Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions.

Advanced Ventilation Technologies

Case Study No 4

EDIFÍCIO SOLAR XXI
LISBON, PORTUGAL

Supported by

Intelligent Energy Europe

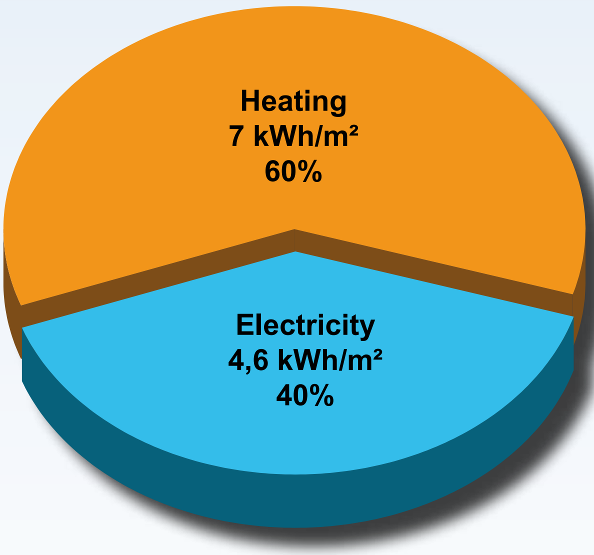
INTRODUCTION

The SOLAR XXI building is in a suburban location and is situated on a campus with several buildings that are well spaced apart. A part of the north façade is shared with another building of similar height. Apart from a building to the west, the immediate surroundings are open with some trees.

Summary Table of key design parameters.

Building data	
Building type	Office and laboratory
Total floor area	1 500 m²
Mean occupant density	30 m²/person
Occupied hours	2 112 hrs/year
HVAC data	
Ventilation system type	Natural ventilation with mechanical assistance.
Heating system	CPC collectors, boiler- assisted
Cooling system	Pre-cooling through buried pipe system
Ventilation rate (or CO_2 concentration)	Not applicable
Heat recovery efficiency	Not applicable
Cooling load (typical)	Not applicable
Heating load (typical)	76 kW (installed boiler power)
Building fabric data	
Window U-value	2.6 W/(m² K)
Window g-value	Winter 0.75 Summer 0.04
Exterior wall U-value	0.5 W/(m² K)
Base floor U-value	0.3 W/(m² K)
Roof U-value	0.3 W/(m² K)
Climate data	
Design outdoor temperature for heating	5.4°C (5%)
Design outdoor temperature and RH for cooling	29.5°C (95%)
Heating degree days (include base temperature)	1 727 degree days (base 20°C)
Cooling degree days (include base temperature)	85 degree days (base 24°C)

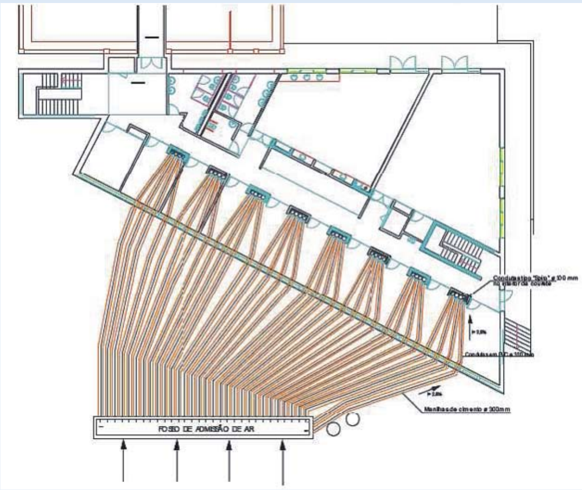
The building is situated in a climate zone with a high cooling load.



