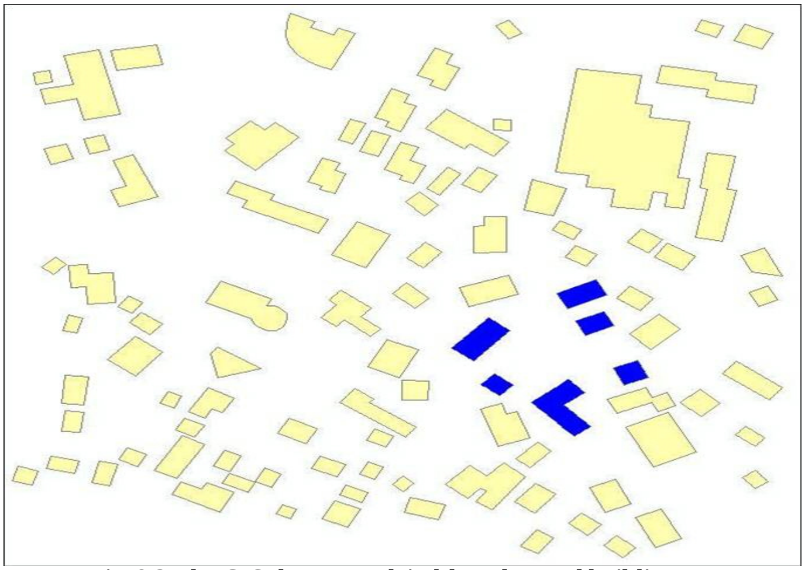

Fig. 8.2 The GIS dataset and, in blue, the used building set

Two text files were exported: the former defined the nodes which compose the buildings (coordinates of the corner of the buildings), the latter the segments that link the nodes, forming the base of the walls. In ArcGIS, the coordinates of where the mouse points are displayed, so from the text file containing the information about the nodes it was possible to identify the buildings most useful for the project. The blue-colored building in Fig.1 were those selected to be the environment used to simulate the urban context surrounding the test house. They were selected because of their homogeneous distribution in a circle.

8.3 Importing the GIS dataset in DEROB

In the GIS database, every building is characterised by a number, which is helpful to find all the nodes that compose the construction. Further, from the node it is possible to find out to which segment every nodes belongs.

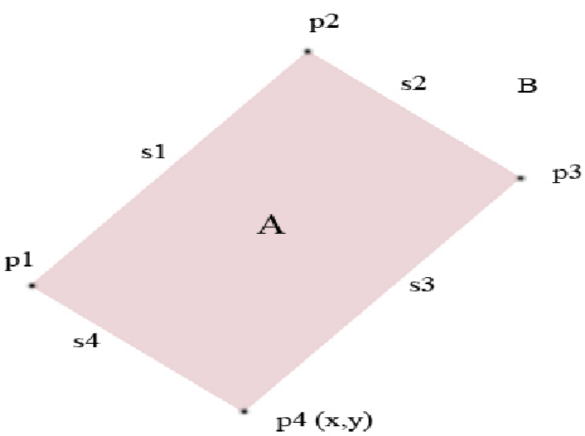

Fig. 8.3 GIS representation of a building

In Fig. 8.3, a simple representation of a single building as described in a GIS is presented. A and B are two areas which belong to different surfaces. A is delimited with the segments s1 to s4 which link point p1 to p4. The surface B is the outside environment.

In DEROB walls are defined by their lower left corner, their orientation and their dimensions. At first, the calculation of the azimuth angle was necessary in order to give each wall the right orientation. In Fig 8.4 a sketch of how a single wall is described in DEROB is depicted.

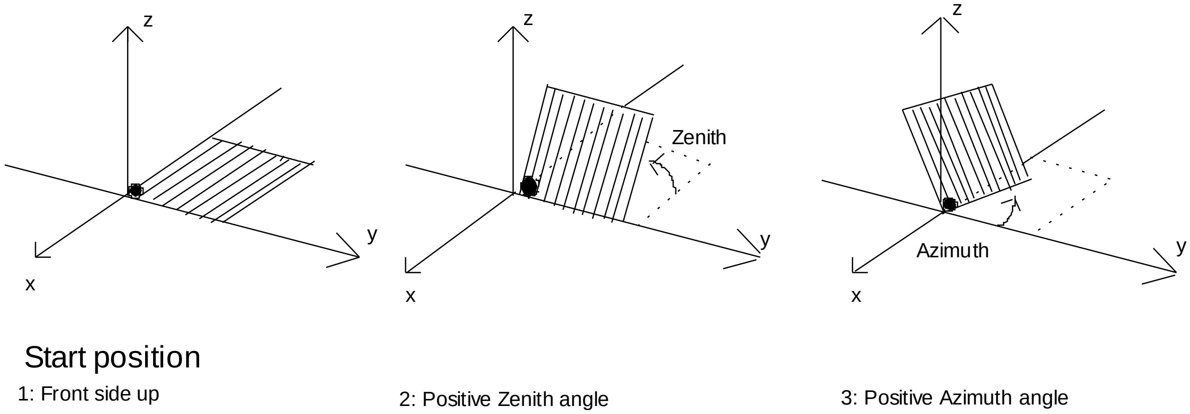

Fig. 8.4 Zenith (2) and Azimuth (3) angle representation in DEROB

The azimuth angle is the angle between the baseline of the building element and the positive y-axis. The angle is countered positive in anti-clockwise direction.

Using trigonometry, it is easy to calculate the azimuth angle for each segment:

$$\alpha = \tan\left(\frac{y_2 - y_1}{x_2 - x_1}\right)$$

x_i and y_i are the coordinate of node i

From the text file containing the information about the edges it was possible to educe the length of the wall, while for the height, which is inserted in a GIS as an attribute, arbitrary values were chosen.
After these few steps, it was possible to import the values for the azimuth angle, the length, and the height in DEROB.

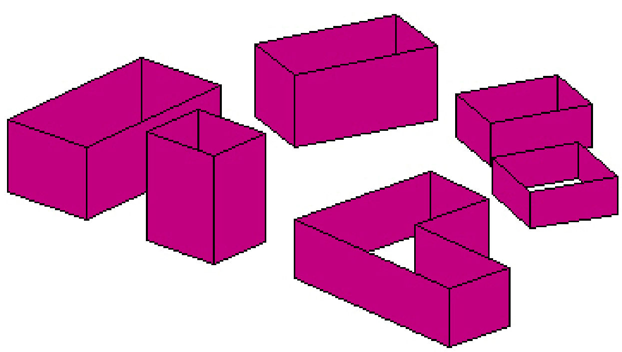

Fig. 8.5 The GIS dataset imported in DEROB

8.4 The final situation

In Fig. 8.6, the final situation can be seen: in the centre, there is the test house, surrounded by the construction exported from the GIS dataset.

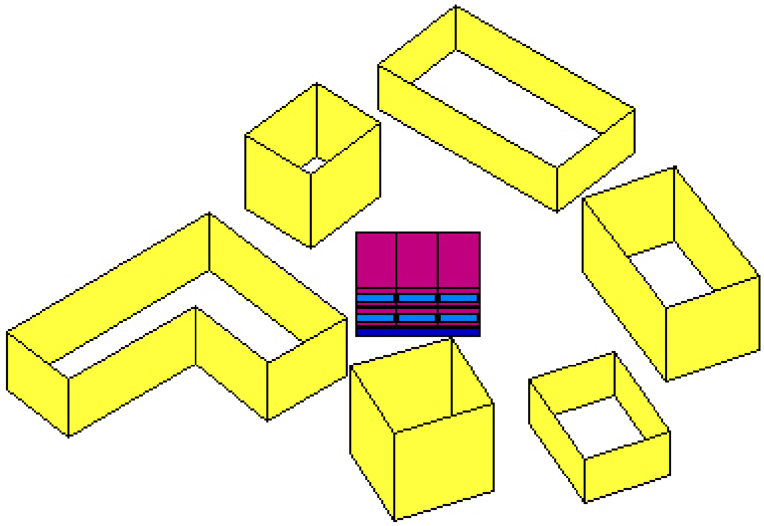

Fig. 8.6 The test house located in the imported urben context

After having imported the set of buildings in DEROB, it was necessary to define the material properties for each wall. The walls' composition, their reflective capabilities and many other parameters were easily inserted using the DEROB interface and the libraries containing many wall-types.

The alteration of these factors offered the possibility to simulate different scenarios, as seen in the next section.

9 Simulation of different scenarios

9.1 Introduction to the simulations

In this report, only a small part of the data resulting the simulations could be exposed in detail. In particular only a few days are explicitly analysed. It was necessary to examine different periods of time and select the most significant because it would just have made confusion to insert data representing the whole year.
Deemed to be the most meaningful, was the period between the first and the fourth day of August. Here the combination between the solar radiation, the temperature and the shading process of the buildings on each other was considered to be the most remarkable.
The parameters that have been modified have different impact on the results. As example, the variation of the size of the buildings near the test house shows how DEROB handles the presence of obstacles related to the direct and reflected solar radiation which arrives at the surface of the test building. On the other hand, the variation of the structural composition of the walls of the buildings illustrate in what measure thermal diffusion changes, using different material.
The simulation presented in this report are divided in two groups. The first has the HVAC schedules activated, the other was simulated without taking account of heating and cooling systems. Each group is divided in seven simulation: one uses the nearby buildings as shading screen, four are performed with different size of the nearby constructions (one of which is the normal stand-alone situation) and in the last two situations the physical structure of the external walls of the test building is modified.
The temperature diagram is presented for all the scenarios, while the solar radiation is considered only for the four situation in which different building sizes occur.

9.1.1 Standard parameters

Due to the fact that the test building was designed (and kindly provided us) by Dr. Maria Wall from the Lund Institute Of Technology it was natural to use climatic data of Sweden. The location of the simulation is Stockholm, so latitude, longitude and time meridian are those of the capital city.
The climatic data in our possess refers to the year 1995: in this file values for the outdoor dry bulb air temperature (ºC), humidity for outdoor air temperature (kg/kg), diffuse solar and sky radiation on horizontal surface (W/m^2), normal solar radiation (W/m^2) and the sky temperature (ºC) are stored.

9.1.2 Naming convention

Due to the fact that is not easy to describe in a few words all the characteristics of a simulation, a brief explanation of the names used in the graphs, diagrams and caption is provided.
The label “TH only” (which stand for “Test House only”) refers to the standard single-building simulation. Only the test house is considered.
The labels “TH without/with/with high house at south” refer to the three different scenarios used to simulate a variable urban context. In the case “with house” the building at south of the test house is six meters tall, in the case “with high” is twelve meters tall.
The label “TH with shading screen” describes the simulation made with the test house surrounded by building made of shading screen. The dimensions of the surrounding building is the same as in the case “TH with house at south”. The variation consists in the different materials which compose the nearby buildings: shading screens replace mineral wool walls, used in all the other simulations.
The label “TH only” describes the situation where the test house is considered as the only building of the simulation (as in the case “TH only”) but the external walls of the test house are made of concrete instead of mineral wool, to simulate an heavy structure building.
The last case is labelled “TH with concrete walls”. This means that the same urban context provided for the case “TH with house at south” is used to simulate the surrounding of the test house and the external walls of the test house are made of concrete.

9.2 Analysis of the results

9.2.1 Overview of the month of August

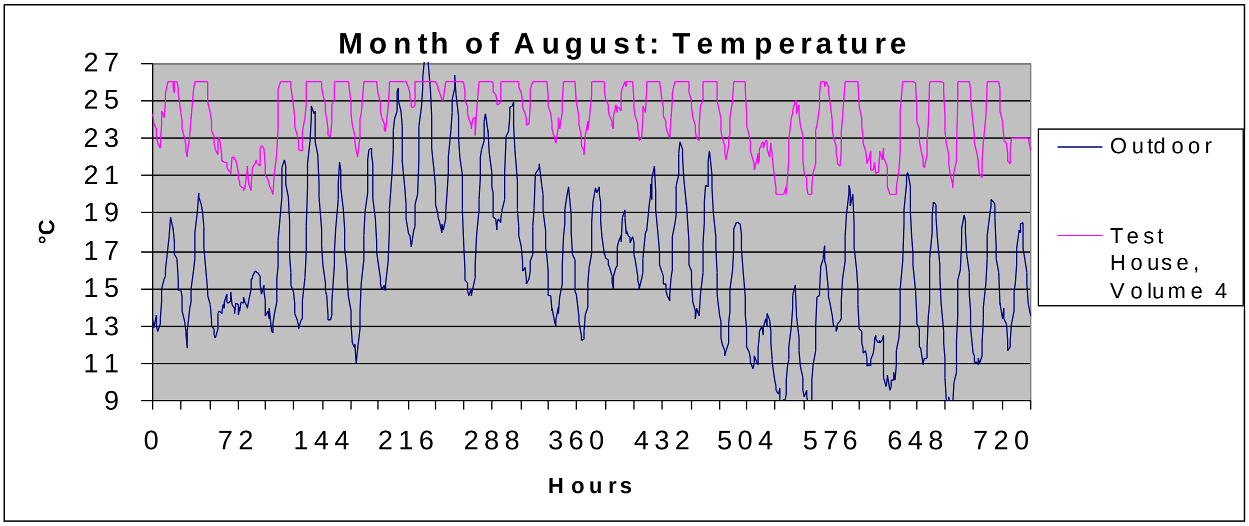

Fig. 9.1 Outdoor and indoor temperature during the month of August

As clearly seen it's a hot month and the cooling system is often called to his duty, nearly everyday at midday. This is an effect of the HVAC schedules: when the temperature go over 26°C or get below 20°C the cooling respectively the heating system activates. It is also noticeable that the indoor temperature is much higher than the outdoor: this is in most part due to the solar radiation (depicted in the graph below).