Annual energy use.
(Cooling: negligible)

BUILDING DESCRIPTION

The Solar XXI building was built in 2006 on the campus of the National Laboratory for Energy and Geology (LNEG). The building is designed to be mainly naturally-ventilated and to make use of both passive and active solar technologies. It has three floors with a total area of 1 500 m². It was designed as a multipurpose building containing both office and laboratory spaces. The office space, being permanently occupied, is situated on the south side of the building to take advantage of solar exposure. Spaces with intermittent use, such as laboratories and meeting rooms are located on the north side of the building. Figures 1 and 2 show the layout and a section through the building. Office spaces are in use from 09:00 to 18:00 each weekday.



DESIGN SOLUTIONS

As its name suggests, Solar XXI was created with the objective of making extensive use of solar exposure. The building is constructed to provide high internal thermal capacity with 5 cm expanded polystyrene external insulation to both walls and roof slab to reduce heat conduction gains and losses.

The main façade faces south and contains the majority of the glazing as well as supporting 100 m² of photovoltaic panels. The glazing arrangement is intended to optimise passive solar gain in the heating season. Additional space heating is provided by a roof-mounted array of 16 m² of CPC solar collectors (Figure 3) which heat water supplying radiators as well as domestic hot water. The hot water supply from the solar collectors can, when necessary, be supplemented by a condensing gas boiler.

Electricity is supplied by the 100 m² of photovoltaic panels mounted on the south façade and an additional array of panels located to provide shelter and shade in the nearby car park. The total installed peak power is 18 kWp. When necessary the electricity supplied by the PV panels is supplemented from the national grid.

Figure 1. Plan view also showing the distribution of buried air pipe pre-cooling system.

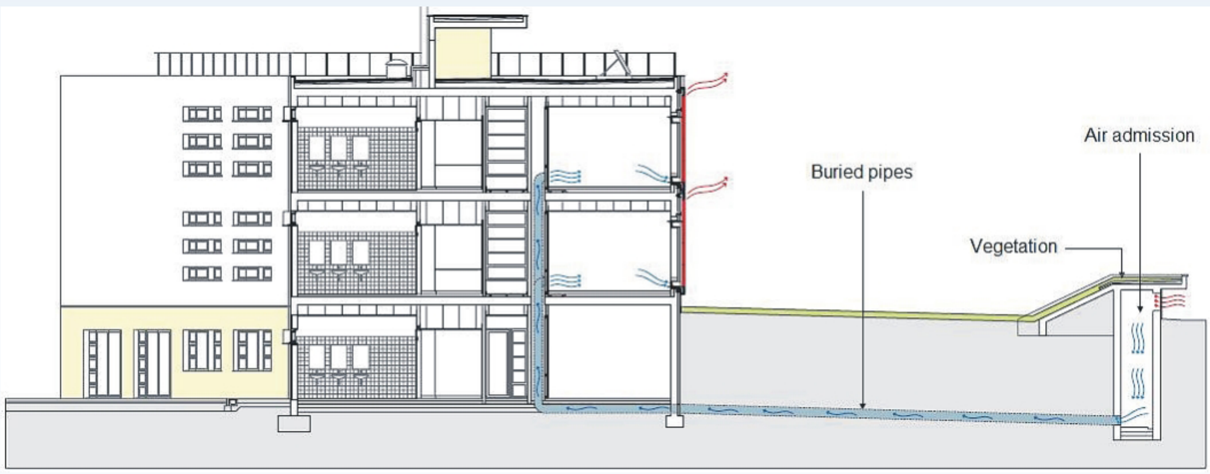


Figure 2. Sectional view of the building.

Solar XXI has no active cooling system and a number of design measures are incorporated to reduce the summertime heat load. Venetian blinds were placed outside the glazing to limit direct solar gains. Natural ventilation during favourable conditions is promoted through the use of openings in the façade and between internal spaces, together with openable clerestory windows at roof level. When these methods are insufficient, incoming air can be pre-cooled by being drawn by small fans through an array of 32 underground pipes, as shown in Figure 1. Each pipe has a diameter of 30 cm, length of 20 m and is buried at a depth of 4.6 m.

Figure 3. CPC thermal collectors on the building roof.

Figure 4. Internal openings that control natural ventilation (also above door).

Attention has been paid to the use natural lighting where possible. In the centre of the building there is a skylight that provides natural light to the corridors and north-facing rooms located on all three storeys. The installed artificial lighting load is 8 W/m².

VENTILATION STRATEGY

Ventilation is provided by three methods: (i) natural ventilation due to cross wind and stack effect via openings in the facades and at roof level; (ii) assisted ventilation due to convection phenomena from the photovoltaic panels heat losses and (iii) fan-driven air drawn through a system of buried pipes.

The openings in the different facades are designed to allow cross ventilation. This is made possible by the use of adjustable openings (Figure 4) above each door that connects south and north rooms to main corridor. When the air reaches the corridor it moves up through the central lightwell and is extracted through openings in the skylight at roof level (Figure 5).

The mounting of the photovoltaic panels is designed to assist ventilation of the south-facing rooms, operating in a manner similar to a Trombe wall. There is an air gap behind each panel which has openings to indoor and outdoor air at both high and low level (see figures 6 and 11). Heat lost from the rear of the panel raises the temperature of the air in the gap, creating a convective flow. In winter, the upper opening is linked to the indoor space, allowing air entering through the lower opening, either from outside or from the room, to be heated. In summer the upper opening is linked to outdoors. The lower opening can either be open to the room removing warm air to provide ventilation or to outside to provide cooling to the PV panels only.

While it is expected that the natural ventilation system, combined with high thermal mass, will be the principal method of room temperature control across summer, additional cooling is provided by drawing air through the buried pipe system (see Figure 1). This is achieved by fans situated in each room on the south façade. Flow is adjusted by regulating the fan speed and the use of moveable doors (see Figure 7). This resource operates as an additional method of cooling, since natural ventilation takes the majority of the heat absorbed in the building mass during the daytime.

PERFORMANCE

(i) Energy

Solar XXI is one of a group of buildings supplied by gas which are not individually metered. However, the energy used has been estimated using the method in the Portuguese regulations. On this basis, the energy needs for Solar XXI were assessed as 6.6 kWh/m² for heating and 25 kWh/m² for cooling. This compares with the maximum allowable energy consumption set by the regulations, for a building in Lisbon, of 51.5 kWh/m² for