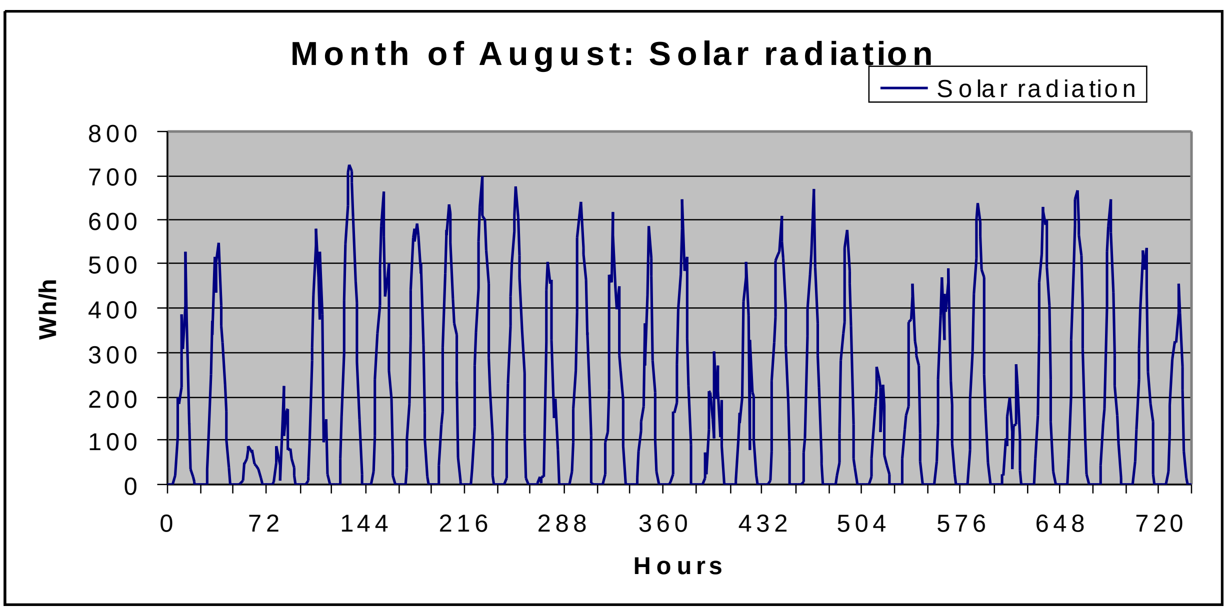

Fig. 9.2 External solar radiation during the month of August

9.2.2 Simulation considering HVAC schedules

In this subsection, results of simulations made without taking account of HVAC schedules, are presented.

9.2.2.1 Stand-alone simulation compared to shading screen scenario

In Fig.9.3 the temperature diagram of a standard stand-alone simulation (blue line) is depicted: only the test house (TH) is considered. The other graph in Fig.9.4 represents the and the solar radiation which penetrates volume 4. This last parameter is a sum two phenomena: one is the radiation that directly flows through the windows, the other is the radiation transmitted through the walls.
The purple line represents (in both graphs) the simulation in an urban context made of "shading screen", instead of real walls, in order to simulate and compare houses with different construction materials. It can be seen that there is a slightly change, a minimal temperature drop is registered. In fact, differently as in the graph before, the heating system activates for a small period of time.

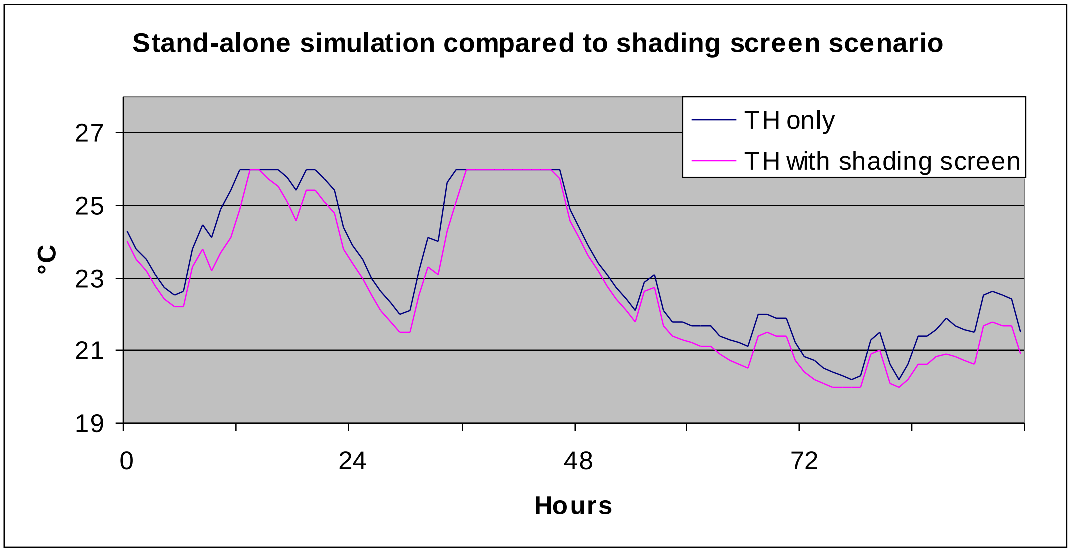

Fig. 9.3 Comparison of the temperature diagram of two scenarios.

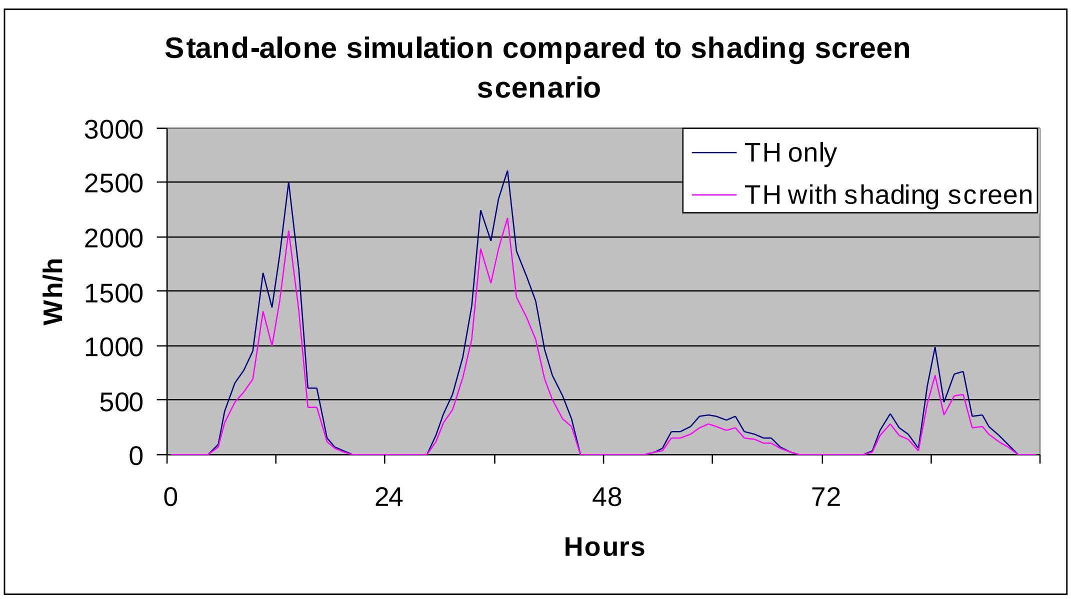

Fig. 9.4 Comparison of the solar radiation diagram of two scenarios

9.2.2.2 Simulation with different house heights located at the south of test house

In Fig.9.5 and Fig.9.6, it is clear to see that as the height of the house located at the south of TH increases, the impact of the sun on TH is less and so the solar radiation on the wall, resulting in a decrease of the temperature of our interested house.

Initially the south-house does not exist (blue line), afterwards the south-house has a height of 6m (purple blue), which is the same height as the TH, in the end the south-house has reached a height of 12 m (yellow line). It could be a simulation of a house in construction.

The differences between the different scenarios in the urban context are all below 0.5° Celsius and a maximum difference of 135 Wh/h.

The shading effect of this tall building can be seen in the two graphs below:

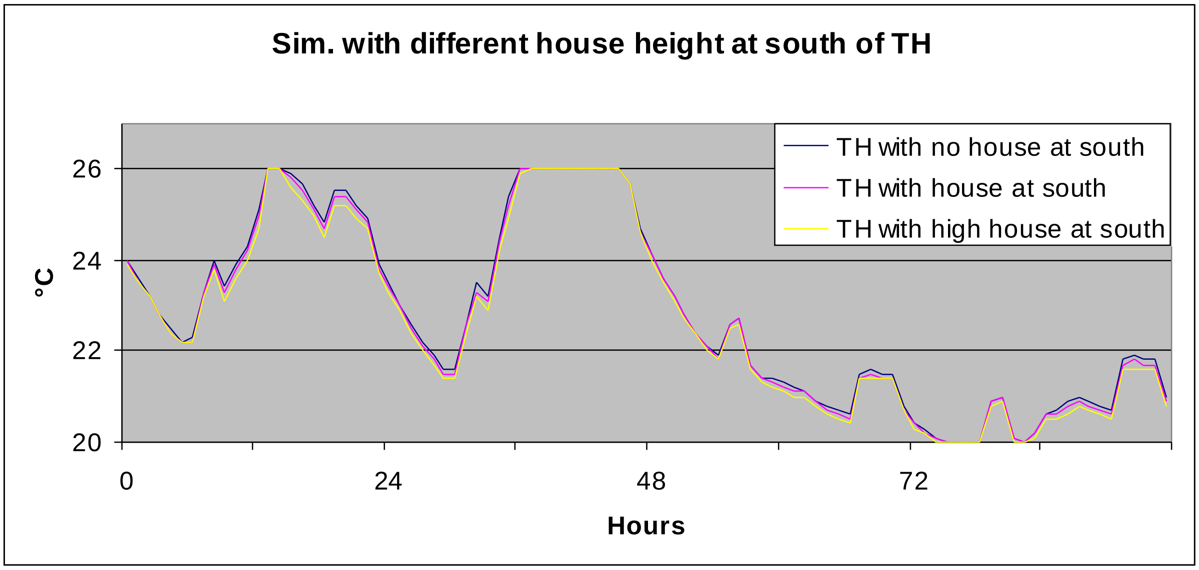

Fig. 9.5 Temperature diagram: Influence of the size of the building at south

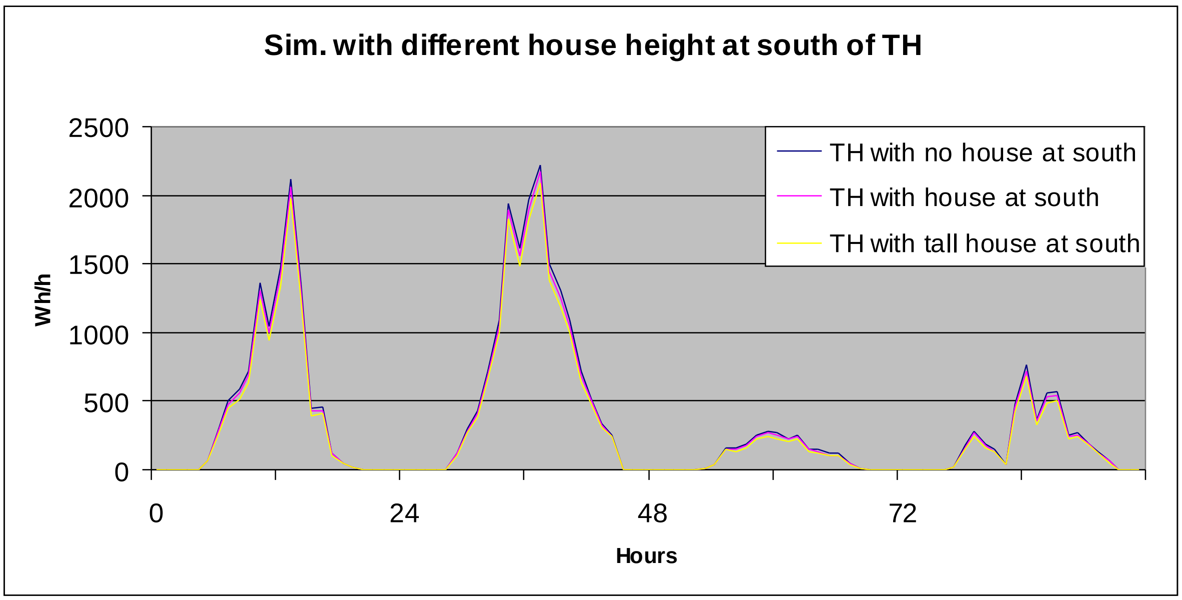

Fig. 9.6 Solar radiation diagram: Influence of the size of the building at south

9.2.2.3 Simulation of an heavy thermal mass structure

In this situation the structure of the external walls of the test house has been modified: the external walls are now made of concrete and no more of mineral wool. Now the test house has a different thermal mass form the scenarios described above.
To be seen is the delay of time that the house need to warm up, if compared with the other simulations.

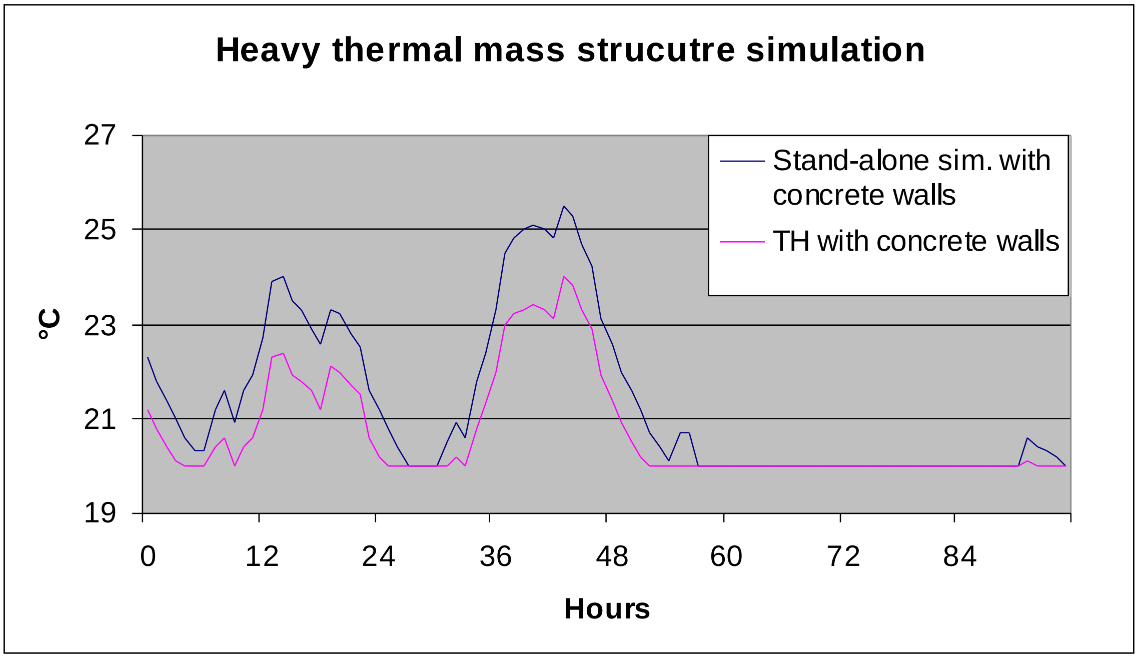

Fig.9.7 Temperature diagram of a heavy thermal mass building

9.2.2.4 Overview of the simulations

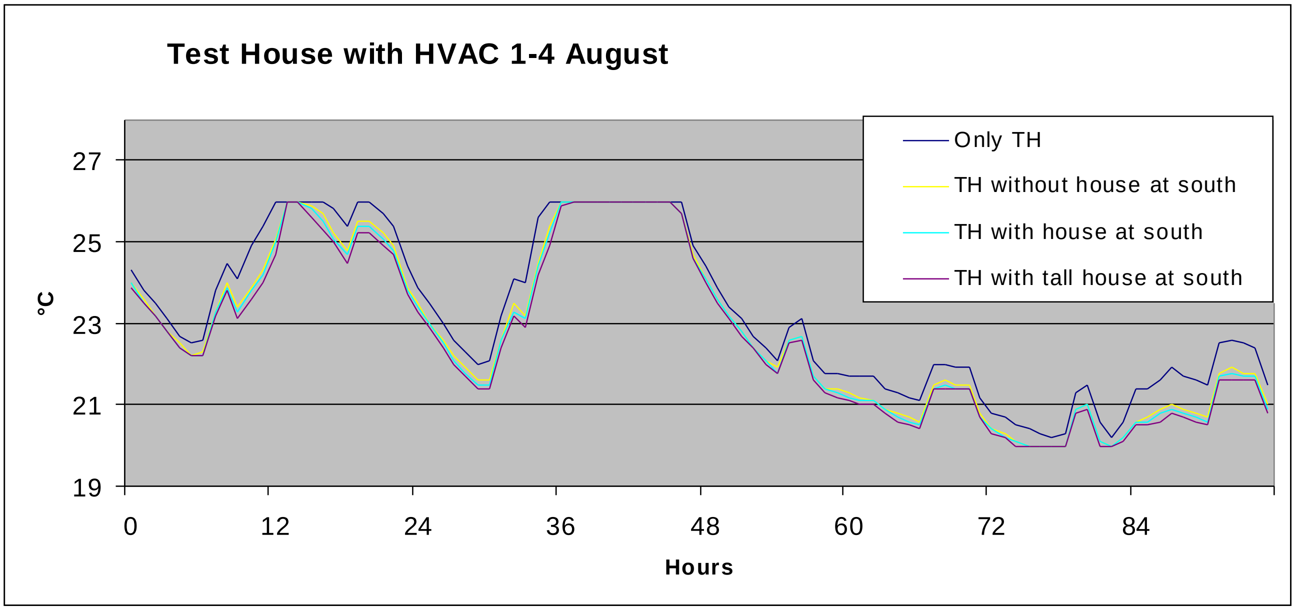

Fig. 9.8 Overview of the resulting temperature of various scenarios

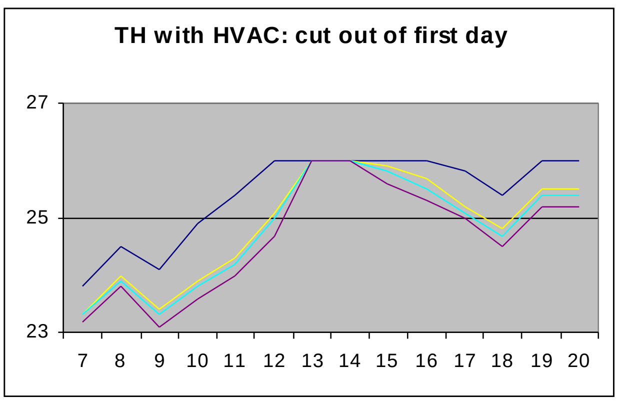

Fig. 9.9 Cut out of Fig.9.8

Two enlargements from Fig. 9.8 are made so that a better comparison is possible.
The temperature of Test House is quite the same for all the simulations.
The simulation of TH with concrete wall is not taken in consideration now, because it is a special case.

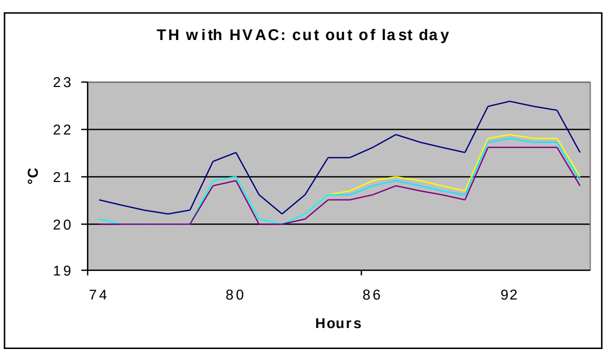

Fig. 9.10 Cut out of Fig.9.8

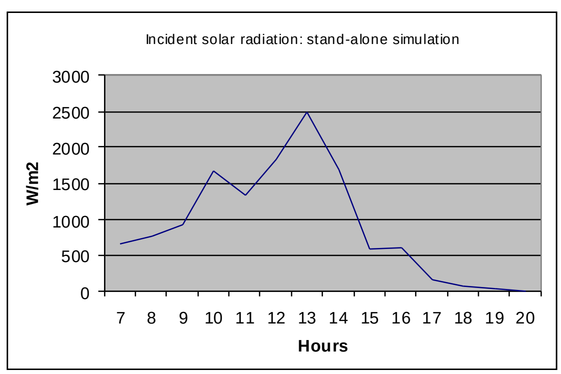

Fig. 9.11 Cut out of solar radiation

Figure 9.9 is a cut out of Figure 9.8: it represents the comparison between the stand-alone simulation and the different scenarious in an urban context.
In the morning, the temperature difference is about 1°C between the stand-alone and the multiple building simulation.
At midday the temperature rapidly increases and at 1 p.m. it reaches the limit of 26 °C , the limit is due to the cooling system that is configured to start at 26 °C.
All the simulations made in a urban context reach the limit temperature at the same time, therefore the scenario with a high house placed at the south has a greater temperature range, Its temperature gradient is also bigger. This situation is more sensitive to solar radiation changes, in fact it has the most rapid temperature decrease as solar radiation lowers.
As shown in figure 9.11 there is a significant decrease of the solar radiation starting from midday until 2 p.m.
Fig. 9.10 is another cut out of the period taken in exam.
The temperature difference are the same, 1°C between the stand-alone situation and the one placed in an urban context.
The various temperatures stay within a 0.5 °C range if a comparison of only the different scenarios simulated in an urban context are considered.
In this figure the maximum temperature reaches 22.6 °C it is quite a cold day compared to the other days in august, the maximum solar radiation is at noon and has a value of 1000 Wh/h .
The characteristics of temperature difference are the same over all the period that is analyzed.
All the periods have more or less the same temperature pattern.