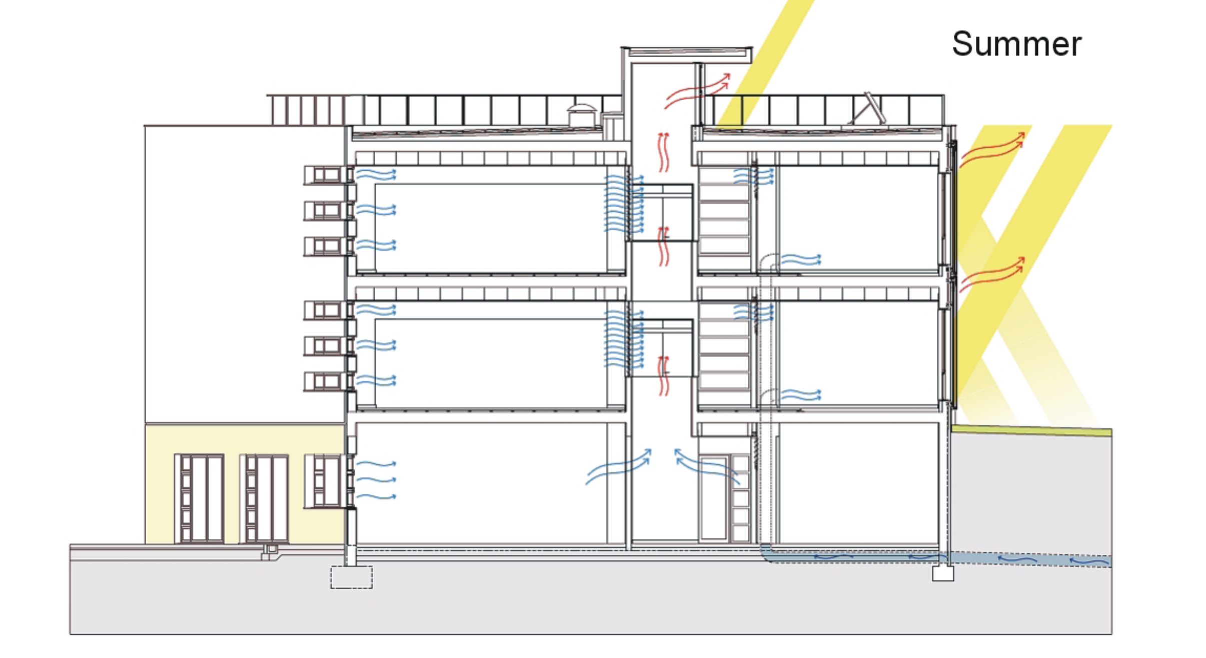


Figure 5. Cross and vertical ventilation systems acting together with the buried pipes system.

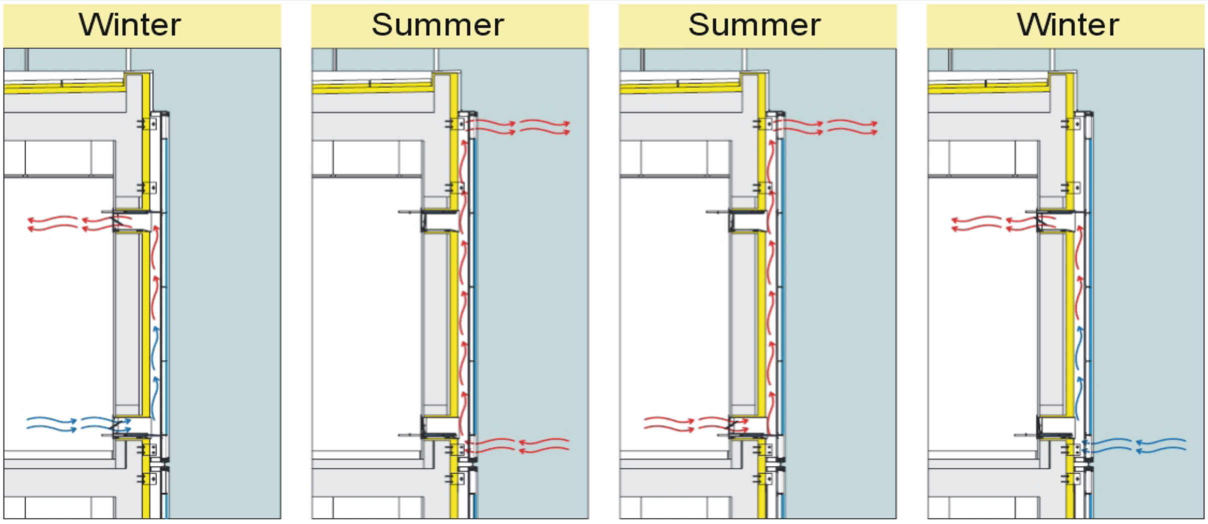


Figure 6. Mode of operation of the photovoltaic panels to supplement ventilation.

heating and 32 kWh/m² for cooling. In addition the heating requirement is reduced by the hot-water solar panels and the cooling requirement by the use of the buried pipe system for pre-cooling. This yields even further below the regulatory requirement. Annual electricity use for the building is approximately 17 kWh/m², of which 12 kWh/m² is supplied by the PV arrays. Consequently, only 30% of demand is drawn from the national electricity grid.

Figure 7. Room air entrance from the buried pipe system.

(ii) Indoor environment

(a) Thermal

Figure 8 shows the mean monthly indoor temperatures July, August and September 2006 and 2007 in comparison with outdoor mean air temperature. Maximum mean temperatures are below 28°C and mean temperatures are close to 26°C, providing satisfactory comfort conditions. Similarly, temperatures for selected winter months are shown in Figure 9. Mean temperatures are always above 20°C, in accordance with Portuguese regulations.