Below, graphs for an overview of the solar radiation values are presented

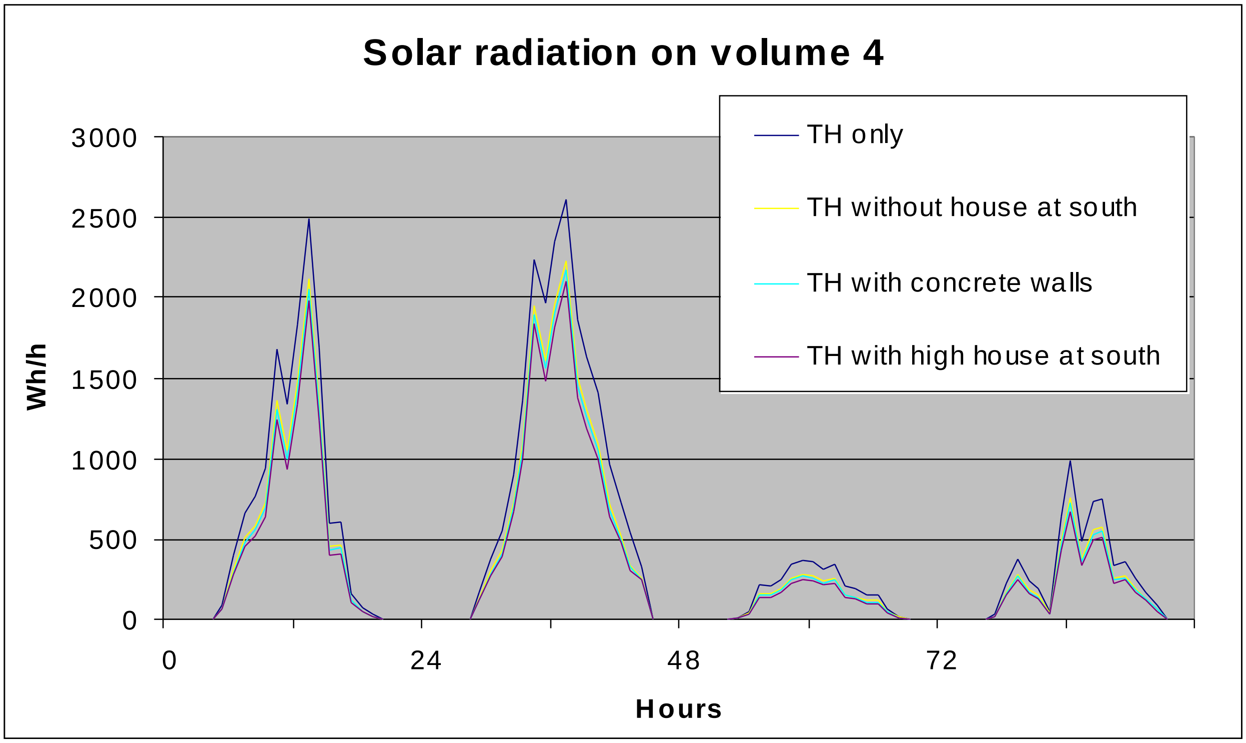

Fig. 9.12 Overview of solar radiation transmitted into volume 4

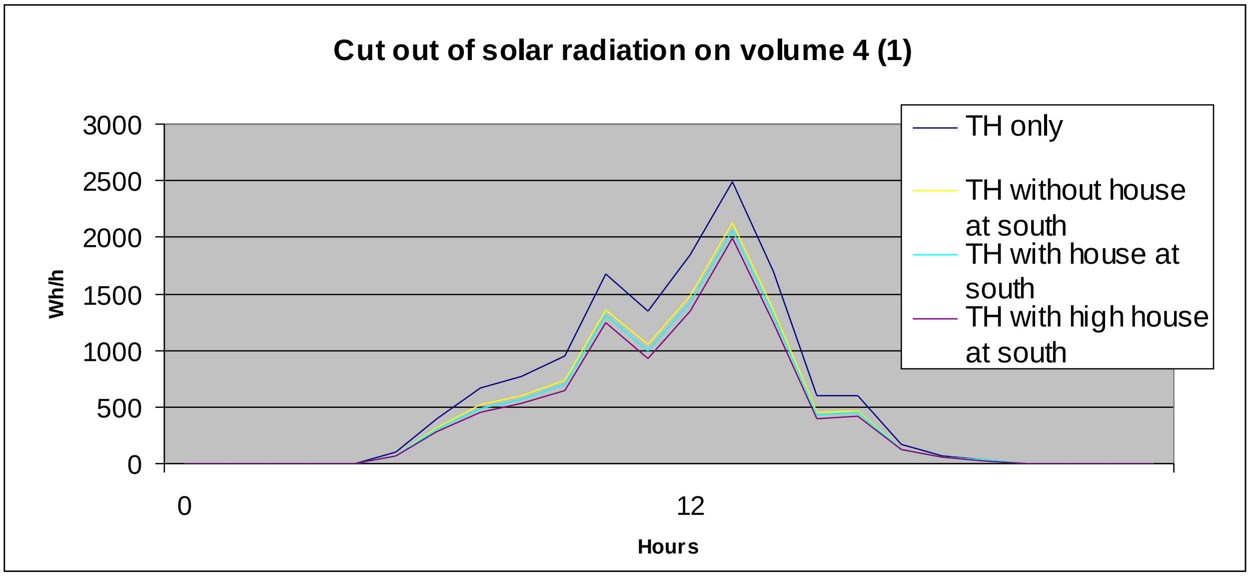

Fig. 9.13 Detail of Fig. 9.12

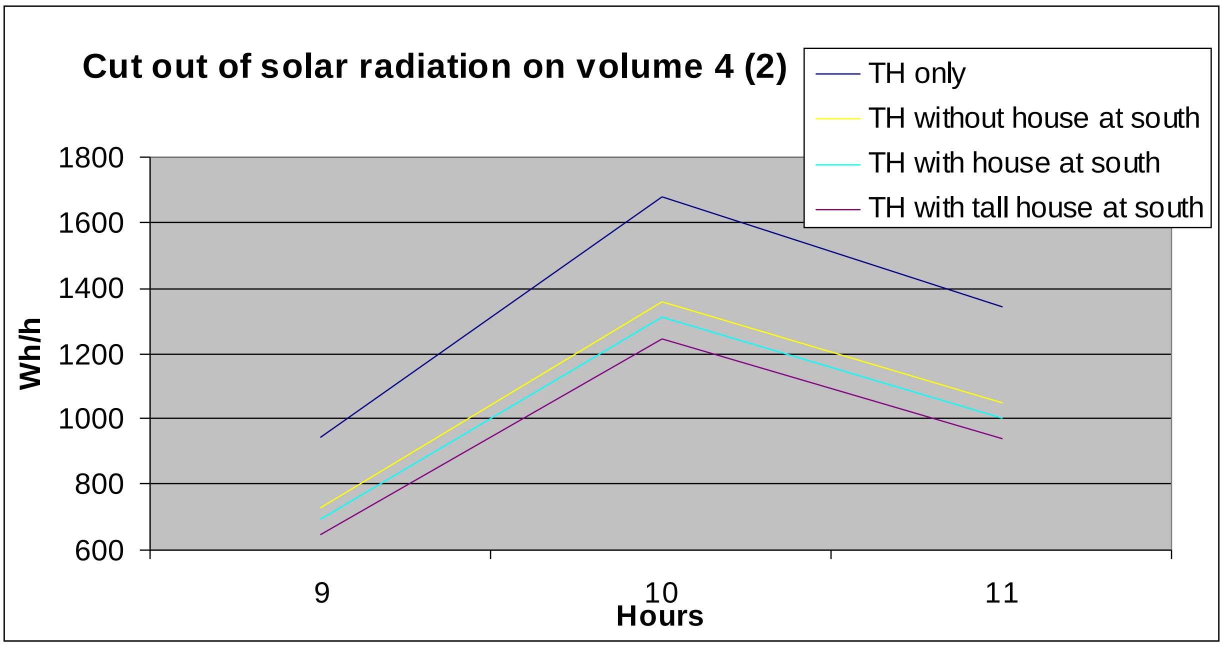

Fig. 9.14 Particular of Fig. 9.12 and Fig. 9.13

9.2.2.5 Conclusions

As expected, the highest temperature in TH is obtained simulating only TH, stand-alone simulation.
A little cut out from the period in exam is taken, as showed in Fig. 9.9. Represented is the first of august, from 7 a.m. until 8 p.m..
In this figure the solar radiation incident on volume 4 of test house reaches a value of 2500 Wh/h, this is simulated in an stand-alone environment, in fact a value of about 2100 Wh/h is reached, with a simulation in an urban context . Having a higher house placed in the south results in a decrease of 100 Wh/h from the maximum value.

9.2.3 Simulation without considering HVAC schedules

The next diagrams shows the results of simulations made without considering the HVAC schedules. The temperature inside volume 4 is no more bounded within 20°C and 26°C.
The first two diagrams represent the temperature in volume 4 in 5 different scenarios: one scenario is a single-building simulation, the second is a simulation of the test house located in an urban context of buildings made of shading screens. The last three simulation were done with different sizes for the building located at the south of the test house.

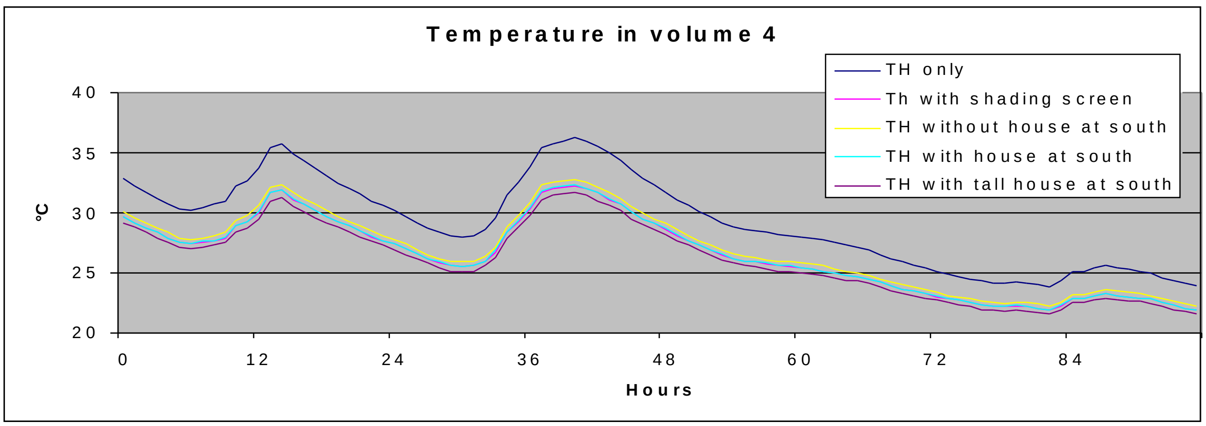

Fig. 9.15 Temperature in volume 4, without HVAC

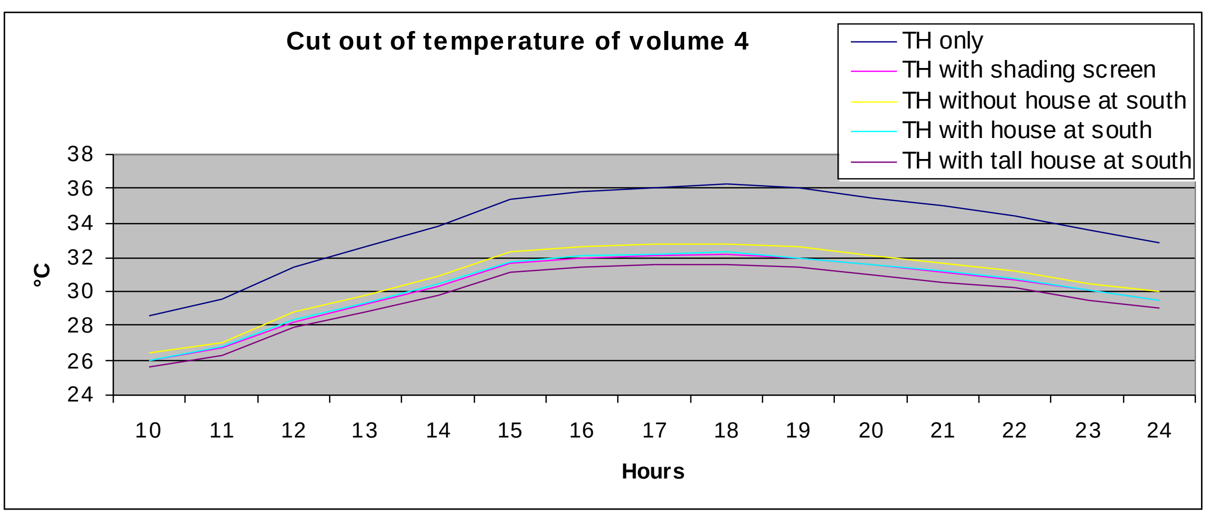

Fig. 9.16 Detail of figure 9.15

As better seen in the Fig. 9.16, the temperature change between the different scenarios is more noticeable here than not in the situation above, where HVAC was active.
Another important consideration refers to the trend of the temperature. Differently from the graph in the previous pages, where different scenarios were characterised from different gradients of

temperature due to the boundary restriction imposed by the HVAC schedules, here the simulation of different urban context results in parallel temperature's trends. The same sensitivity to variations of solar radiation is observed for all the different scenarios.

The next diagrams represent the simulation of the modified test house.

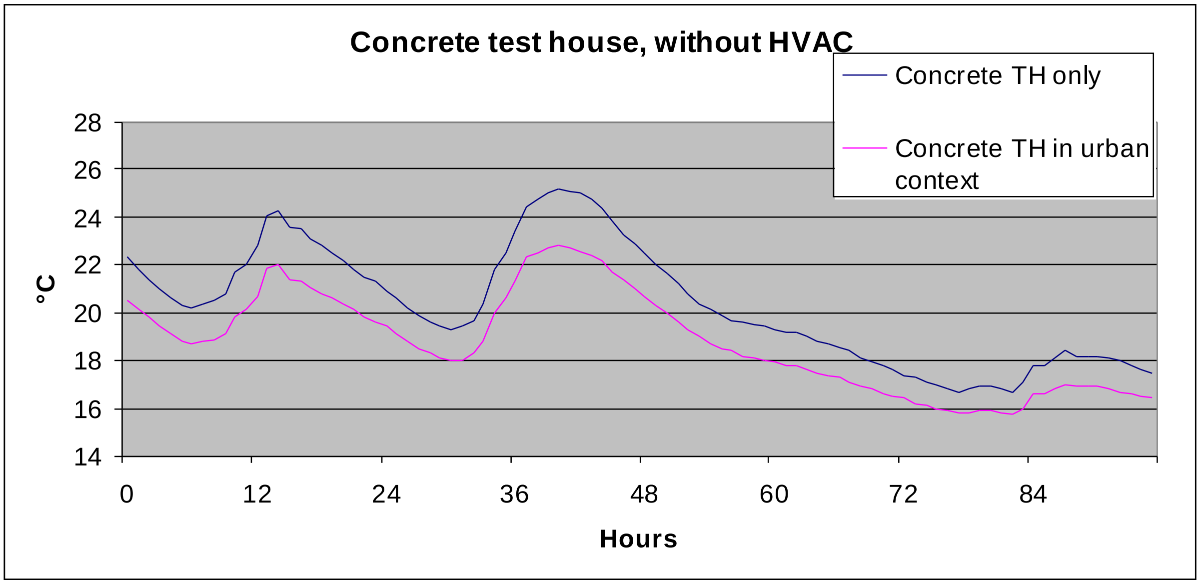

Fig. 9.17 Concrete test house, without HVAC

Confronting Fig. 9.16 with Fig. 9.15, it is possible to see that the temperature inside volume 4 is about 9°C lower in the case of concrete external walls. This is due to the fact that concrete walls have a minor heat transmitting coefficient. So the solar radiation that flows through the windows do not vary, but there are less solar radiation flowing through the walls. This results in a significant temperature drop.

9.3 Energy consumption

Influenced by the variation of temperature, incident and transmitted solar radiation, there is another factor of major concern which has to be considered: the energy consumption. As explained in section 5.3 it is crucial to take account also of the energy balance of the simulated building, in order to correctly plan the energy load that the heating and cooling system will face.

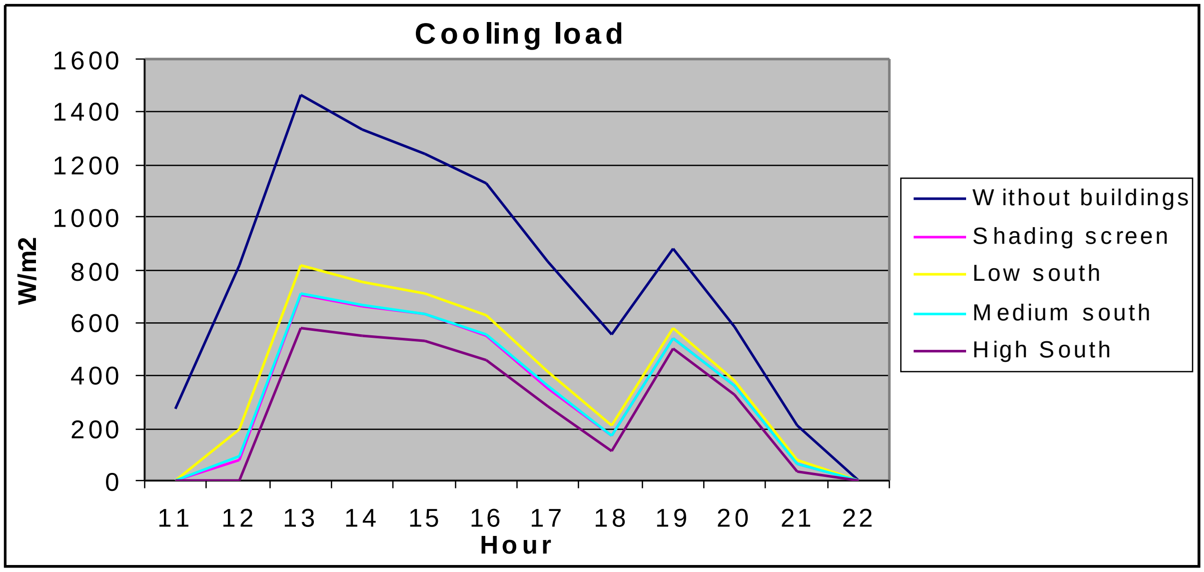

Fig. 9.18 Cooling load of 5 different scenarios

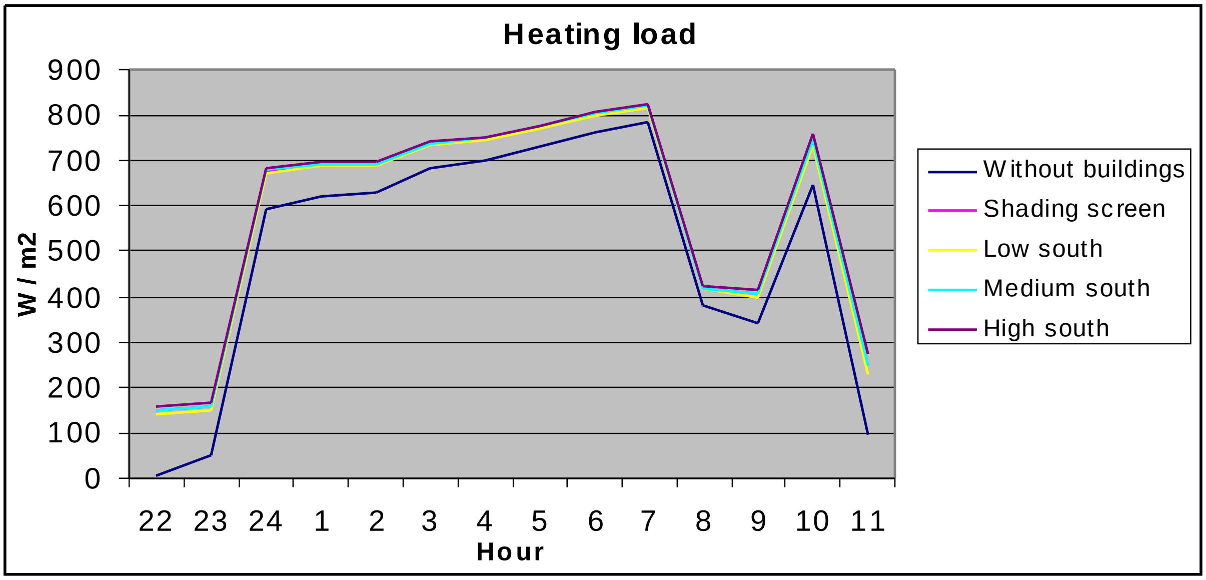

Fig. 9.19 Heating load of 5 different scenarios

In Fig. 9.18 and in Fig. 9.19 the cooling respectively the heating load in volume 4 in two different days for five different scenarios is visible. The cooling diagram refers to the second day of August days of August, the heating load graph to the night between the second and the third of October.
As already seen in the graphs of section 9.2, the values of the temperature resulting from the simulations made with only the test house are always a little higher than in the other cases. Due to this fact, the cooling of the test house in case of a single-building simulation needs a bigger load in terms of Watt. On the other hand, when referring to the heating system, this load is a little lower.

In the table below, values for the power consumption (expressed in Watt) for the months of January and August are presented. Besides, also the yearly summary can be seen. All these values refers to volume 4 of the test house. The last column, labelled "%", presents the different power consumption, in percentage, between the correspondent scenario and the single-building simulation (labelled TH only). A negative value means that less energy was necessary.

	August		January		Yearly Summary			%
	Heating	Cooling	Heating	Cooling	Heating	Cooling	Total	
TH only	5.90	389.41	1555.54	0	7361.70	2256.39	9618.09	
TH with shading screen	12.07	265.83	1619.13	0	7989.73	1489.80	9479.54	-1.44
TH without house at south	11.32	277.93	1588.74	0	7868.63	1559.98	9428.62	-1.96
TH with house at south	12.04	266.85	1619.12	0	7988.39	1496.08	9484.47	-1.38
TH with high house at south	13.11	254.51	1653.00	0	8280.21	1397.02	9677.23	0.61
TH only, with concrete walls	86.92	136.60	3479.20	0	18550.01	745.80	19295.81	100.62
TH with concrete walls	34.21	68.47	3564.79	0	19815.05	385.07	20200.13	110.02

Fig. 9.20 Table for the values of power consumption

Before starting an analysis of the values of the table above, it is necessary to consider the assumptions made earlier. Only the test house has a thermal mass, the surrounding buildings do not store heat. If it was not so, the expected values would have been very different from the obtained values. In fact, in the case where the test house is surrounded by buildings, the test house would have been protected by the neighbour buildings, and it would have been much hotter inside it than in the stand-alone case.

Taking account of that, the percentages in Fig.9.20 can be considered as a consequence of the variation of the incident solar radiation due to the variation of the urban context. Less radiation results in more heating power load requested. On the other hand, a decrease in the cooling load is noticeable.

Considering rows 3,4 and 5 and the large preponderance of the heating load in respect to the cooling load it can be affirmed that the more the test house is screened by other buildings, the more energy is consumed.

The last two rows refer to the cases in which the test house was modified in its structure. Walls made of concrete substituted the external walls made of mineral wool. Here, an important change is observed. The heating load is more than doubled while the cooling load is halved. Also a confrontation between these two scenarios is interesting: considering an heavy thermal mass, the differences increase in importance.

The histograms represented below in Fig.9.21 and Fig.9.22 offer a better visualisation of these percentages.

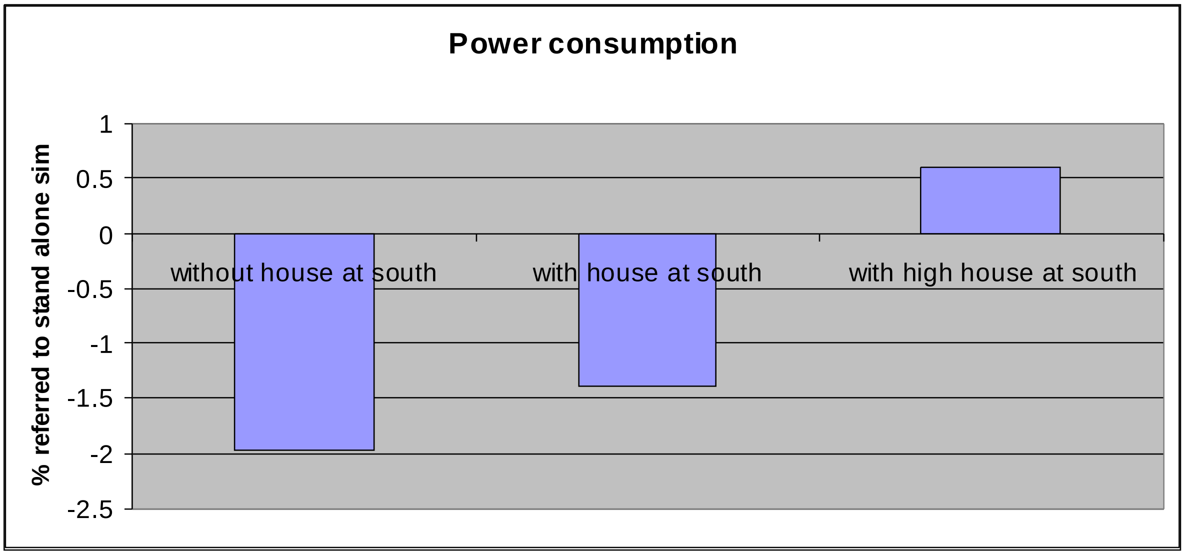

Fig. 9.21 Power consumption: difference between three scenarios

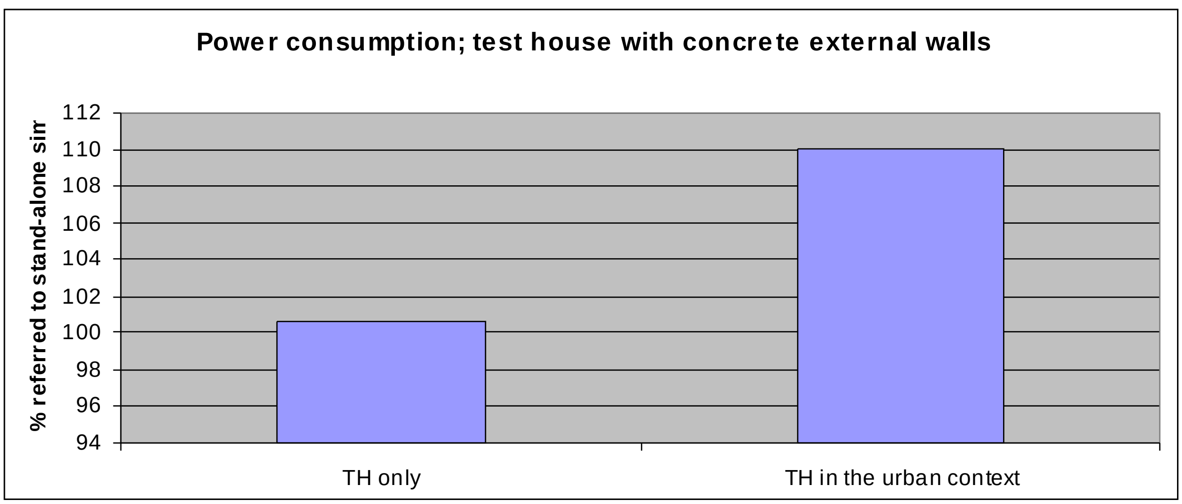

Fig. 9.22 Power consumption for concrete external walls test house: difference between two scenarios

10 Simulation of sudden climate changes

Intelligent buildings (IB) must have the capability to respond quickly to external stimuli, in order to provide comfort for the occupants. Hence, also the simulation software has to provide a good environment to properly simulate fast changes of the climate conditions.

If it's a sunny day, probably some sunshades are closed to reduce the sun radiation that hits on windows.
If suddenly a cloud shades the sun partially or totally, the light will decrease very quickly. The building must know that there is a change going on outside, and will respond by opening the sunshades, so that there is again enough light in the rooms.
Now, if data is provided only once an hour to the building, it is clear that the IB would not be able to respond in an appropriate way to sudden variations of the weather.
Nowadays, simulating software has a time resolution of 1 hour; that is not enough in order to program the behaviour of the buildings actuators which receive data from sensors. So it is important that simulation are done with a little time-step, a time resolution of 1 minute.
Obviously, changing the time-step would have required to modify the simulation software, which is impossible if the sourcecode is not provided.
So, as an alternative a work-around was studied: oversampling the climate data.
This solution consists of instead having 24 data for a single day, you would have 1440 data (24x60).
A first try was to have 60 constant temperature values, that would replace an old 1-hour data element, to see if DEROB could manage to simulate the situation in a proper way.
Of these 60 values 4 of them were modified to simulate a sudden climate change.

There are two options in DEROB for the sun radiation:

1- With sun: DEROB uses sun-radiation values from climate file
2- No sun: DEROB uses outdoor temperature to establish the building temperature, sun radiation is set to zero.

There are also two options for the outside temperature:

1 – DEROB reads the outdoor temperature from climate file.
2 – DEROB uses a user-specified constant for the outdoor temperature.

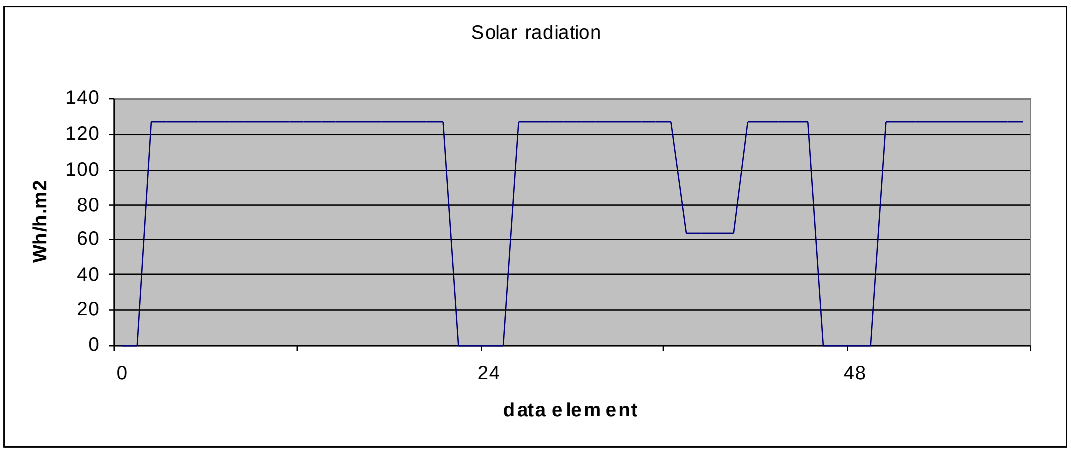

Fig 10.1 The solar radiation as modified to simulate more than one radiation value pro hour

DEROB failed in simulating the oversampled-data input file, the solar radiation at data element 24 has a value of zero as clearly to be seen in figure 10.1. This value does not agree at all with the value in the input file that was provided for the simulation. Expected was a constant graphic at a value of 100 Wh/h.m2 over all the simulation period, with 4 data with value of 50 Wh/h.m2.
First the specified solar radiation of 100 Wh/h.m2 becomes 126 Wh/h.m2 after a simulation is done, this is quite strange because the solar radiation does not have to change.
Secondly, after that several simulations were made, modifying various parameters, we can say that DEROB always resets the values each 24 data, more precisely data element 22,23,24 and 25 are set to zero, so it is impossible to oversample the climate file.