(b) Ventilation

Measurements of carbon dioxide concentration were made on two days in May 2009 in a number of rooms and the results are shown in Figure 10. In all cases the concentration was below 600 ppm and in most cases below 500 ppm. These values are well below the requirements of the Portuguese regulations and indicate a good standard of indoor air quality.

(iii) Occupant assessment of performance

A sample survey of 19 occupants was undertaken in 2008 to investigate their assessment of the indoor environment. The results are summarised in Table 1. In general, occupants were very satisfied with conditions in both summer and winter. 77% found the overall environment acceptable in both seasons and a higher proportion found lighting and noise acceptable. A slightly lower percentage found the thermal environment satisfactory. This result was influenced by occupants of north-facing rooms who do not benefit from the pre-cooled air in summer or solar gain in winter.

DESIGN LESSONS

It is important when a building employs extensive use of passive techniques that the building users have an understanding of how these work and how they may be best used. Solar XXI is no exception to this requirement. It is necessary, for

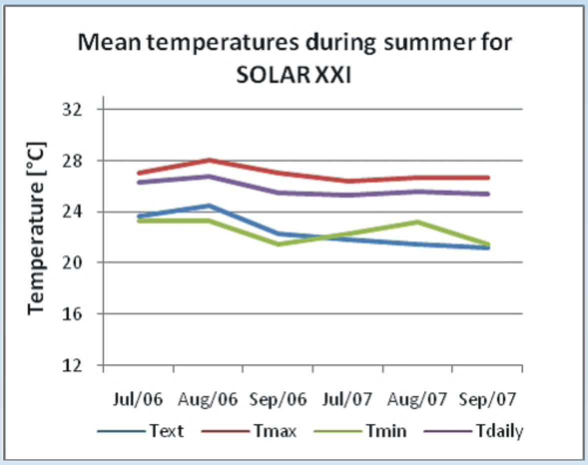


Figure 8.
Mean temperatures during warm months.

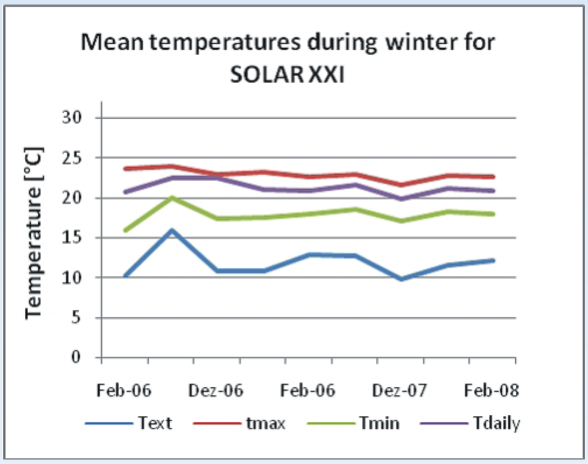


Figure 9.
Mean temperatures during cold months.

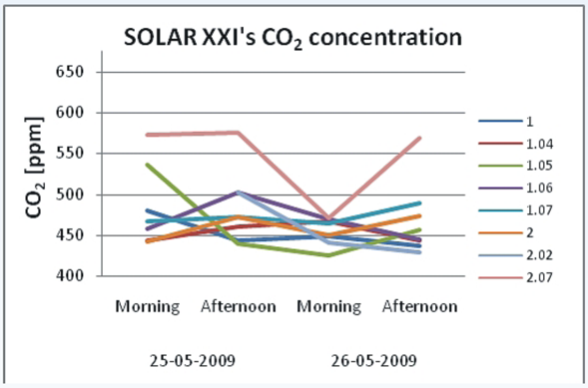


Figure 10. CO_2 measurements across two spring days.

Table 1.
Summary of occupant assessment of the indoor environment.

	Summer %	Winter %
People finding the **overall indoor environment** acceptable	77	77
People finding the **thermal environment** acceptable	73	75
People finding the **indoor air quality** acceptable	83	73
People finding the **acoustic environment** acceptable	92	91
People finding the **lighting** acceptable	83	91

Figure 11. The two openings that lead to the rear of a PV panel.