To see is also that when the half radiation is provided in the climate file, DEROB simulates that correctly, in fact in the second day we have a decrease of the solar radiation of half of the maximum value.

The temperature of volume 4 is represented in the chart below (Fig. 10.2). The simulation was done with the “No sun” option activated.
In the climate file there was a change of the outside temperature from 20° to 10° for 4 hours. It is clearly visible that the temperature of the volume falls down and then slowly increases again.
The temperature of volume 1 is represented in the chart below (Fig. 10.3). The simulation was done with the “No sun” option activated.
In the climate file there was a change of the outside temperature from 20° to 10° for 4 hours. It is clearly visible that the temperature of the volume falls down and then slowly increases again.

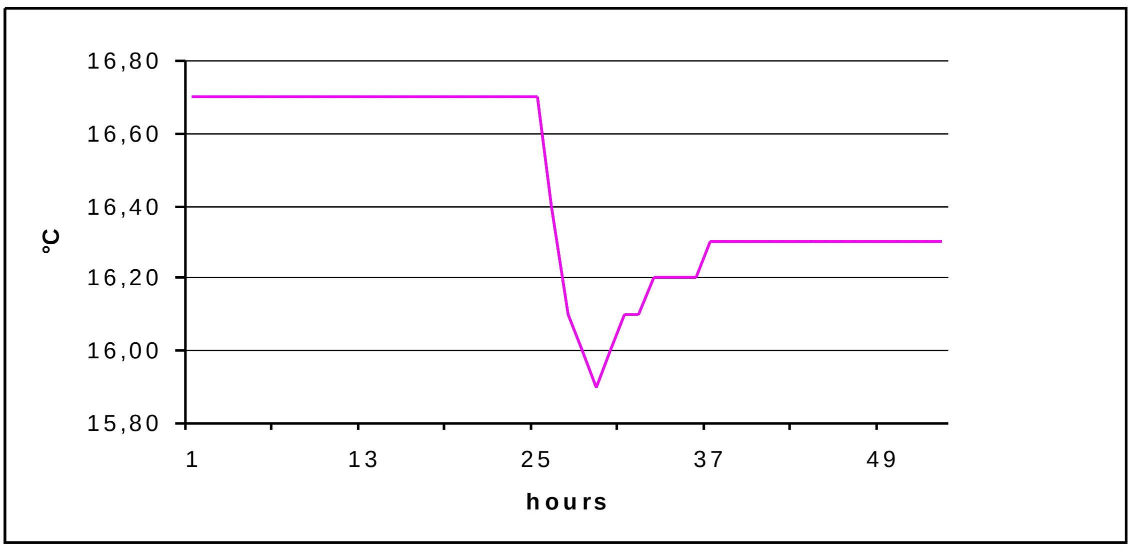

Fig 10.2 Temperature in volume 1, measured with no solar radiation influence

With this option, it is only possible to simulate with variations of the outdoor temperature and not the insulation, which is the major issue simulating sudden climate changes.
Outside temperature is also an effect of solar radiation, so these two measures are linked, it makes no sense to simulate a building without taking account of the sun. It could be only useful if a storm occurs, in fact causing a relevant temperature drop, however the problem of the sun radiation persists.

Clearly, DEROB does not fulfill this task in a proper way.

11 Conclusions

11.1 Integration of GIS data with DEROB

A single dataset was effectively imported in DEROB. Due to lack of time, an automatic tool could not be implemented. However, the solution proposed in this thesis shows how this application could be realised.

11.2 Analysis of the stand-alone vs. integrated building thermal behaviour

This project successfully depicted the differences between a simple stand-alone simulation and a multiple-building simulation. Significant changes are showed in terms of temperature, solar radiation and energy consumption.
It has to be said that the starting assumptions, like the fact that only one building has a thermal mass, influenced the results. This is in great part imputable to the restrictions that most simulators present. Hence an upgrade of existing software or a development of a new simulator would be of major benefit for further simulation.

11.3 Simulation of quick weather changes

As described in section 10, DEROB does not meet the request to provide a simulation of fast climate changes. The problem is that the time granularity is to high to provide a correct simulation for events that last only minutes.
This is not a problem that only DEROB presents: the existing simulation application are not developed to support climate's sudden variation.

11.4 Personal conclusions

The opportunity to experience a research field outside our competences was very attractive. It is likely that we will no more have an occasion to work on a semester thesis or a similar project that concerns IBs, a GIS or simulation software, although it was very interesting and stimulating.
At the beginning, and at the time to comment the results, our inexperience with these topics was a great handicap. However, we were significantly motivated by this challenge.
Clearly we could not achieve all the goals nor answer all the upcoming problems within this project, but we are satisfied of the job done.

12 Outlook

The goal of the main project in which this semester thesis is embedded is to couple GIS with a software for the simulation of the thermal behaviour of intelligent buildings.

As described in the previous chapters, existing simulation software are not compatible with GIS data. There are two solutions: one is to develop software to automatically integrate GIS data in a specific simulator, the other is to develop a thermal simulator in GIS.

The former solution presents the advantage that it can be achieved quickly. As exposed in chapter 8, a tool to import GIS data in DEROB would be a good solution in a reasonable period of time. The latter should be thought of as a long-term goal; it offers the possibility to develop a tool with all the features necessary to provide a proper and precise simulation.

These two possibilities lead to another interesting characteristic: the capability to couple online meteorological data with the simulator in order to have parameters in real-time. Up to now, climate data are not easy to obtain and often have to be bought.

The major advantage of an online binding is the possibility to acknowledge a changing weather condition before the sensors of the IB sense the variation. An integrated simulator linked to the IB's central unit could perceive a variation in the climate data and inform the actuators how to react to the new environmental situation. To achieve the greatest efficiency many neighbor IBs could be connected.

13 Bibliography

Clarke, J.A. “Assessing building performance by simulation”, Building and Environment, Vol. 28. No. 4, 1993.

Karlsson, J., Roos, A., Karlsson, B. “Building and climate influence on the balance temperature of buildings”, Building and Environment, Vol. 38, 2003

Augenbroe, G., Hansen, J. “Simulation for better building design”, Building and Environment, Vol. 39, 2004

Kua, H.W., Lee, S.E. “Demonstration intelligent building—a methodology for the promotion of total sustainability in the built environment”, Building and Environment, Vol. 37, 2002

Guillemin, A., Morel, N. “An innovative lighting controller integrated in a self-adaptive building control system”, Energy and Buildings, Vol. 33, 2001

Müller, M., Landtwing, S. “Coupling of GIS and building simulation software”, Semester project GeoIT-ETHZ, 2005

14 Internet resources

Simulation Software

DEROB-LTH: http://www.byggark.lth.se/shade/Derob.htm, April 2005

ParaSol: http://www.byggark.lth.se/shade/parasol.htm, April 2005

TRNSYS: http://www.trnsys.com/, April 2005

Geographic Information System

Homepage: http://www.gis.com, April 2005

Environmental Systems Research Institute (ESRI, GIS developer): http://www.esri.com, April 2005

15 List of figures

Appendix A

Tables of values of the simulated scenarios

Legend:
TH only: Test House only, no urban context.
SS: Test House integrated in an urban context made of shading screen.
SSB: Small-size South Building.
MSB: Medium-size South Building.
TSB: Tall South Building.
CTH only: Concrete Test House, no urban context.
CTH: Concrete Test House integrated in an urban context.

Volume 4, 1./4.August, with HVAC

Temperature (°C):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	24.3	24	24	24	23.9	21.2	22.3
2	23.8	23.5	23.6	23.5	23.5	20.8	21.8
3	23.5	23.2	23.2	23.2	23.2	20.4	21.4
4	23.1	22.8	22.8	22.8	22.8	20.1	21
5	22.7	22.4	22.5	22.4	22.4	20	20.6
6	22.5	22.2	22.2	22.2	22.2	20	20.3
7	22.6	22.2	22.3	22.2	22.2	20	20.3
8	23.8	23.3	23.3	23.3	23.2	20.4	21.2
9	24.5	23.8	24	23.9	23.8	20.6	21.6
10	24.1	23.2	23.4	23.3	23.1	20	20.9
11	24.9	23.7	23.9	23.8	23.6	20.4	21.6
12	25.4	24.1	24.3	24.2	24	20.6	21.9
13	26	24.9	25.1	25	24.7	21.2	22.7
14	26	26	26	26	26	22.3	23.9
15	26	26	26	26	26	22.4	24
16	26	25.7	25.9	25.8	25.6	21.9	23.5
17	26	25.5	25.7	25.5	25.3	21.8	23.3
18	25.8	25.1	25.2	25.1	25	21.6	22.9
19	25.4	24.6	24.8	24.7	24.5	21.2	22.6
20	26	25.4	25.5	25.4	25.2	22.1	23.3
21	26	25.4	25.5	25.4	25.2	22	23.2
22	25.7	25.1	25.2	25.1	24.9	21.7	22.8
23	25.4	24.8	24.9	24.8	24.7	21.5	22.5
24	24.4	23.8	23.9	23.8	23.7	20.6	21.6
25	23.9	23.4	23.5	23.4	23.3	20.2	21.2
26	23.5	23	23	23	22.9	20	20.8
27	23	22.5	22.6	22.5	22.4	20	20.4
28	22.6	22.1	22.2	22.1	22	20	20
29	22.3	21.8	21.9	21.8	21.7	20	20
30	22	21.5	21.6	21.5	21.4	20	20
31	22.1	21.5	21.6	21.5	21.4	20	20
32	23.2	22.5	22.6	22.6	22.4	20	20.5
33	24.1	23.3	23.5	23.3	23.2	20.2	20.9
34	24	23.1	23.2	23.1	22.9	20	20.6
35	25.6	24.3	24.5	24.4	24.2	20.8	21.8
36	26	25.1	25.4	25.2	24.9	21.3	22.4
37	26	26	26	26	25.9	22	23.3
38	26	26	26	26	26	23	24.5
39	26	26	26	26	26	23.2	24.8
40	26	26	26	26	26	23.3	25

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
41	26	26	26	26	26	23.4	25.1
42	26	26	26	26	26	23.3	25
43	26	26	26	26	26	23.1	24.8
44	26	26	26	26	26	24	25.5
45	26	26	26	26	26	23.8	25.3
46	26	26	26	26	26	23.3	24.7
47	26	25.7	25.7	25.7	25.7	22.9	24.2
48	24.9	24.6	24.7	24.6	24.6	21.9	23.1
49	24.4	24.1	24.1	24.1	24	21.4	22.6
50	23.9	23.6	23.6	23.6	23.5	20.9	22
51	23.4	23.2	23.2	23.2	23.1	20.5	21.6
52	23.1	22.8	22.8	22.8	22.7	20.2	21.2
53	22.7	22.4	22.4	22.4	22.4	20	20.7
54	22.4	22.1	22.1	22.1	22	20	20.4
55	22.1	21.8	21.9	21.8	21.8	20	20.1
56	22.9	22.6	22.6	22.6	22.5	20	20.7
57	23.1	22.7	22.7	22.7	22.6	20	20.7
58	22.1	21.7	21.7	21.7	21.6	20	20
59	21.8	21.4	21.4	21.4	21.3	20	20
60	21.8	21.3	21.4	21.3	21.2	20	20
61	21.7	21.2	21.3	21.2	21.1	20	20
62	21.7	21.1	21.2	21.1	21	20	20
63	21.7	21.1	21.1	21.1	21	20	20
64	21.4	20.9	20.9	20.9	20.8	20	20
65	21.3	20.7	20.8	20.7	20.6	20	20
66	21.2	20.6	20.7	20.6	20.5	20	20
67	21.1	20.5	20.6	20.5	20.4	20	20
68	22	21.4	21.5	21.4	21.4	20	20
69	22	21.5	21.6	21.5	21.4	20	20
70	21.9	21.4	21.5	21.4	21.4	20	20
71	21.9	21.4	21.5	21.4	21.4	20	20
72	21.2	20.7	20.8	20.7	20.7	20	20
73	20.8	20.4	20.4	20.4	20.3	20	20
74	20.7	20.2	20.3	20.2	20.2	20	20
75	20.5	20.1	20.1	20.1	20	20	20
76	20.4	20	20	20	20	20	20
77	20.3	20	20	20	20	20	20
78	20.2	20	20	20	20	20	20
79	20.3	20	20	20	20	20	20
80	21.3	20.9	20.9	20.9	20.8	20	20
81	21.5	21	21	21	20.9	20	20
82	20.6	20.1	20.1	20.1	20	20	20
83	20.2	20	20	20	20	20	20
84	20.6	20.2	20.2	20.2	20.1	20	20
85	21.4	20.6	20.6	20.6	20.5	20	20
86	21.4	20.6	20.7	20.6	20.5	20	20
87	21.6	20.8	20.9	20.8	20.6	20	20
88	21.9	20.9	21	20.9	20.8	20	20
89	21.7	20.8	20.9	20.8	20.7	20	20
90	21.6	20.7	20.8	20.7	20.6	20	20
91	21.5	20.6	20.7	20.6	20.5	20	20
92	22.5	21.7	21.8	21.7	21.6	20.1	20.6
93	22.6	21.8	21.9	21.8	21.6	20	20.4
94	22.5	21.7	21.8	21.7	21.6	20	20.3
95	22.4	21.7	21.8	21.7	21.6	20	20.2
96	21.5	20.9	21	20.9	20.8	20	20

Volume 4, 1./4.August, without HVAC

Temperature (°C):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	32.9	29.7	30.1	29.7	29.2	20.5	22.3
2	32.2	29.2	29.6	29.2	28.8	20.1	21.8
3	31.7	28.7	29.1	28.7	28.3	19.8	21.4
4	31.2	28.3	28.7	28.3	27.9	19.4	21
5	30.7	27.9	28.3	27.9	27.5	19.1	20.6
6	30.3	27.5	27.9	27.5	27.1	18.8	20.3
7	30.2	27.4	27.8	27.4	27	18.7	20.2
8	30.4	27.5	27.9	27.6	27.1	18.8	20.4
9	30.7	27.7	28.1	27.7	27.3	18.9	20.5
10	31	27.9	28.4	28	27.5	19.1	20.8
11	32.2	28.9	29.4	28.9	28.4	19.8	21.7
12	32.7	29.3	29.8	29.3	28.7	20.1	22
13	33.7	30	30.6	30.1	29.5	20.7	22.8
14	35.4	31.6	32.1	31.6	31	21.9	24.1
15	35.8	31.9	32.4	31.9	31.3	22	24.3
16	34.9	31.1	31.7	31.2	30.5	21.4	23.6
17	34.4	30.7	31.2	30.7	30.1	21.3	23.5
18	33.7	30.2	30.7	30.2	29.6	21.1	23.1
19	33	29.7	30.2	29.7	29.2	20.8	22.8
20	32.5	29.3	29.7	29.3	28.8	20.6	22.5
21	32	28.9	29.3	28.9	28.4	20.4	22.2
22	31.5	28.5	28.9	28.5	28	20.1	21.8
23	31	28	28.5	28.1	27.6	19.8	21.5
24	30.6	27.7	28.1	27.7	27.3	19.6	21.3
25	30.2	27.4	27.8	27.4	26.9	19.4	20.9
26	29.7	27	27.4	27	26.5	19.1	20.6
27	29.2	26.6	26.9	26.6	26.2	18.8	20.2
28	28.7	26.2	26.5	26.2	25.8	18.5	19.9
29	28.3	25.8	26.2	25.9	25.4	18.3	19.6
30	28.1	25.6	25.9	25.6	25.2	18.1	19.4
31	28	25.5	25.9	25.5	25.1	18	19.3
32	28.1	25.6	26	25.6	25.2	18	19.4
33	28.6	26	26.4	26	25.6	18.3	19.7
34	29.6	26.7	27.1	26.8	26.3	18.8	20.4
35	31.4	28.3	28.8	28.4	27.9	20	21.8
36	32.6	29.3	29.8	29.4	28.8	20.6	22.5
37	33.8	30.3	30.9	30.4	29.8	21.3	23.4
38	35.4	31.7	32.3	31.8	31.1	22.3	24.5
39	35.8	32	32.6	32.1	31.4	22.5	24.8
40	36	32.1	32.7	32.2	31.5	22.7	25
41	36.2	32.2	32.8	32.3	31.6	22.8	25.2
42	36	32	32.6	32	31.4	22.7	25.1
43	35.5	31.6	32.1	31.6	31	22.6	25
44	35	31.1	31.7	31.2	30.6	22.4	24.8
45	34.4	30.7	31.2	30.8	30.2	22.2	24.4
46	33.6	30.1	30.5	30.1	29.5	21.7	23.8
47	32.9	29.5	30	29.5	29	21.4	23.3
48	32.3	29.1	29.5	29.1	28.6	21	22.9
49	31.7	28.6	29.1	28.7	28.2	20.7	22.5
50	31.1	28.1	28.6	28.2	27.7	20.3	22
51	30.6	27.7	28.1	27.7	27.3	20	21.6

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
52	30.1	27.3	27.7	27.3	26.9	19.6	21.2
53	29.7	26.9	27.3	26.9	26.5	19.3	20.8
54	29.2	26.5	26.9	26.6	26.1	19	20.4
55	28.8	26.2	26.6	26.2	25.8	18.7	20.1
56	28.6	26	26.4	26	25.6	18.5	19.9
57	28.5	25.9	26.3	25.9	25.5	18.4	19.7
58	28.3	25.7	26.1	25.8	25.3	18.2	19.6
59	28.2	25.6	26	25.6	25.2	18.1	19.5
60	28.1	25.5	25.9	25.6	25.1	18	19.4
61	28	25.4	25.8	25.4	25	17.9	19.3
62	27.9	25.3	25.7	25.3	24.9	17.8	19.2
63	27.8	25.2	25.6	25.2	24.8	17.8	19.2
64	27.5	25	25.3	25	24.6	17.6	19
65	27.3	24.8	25.2	24.8	24.4	17.5	18.8
66	27.1	24.7	25	24.7	24.3	17.4	18.7
67	26.9	24.5	24.8	24.5	24.1	17.3	18.6
68	26.5	24.2	24.5	24.2	23.8	17.1	18.4
69	26.2	23.9	24.2	23.9	23.5	16.9	18.1
70	25.9	23.7	24	23.7	23.3	16.8	17.9
71	25.6	23.5	23.8	23.5	23.1	16.6	17.8
72	25.4	23.3	23.6	23.3	22.9	16.5	17.6
73	25.1	23	23.4	23.1	22.7	16.4	17.4
74	24.9	22.8	23.1	22.9	22.5	16.2	17.3
75	24.7	22.7	23	22.7	22.3	16.1	17.1
76	24.5	22.5	22.8	22.5	22.2	16	17
77	24.3	22.3	22.6	22.3	22	15.9	16.8
78	24.1	22.2	22.5	22.2	21.9	15.8	16.7
79	24.1	22.2	22.4	22.2	21.8	15.8	16.8
80	24.2	22.2	22.5	22.3	21.9	15.9	16.9
81	24.1	22.2	22.5	22.2	21.8	15.9	16.9
82	24	22.1	22.4	22.1	21.7	15.8	16.8
83	23.8	21.9	22.2	21.9	21.6	15.7	16.7
84	24.3	22.2	22.5	22.3	21.9	16	17.1
85	25.1	22.9	23.2	22.9	22.5	16.6	17.8
86	25.1	22.9	23.2	22.9	22.5	16.6	17.8
87	25.4	23.1	23.4	23.1	22.7	16.8	18.1
88	25.6	23.3	23.6	23.3	22.9	17	18.4
89	25.4	23.1	23.5	23.1	22.7	16.9	18.2
90	25.3	23	23.4	23	22.6	16.9	18.2
91	25.2	22.9	23.3	22.9	22.6	16.9	18.2
92	25	22.8	23.1	22.8	22.4	16.8	18.1
93	24.6	22.5	22.8	22.5	22.2	16.7	18
94	24.4	22.3	22.6	22.3	22	16.6	17.8
95	24.1	22.1	22.4	22.1	21.8	16.5	17.6
96	23.9	21.9	22.2	21.9	21.6	16.4	17.5

Volume 4, 1./4.August

Solar radiation (Wh/h):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	91.3	66.4	69.7	66.4	61.7	66.4	91.4
7	396.7	296.1	309.7	296.1	277.9	296.1	397.5
8	657.5	481.9	505.9	481.9	450.2	481.9	659
9	770.5	562.1	590.1	562.1	523.1	562.1	771.8
10	942.5	691.5	725.1	691.5	644.4	691.5	944.1
11	1678.5	1310.7	1360.5	1310.8	1243.7	1310.7	1681.4
12	1342.6	1000.2	1046.2	1000.2	936.2	1000.2	1344.9
13	1832.2	1418.6	1474.3	1418.7	1342.4	1418.6	1835.3
14	2491.5	2058.5	2117.5	2058.5	1981.7	2058.5	2495.4
15	1687.7	1308	1359.1	1308	1238	1308	1690.4
16	595.4	433.1	454.8	433.1	402.5	433.1	596.4
17	604.1	439.4	461.5	439.4	408.4	439.4	605.1
18	160.8	117	122.8	117	108.7	117	161.1
19	73.9	53.7	56.4	53.7	50	53.7	74
20	34.8	25.3	26.6	25.3	23.5	25.3	34.8
21	4.3	3.2	3.3	3.2	2.9	3.2	4.4
22	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0
30	170.3	122.7	128	122.7	115.3	122.7	170.5
31	383.7	285.1	298.4	285.1	267	285.1	384.5
32	553.3	411.9	432.3	412	389.1	411.9	555.3
33	901.5	701.6	730.2	701.6	669.8	701.6	904.5
34	1362.1	1048.9	1091.4	1048.9	992.1	1048.9	1364.7
35	2245.8	1896.6	1944.9	1896.6	1837.2	1896.6	2249.8
36	1973.3	1563	1618.5	1563	1488.4	1563	1976.6
37	2350.9	1901.9	1962.8	1901.9	1821	1901.9	2354.7
38	2605.8	2172.2	2231.3	2172.2	2095.8	2172.2	2609.9
39	1857.7	1454.4	1508.8	1454.5	1380.4	1454.4	1860.7
40	1635.7	1258.8	1308	1258.8	1191.7	1258.8	1638.4
41	1407.3	1052.1	1095.4	1052.2	993.1	1052.1	1409.6
42	964.3	686.2	717.7	686.2	643.2	686.2	966
43	723	501.5	523.6	501.5	471.7	501.5	724.2
44	539.2	323.9	335.9	324	308.6	323.9	539.9
45	321.1	251.1	255.9	251.1	244.6	251.1	321.3
46	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
52	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0
54	13	9.5	10	9.5	8.8	9.5	13.1
55	52.1	37.9	39.8	37.9	35.3	37.9	52.2
56	212.9	154.9	162.7	154.9	144	154.9	213.3
57	208.6	151.7	159.4	151.7	141	151.7	208.9
58	252.1	183.4	192.5	183.4	170.4	183.4	252.5
59	343.3	249.7	262.3	249.7	232.1	249.7	343.9
60	369.4	268.7	282.2	268.7	249.8	268.7	370
61	352	256.1	268.9	256.1	238	256.1	352.6
62	312.9	227.6	239	227.6	211.6	227.6	313.4
63	343.3	249.7	262.3	249.7	232.1	249.7	343.9
64	204.2	148.6	156	148.6	138.1	148.6	204.6
65	191.2	139.1	146.1	139.1	129.3	139.1	191.5
66	152.1	110.6	116.2	110.6	102.8	110.6	152.4
67	152.1	110.6	116.2	110.6	102.8	110.6	152.4
68	69.5	50.6	53.1	50.6	47	50.6	69.6
69	21.7	15.8	16.6	15.8	14.7	15.8	21.8
70	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0
78	34.8	25.3	26.6	25.3	23.5	25.3	34.8
79	226	164.4	172.6	164.4	152.8	164.4	226.4
80	373.7	271.9	285.5	271.9	252.7	271.9	374.4
81	243.4	177	185.9	177	164.5	177	243.8
82	195.6	142.3	149.4	142.3	132.2	142.3	195.9
83	52.1	37.9	39.8	37.9	35.3	37.9	52.2
84	634.5	461.6	484.7	461.6	429	461.6	635.6
85	984	724.9	759.6	724.9	676.3	724.9	985.7
86	491.1	357.2	375.1	357.2	332	357.2	491.9
87	734.1	535	561.6	535	497.5	535	735.3
88	751	547.1	574.3	547.1	508.7	547.1	752.3
89	339	246.6	258.9	246.6	229.2	246.6	339.5
90	360.7	262.4	275.5	262.4	243.9	262.4	361.3
91	256.4	186.5	195.9	186.5	173.4	186.5	256.8
92	173.8	126.5	132.8	126.5	117.5	126.5	174.1
93	86.9	63.2	66.4	63.2	58.8	63.2	87.1
94	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0

Volume 4, 1./4.October, with HVAC

Temperature (°C):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	21.4	20.9	20.9	20.9	20.8	20	20
2	21	20.5	20.6	20.5	20.5	20	20
3	20.7	20.2	20.2	20.2	20.2	20	20
4	20.4	20	20	20	20	20	20
5	20	20	20	20	20	20	20
6	20	20	20	20	20	20	20
7	20	20	20	20	20	20	20
8	20	20	20	20	20	20	20
9	20	20	20	20	20	20	20
10	20	20	20	20	20	20	20
11	20	20	20	20	20	20	20
12	20	20	20	20	20	20	20
13	20	20	20	20	20	20	20
14	20.3	20	20	20	20	20	20
15	20.6	20	20.1	20	20	20	20
16	20.5	20	20	20	20	20	20
17	20.2	20	20	20	20	20	20
18	20.1	20	20	20	20	20	20
19	20	20	20	20	20	20	20
20	20.4	20.1	20.1	20.1	20	20	20
21	20.1	20	20	20	20	20	20
22	20	20	20	20	20	20	20
23	20	20	20	20	20	20	20
24	20	20	20	20	20	20	20
25	20	20	20	20	20	20	20
26	20	20	20	20	20	20	20
27	20	20	20	20	20	20	20
28	20	20	20	20	20	20	20
29	20	20	20	20	20	20	20
30	20	20	20	20	20	20	20
31	20	20	20	20	20	20	20
32	20	20	20	20	20	20	20
33	20	20	20	20	20	20	20
34	20	20	20	20	20	20	20
35	20	20	20	20	20	20	20
36	21.3	20.8	21	20.9	20.1	20	20
37	21.6	21	21.1	21.1	20.5	20	20
38	21.2	20.6	20.6	20.6	20.2	20	20
39	21.1	20.4	20.5	20.4	20	20	20
40	21.3	20.3	20.4	20.3	20	20	20
41	21.8	20.1	20.2	20.1	20	20	20
42	21.1	20	20	20	20	20	20
43	20.4	20	20	20	20	20	20
44	21	20.2	20.2	20.2	20.1	20	20
45	20.7	20	20	20	20	20	20
46	20.3	20	20	20	20	20	20
47	20	20	20	20	20	20	20
48	20	20	20	20	20	20	20
49	20	20	20	20	20	20	20
50	20	20	20	20	20	20	20
51	20	20	20	20	20	20	20