Design team information *Designers and contractors*	
Client	INETI
Tenant	INETI – Renewable Energy Department
Main Responsible and Coordinator	Dr. Hélder Gonçalves
Architects	Pedro Cabrito and Isabel Diniz
Engineering coordination	Eng. Luis Alves Pereira
HVAC project	Eng. Manuel Nogueira
Structural project	Grepes S. A.
Electrical Installations project	Lomarisco Lda
Construction	Obrecol SA
Photovoltaic systems	Eng António Joyce and Eng. Carlos Rodrigues

example, that occupants know how to operate shading and the inlet and outlet vents. A possible method of improvement would be the installation of an automatic control system that would respond according to indoor and outdoor conditions.

Another option for improvement would be the extension of ground air cooling to serve the north-facing rooms which, at present, have no method of cooling.

GENERAL

Key points concerning the design

This building has demonstrated that sustainable technologies such as solar passive heating, passive cooling, active solar thermal and solar photovoltaic systems can be successfully integrated into the design of a building to provide energy consumption performance below Portuguese EPBD limits while maintaining a satisfactory internal environment.

The total cost for the building was 1.3 million Euros, which represents a cost/floor area ratio similar to that for newly-constructed buildings with a conventional cooling and heating systems.

REFERENCES

Edifício Solar XXI, Um edifício energeticamente eficiente em Portugal, INETI, Lisbon, 2005 (portuguese).

Gonçalves H and Cabrito P. A passive solar office building in Portugal. PLEA2006 – The 23rd Conference on Passive and Low Energy Architecture. Geneva, Switzweland, 6th – 8th September, 2006.

Service Buildings Keep Cool: Promotion of sustainable cooling in the service building sector, KEEPCOOL project, Austrian Energy Agency, Vienna, 2007.

H. Gonçalves et al, Thermal performance of a passive solar office building in Portugal, Department of Renewable energies, INETI, Lisbon, 2008.

Brochure authors: J L Alexandre and M Silva, Faculdade de Engenharia da Universidade do Porto (FEUP).

The authors wish to thank the National Laboratory for Energy and Geology for its contribution to the preparation of this brochure.

BUILDING ADVENT

Full title of the project: Building Advanced Ventilation Technological examples to demonstrate materialised energy savings for acceptable indoor air quality and thermal comfort in different European climatic regions. Building AdVent is funded by the European Commission, Directorate-General for Energy and Transport as part of the Intelligent Energy - Europe Programme.

It is estimated that energy consumption due to ventilation losses and the operation of fans and conditioning equipment is almost 10% of total energy use in the European Union and that about one third of this could be saved by implementing improved ventilation methods. A number of projects have been undertaken under the auspices of the European Union (under the SAVE and ALTENER programmes) and the International Energy Agency (Energy Conservation in Buildings and Community Systems Annexes 26 and 35) to identify and develop improvements in ventilation technology.

The AdVent programme is intended to build on these and has three principal objectives:

- Classification of existing building ventilation technologies as applied in built examples and collection of information on building performance.
- Identification of barriers for future application.
- Preparation of case-studies in a common format, together with training material

BUILDING ADVENT PARTICIPANTS

Coordinator

Buro Happold Consulting Engineers .... UK

Participating Organisations

Brunel University .... UK
National and Kapodistrian University of Athens .... Greece
Helsinki University of Technology .... Finland
Aalborg University .... Denmark
Faculdade de Engenharia da Universidade do Porto .... Portugal
International Network for Information on Ventilation and Energy Performance (INIVE) .... Belgium

Major Sub-Contractors

Federation of European Heating and Air-Conditioning Associations (REHVA) .... The Netherlands
International Union of Architects .... France/Greece
—Architectural and Renewable Energy Sources Work Programme (UIA - ARESWP)

Supported by

Intelligent Energy Europe