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
52	20	20	20	20	20	20	20
53	20	20	20	20	20	20	20
54	20	20	20	20	20	20	20
55	20	20	20	20	20	20	20
56	20	20	20	20	20	20	20
57	20	20	20	20	20	20	20
58	20	20	20	20	20	20	20
59	20.5	20.1	20.1	20.1	20	20	20
60	21.4	20.9	21	20.9	20.2	20	20
61	22.8	22.1	22.2	22.2	21.5	20	20
62	23	23	23	23	23	20	20.2
63	23	23	23	23	23	20	21.1
64	23	22.6	22.7	22.6	22.4	20	22.1
65	23	22.2	22.3	22.2	22	20	21.6
66	23	21.6	21.6	21.6	21.4	20	20.3
67	22.4	21	21	20.9	20.7	20	20
68	23	21.7	21.7	21.6	21.5	20	20
69	22.9	21.6	21.6	21.6	21.4	20	20
70	22.5	21.3	21.4	21.3	21.2	20	20
71	22.1	21	21	21	20.8	20	20
72	20.7	20	20	20	20	20	20
73	20	20	20	20	20	20	20
74	20	20	20	20	20	20	20
75	20	20	20	20	20	20	20
76	20	20	20	20	20	20	20
77	20	20	20	20	20	20	20
78	20	20	20	20	20	20	20
79	20	20	20	20	20	20	20
80	20	20	20	20	20	20	20
81	20.3	20.1	20.1	20.1	20	20	20
82	20.3	20	20	20	20	20	20
83	20.3	20	20	20	20	20	20
84	21.4	20.7	20.8	20.8	20.3	20	20
85	21.7	20.9	21	20.9	20.6	20	20
86	21.3	20.6	20.7	20.6	20.3	20	20
87	21.7	20.8	20.9	20.8	20.5	20	20
88	21.4	20.5	20.6	20.5	20.3	20	20
89	21.6	20.4	20.4	20.4	20.1	20	20
90	21.1	20	20.1	20	20	20	20
91	20.5	20	20	20	20	20	20
92	21.2	20.5	20.5	20.5	20.4	20	20
93	21.2	20.4	20.5	20.4	20.3	20	20
94	21	20.3	20.3	20.3	20.2	20	20
95	20.7	20	20.1	20	20	20	20
96	20	20	20	20	20	20	20

Volume 4, 1./4.October, without HVAC

Temperature (°C):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	23.1	20.2	20.4	20.2	20	14.1	15.6
2	22.8	19.9	20.1	20	19.8	14	15.4
3	22.5	19.7	19.9	19.7	19.5	13.9	15.3
4	22.2	19.5	19.7	19.5	19.3	13.8	15.1
5	21.9	19.2	19.4	19.3	19.1	13.6	14.9
6	21.5	18.9	19.1	19	18.8	13.4	14.6
7	21.2	18.7	18.9	18.8	18.6	13.3	14.4
8	21	18.5	18.7	18.6	18.4	13.1	14.2
9	20.9	18.5	18.7	18.5	18.3	13.1	14.2
10	21.2	18.7	18.9	18.7	18.5	13.2	14.4
11	21.7	19	19.3	19.1	18.8	13.5	14.8
12	21.8	19.2	19.4	19.2	19	13.6	14.9
13	21.9	19.2	19.5	19.2	19	13.5	14.9
14	22.2	19.5	19.7	19.5	19.2	13.8	15.2
15	22.5	19.7	20	19.7	19.4	13.9	15.4
16	22.4	19.6	19.9	19.6	19.3	13.9	15.3
17	22	19.3	19.6	19.4	19.1	13.7	15.1
18	21.9	19.1	19.4	19.2	18.9	13.6	15.1
19	21.5	18.8	19.1	18.9	18.6	13.5	14.8
20	21	18.5	18.8	18.5	18.3	13.3	14.5
21	20.7	18.2	18.5	18.3	18	13.1	14.3
22	20.4	18	18.2	18	17.8	12.9	14.1
23	20.1	17.8	18	17.8	17.6	12.7	13.9
24	19.8	17.6	17.8	17.6	17.4	12.6	13.6
25	19.6	17.4	17.6	17.4	17.2	12.4	13.5
26	19.4	17.3	17.5	17.3	17.1	12.3	13.3
27	19.2	17.1	17.3	17.1	16.9	12.1	13.1
28	18.9	16.9	17.1	16.9	16.7	12	13
29	18.8	16.8	16.9	16.8	16.6	11.9	12.8
30	18.6	16.6	16.8	16.6	16.4	11.8	12.7
31	18.4	16.4	16.6	16.5	16.3	11.6	12.5
32	18.2	16.3	16.5	16.3	16.1	11.5	12.4
33	18.1	16.2	16.4	16.3	16.1	11.5	12.3
34	18.3	16.3	16.5	16.3	16.1	11.5	12.4
35	19.3	17.3	17.5	17.3	17.1	12.2	13.3
36	21.6	19.4	19.7	19.4	18.3	13.9	15
37	22.1	19.8	20.1	19.8	18.9	13.9	15.1
38	21.7	19.3	19.6	19.4	18.7	13.5	14.7
39	21.6	19.2	19.5	19.2	18.6	13.4	14.7
40	21.9	19.2	19.5	19.2	18.6	13.5	15.1
41	22.5	19	19.3	19.1	18.5	13.4	15.6
42	22	18.7	19	18.7	18.2	13.3	15.1
43	21.2	18.4	18.6	18.4	17.9	13.1	14.6
44	20.7	18	18.3	18.1	17.6	12.9	14.3
45	20.3	17.7	18	17.8	17.3	12.7	14.1
46	19.9	17.4	17.6	17.4	17	12.4	13.8
47	19.5	17.1	17.3	17.1	16.7	12.2	13.4
48	19.2	16.9	17.1	16.9	16.5	12	13.2
49	18.8	16.6	16.8	16.6	16.2	11.7	12.9
50	18.5	16.3	16.5	16.3	15.9	11.5	12.6
51	18.1	16	16.2	16.1	15.7	11.2	12.3

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
52	17.8	15.8	15.9	15.8	15.4	11	11.9
53	17.5	15.5	15.7	15.5	15.2	10.7	11.7
54	17.1	15.3	15.4	15.3	14.9	10.5	11.3
55	16.8	15	15.2	15	14.7	10.2	11.1
56	16.6	14.8	15	14.8	14.5	10	10.8
57	17.4	15.6	15.8	15.7	15.3	10.5	11.4
58	19.1	17.3	17.5	17.3	17	11.7	12.6
59	20.2	18.2	18.5	18.3	17.9	12.2	13.2
60	21.4	19.3	19.6	19.4	18.3	12.9	14
61	23	20.8	21.1	20.9	19.7	14	15.1
62	24.5	22.3	22.6	22.4	21.6	14.9	16.1
63	26.3	22.7	23.1	22.8	22.1	15.1	17.3
64	28.1	21.9	22.2	22	21.3	14.5	18.6
65	28	21.3	21.5	21.3	20.7	14.1	18.2
66	26.4	20.8	21.1	20.8	20.2	13.8	17
67	25.2	20.3	20.6	20.4	19.8	13.6	16.3
68	24.5	20	20.2	20	19.4	13.4	15.9
69	24	19.7	19.9	19.7	19.2	13.2	15.6
70	23.5	19.3	19.6	19.4	18.8	13	15.3
71	23	19	19.2	19	18.5	12.8	14.9
72	22.5	18.7	18.9	18.7	18.2	12.6	14.6
73	22	18.3	18.5	18.4	17.9	12.3	14.3
74	21.6	18	18.2	18	17.6	12.1	13.9
75	21.2	17.7	17.9	17.7	17.3	11.9	13.6
76	20.8	17.4	17.6	17.5	17	11.6	13.3
77	20.4	17.2	17.4	17.2	16.8	11.4	13
78	20	16.9	17.1	16.9	16.5	11.2	12.7
79	19.7	16.7	16.9	16.7	16.3	11	12.4
80	19.5	16.5	16.7	16.6	16.1	10.9	12.3
81	20.1	17.2	17.4	17.2	16.8	11.3	12.7
82	21.2	18.3	18.5	18.3	17.9	12.2	13.5
83	21.4	18.4	18.7	18.5	18.1	12.2	13.6
84	22.6	19.5	19.8	19.6	18.7	13	14.5
85	23	19.8	20.1	19.9	19	13.2	14.7
86	22.6	19.4	19.7	19.5	18.8	12.9	14.4
87	23.1	19.7	20	19.8	19.1	13.3	15
88	22.7	19.5	19.8	19.6	18.9	13.2	14.7
89	22.9	19.3	19.6	19.4	18.8	13.1	15
90	22.5	19.1	19.3	19.1	18.6	13.1	14.8
91	21.9	18.7	19	18.8	18.2	12.9	14.5
92	21.5	18.5	18.7	18.5	18	12.8	14.3
93	21.2	18.2	18.5	18.3	17.8	12.7	14.1
94	20.9	18	18.2	18	17.6	12.6	13.9
95	20.5	17.7	18	17.8	17.3	12.4	13.7
96	20.2	17.5	17.8	17.6	17.1	12.3	13.5

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Solar radiation (Wh/h):

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0
8	65.2	47.4	49.8	47.4	44.1	47.4	65.3
9	278.1	202.3	212.5	202.3	188.1	202.3	278.6
10	573.7	431	450.2	431	404.3	431	574.7
11	813.7	619.5	645.6	619.5	583.2	619.5	815
12	702.9	517.9	542.6	517.9	474.3	517.9	704.1
13	617.1	448.9	471.4	448.9	417.2	448.9	618.1
14	807.2	602.8	630.2	602.8	564.4	602.8	808.5
15	799.2	571	597	571.1	534.7	571	800.5
16	417.2	303.5	318.7	303.5	282.1	303.5	417.9
17	208.6	151.7	159.4	151.7	141	151.7	208.9
18	367.6	138.2	145.1	138.2	128.8	138.2	367.9
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0
32	26.1	19	19.9	19	17.6	19	26.1
33	212.9	154.9	162.7	154.9	144	154.9	213.3
34	343.3	249.7	262.3	249.7	232.1	249.7	343.9
35	1213.8	1018.6	1045	1018.6	982.9	1018.6	1215.3
36	2299	2073.6	2104.4	2073.6	1493.2	2073.6	2301.3
37	1452.3	1203.3	1236.9	1203.3	1116.3	1203.3	1454.2
38	754	562.6	588.3	562.7	526.7	562.6	755.2
39	667.5	481.3	504.4	481.4	449	481.3	668.6
40	908.6	464.1	485.2	464.1	435.1	464.1	909.7
41	1173.6	280.1	293.8	280.1	262.5	280.1	1174.4
42	225.1	106.7	112.1	106.7	99.4	106.7	225.3
43	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0
48	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0
50	0	0	0	0	0	0	0
51	0	0	0	0	0	0	0

hours	TH only	SS	SSB	MSB	TSB	CTH	CTH only
52	0	0	0	0	0	0	0
53	0	0	0	0	0	0	0
54	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0
56	101.9	72.8	76.4	72.8	67.6	72.8	102
57	928.4	844.1	856.1	844.1	829.7	844.1	929.5
58	1770	1638.2	1656.8	1638.2	1616.2	1638.2	1771.8
59	1781.6	1590.4	1616.6	1590.5	1556.8	1590.4	1783.5
60	2131.7	1912.7	1942.6	1912.7	1386.1	1912.7	2133.9
61	2537.5	2317.3	2347.6	2317.3	2147.2	2317.3	2539.9
62	2683.2	2470.1	2499.4	2470.2	2434.6	2470.1	2685.7
63	3051.5	1930.7	1954	1930.7	1904.5	1930.7	3053.8
64	3329.5	683.7	699.5	683.7	668.6	683.7	3331.5
65	1849.4	292.7	306.9	292.7	276.1	292.7	1850.5
66	295.3	102.7	107.8	102.7	95.8	102.7	295.6
67	0	0	0	0	0	0	0
68	0	0	0	0	0	0	0
69	0	0	0	0	0	0	0
70	0	0	0	0	0	0	0
71	0	0	0	0	0	0	0
72	0	0	0	0	0	0	0
73	0	0	0	0	0	0	0
74	0	0	0	0	0	0	0
75	0	0	0	0	0	0	0
76	0	0	0	0	0	0	0
77	0	0	0	0	0	0	0
78	0	0	0	0	0	0	0
79	0	0	0	0	0	0	0
80	181.1	108.2	113.7	108.2	100.6	108.2	181.4
81	784.8	712.4	722.7	712.4	699.9	712.4	785.7
82	1307.5	1173.9	1192.4	1173.9	1150.5	1173.9	1308.9
83	896.1	718	742	718	685	718	897.3
84	1720.8	1487	1518.7	1487.1	1127.6	1487	1722.8
85	1066.5	836.5	867.4	836.5	776.7	836.5	1068.1
86	517.1	376.2	395.1	376.2	349.7	376.2	518
87	1118.5	765	791	765	729.5	765	1120
88	243.4	177	185.9	177	164.5	177	243.8
89	786.3	262.9	276	262.9	245.5	262.9	787.1
90	148.9	89.3	93.8	89.3	83.1	89.3	149.1
91	0	0	0	0	0	0	0
92	0	0	0	0	0	0	0
93	0	0	0	0	0	0	0
94	0	0	0	0	0	0	0
95	0	0	0	0	0	0	0
96	0	0	0	0	0	0	0