AN EXAMPLE OF BIOCLIMATIC CONSTRUCTION.THE BUILDING PETER[3]

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Abstract

The principal objective of this communication is to show an example of bioclimatic building. It is about the construction of an Intelligent "Zero Energy Building" (ZEB) of 1.000 m^2 in the Campus of the University of Extremadura in Badajoz. The concepts of energy efficiency, power storage, environmental impacts, etc., in construction will be put in practice. A comparative analysis between the different conventional technologies and the renewable ones will be carried out. Between the used technologies are those of passive and active solar heating, photovoltaic power, ventilated façade, Trombe walls, use of an hybrid solar-biomass system to feed an absorption engine for refrigeration, etc. Finally, a complete control and analysis of the more important confort variables will be made in real time.

Keywords: *Zero Energy Building (ZEB), Energy Efficiency in Edification, Bioclimatic Building*

1. Introduction

Energy consumption in the housing and service sectors has great relevance in the ambit of the European Union, provided that it exceeds 40% of the total. All European countries have taken steps to restrict the energy demand (like for instance the new Royal Decree for the *Technical Building Code* –TBC- in Spain). Therefore, the application of sustainability criteria to building activity in order to favour energy collection is a priority task for public administrations.

Spain is the most energy consuming country in the European Union if referring to the tertiary sector. It has also the greatest potential for harnessing renewable energy sources.

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[3] PETER. Parque Experimental Transfronterizo de energías renovables, (Experimental Transborder Park on Renewable Energies)

The use of bioclimatic architecture is far from being a modern technique: caves and most traditional constructions are based on bioclimatic principles. However, bioclimatic buildings are an unusual type of housing at present. Although there is no specific official registry, it is estimated that there are between 5000 and 10000 buildings of this type in Spain, according to the Centre for Energetic, Environmental and Technological Research (*CIEMAT*).
Unfortunately, many housing projects are promoted nowadays as bioclimatic, although they should not be taken as such. To what extent should a building be considered to be bioclimatic? Such a denomination is wrongly being assigned to buildings that have a single eave as passive shading element and that integrate certain renewable energy devices.
It is important to note that the concept of *bioclimatic construction* might be seen as new from a textual point of view, but it is not as the constructive concept itself. Yet the Romans designed ventilated covers, and the Arabs invented the tile, the courtyards with ponds and convective loops, and inside gardened zones. In this sense, let us cite some examples like the ventilated adobe walls in centenary constructions of Marrakech, or the efficient cow-dung huts of the Nubis people in the High Nile.
There are some projects being undertaken both inside and outside Spain which are similar to that proposed in the present communication. Some of the most relevant are the following:

- Sustenergy (Sustenergy, 2007). It was supported by the INTERREG III C Program, and ended in 2007. Six different institutions took part in this project, and was led by the Centre of Environmental Resources of Navarra (CRAN). The main goal was the development of common technologies in order to achieve energy saving and efficiency strategies in construction. One of the actions promoted was the set up of thirty pilot experiences, among which the Program for Efficiency in Construction was the most relevant.
- PSE-ARFRISOL(http:/www.energiasrenovables.ciemat.es /suplementos/arfrisol/ pse-arfrisol.htm). Bioclimatic architecture and solar cooling. It is a Singular and Strategic project included in the National Plan of MEC and led by the CIEMAT. It is developed by twelve institutions, like solar energy technology companies and research groups from different universities and from the CIEMAT itself.
- Project CONAMA VII. It was presented in the Sustainable Development Conference held in November 25th 2004, in connection with the topic of Ecoefficiency in Construction. This project allowed to carry out detailed studies on the evaluation of the environmental behaviour of several buildings in Spain.
- Contest of ideas for the construction of a rural house in Chile, according to the principles of sustainability and energy saving -
- Cities for a More Sustainable Future, which can be looked up at the website of the Department of Urban and Landscape Planning in the Superior Technical School of Architecture (Polytechnic University, Madrid).
- Agenda for Sustainable Construction (Sustainability and construction, 2000) , a website designed by the Official College of Master Builders and Technical Architects of Barcelona, the Superior Technical School of Architecture of Vallés, the Association for Geobiological Studies and the Cerdá Institute.
- New York’s Department of Design and Construction. Office for Sustainable Design. This website is specialised in resources for sustainable construction, and is organised in six categories: projects, local legislation, reports and manuals, specification documents, pilot projects and reference examples.
- Website of the Official College of Architects of Cataluña (http://www.coac.net/mediambient/), devoted to the Environment in the ambit of sustainable construction.

- CIEMAT, a technology centre linked to the Ministry of Education and Science devoted to promote Research-and-Development projects in the fields of energy (energy use of conventional and alternative sources), of environment (impact of energy on population and environment), of radiation protection (control and surveillance of ionizing radiation generated at CIEMAT), of magnetic confinement fusion (study of the device Stellerator Heliac flexible TJ-II) and also on basic research.
- Project LIFE-EcoValle. Bioclimatic conditioning of the road C-91 of UE-1 in the outskirts of Vallecas, in collaboration with CIEMAT.
- Project Regen-Link, for the restoration of buildings and commercial lots in San Cristóbal, Madrid. In collaboration with CIEMAT.
- Ecocity in Sarriguren, promoted by the Department of Environment, Landscape Planning and Housing of the Government of Navarra. The actions for planning and management are being held by the public company *Navarra de Suelo Residencial* (NASURSA).
- Forum Barcelona, a recent project based on the recycling of urban land.

The present communication describes the development of a project for the construction of an *intelligent zero-conventional-energy building* (“bioclimatic”) in the Campus of the University of Extremadura. It is linked to the development of the Project PETER (Experimental Transborder Park on Renewable Energies), which involves the Spanish institutions University of Extremadura, Province Deputation of Badajoz, Government of Extremadura (General Direction of University and Technology, Regional Ministry of Economy, Commerce and Innovation), IDEA and CIEMAT, and the Portuguese institutions University of Évora, INETI and ADRAL. The project is being carried out under the auspices of the Program INTERREG III of the European Union.

This proposal corresponds to what is referred to as sustainable edification, which includes actions in three different aspects: economic, environmental and social, and can be regarded as the continuation of other previous works performed by the research group DTERMA, from the University of Extremadura (Cuadros et al., 2007; Lopez-Rodríguez et al., 2006; García Sanz-Calcedo et al., 2008)

The main goal of the project described here are:

- To put in practice the concepts of energy saving and efficiency for the energy transformation devices relating different sources, energy storage, environmental impact, etc.
- To carry out a comparative empirical analysis among different energy sources, in order to emphasise the advantages of renewable versus conventional energy sources.

2. Description and technologies

The main features and technologies used in the construction of the bioclimatic building are listed below. The building is projected to have two floors with approximately 400 m^2 each, and a 300 m^2 cellar. Laboratories and office rooms will be oriented to the south, whereas rooms of general use (like bathrooms, meeting rooms, conference room...) will face North. The building shape is rectangular and its main facade will be oriented to the South.

Figures 1 and 2 show some views of the building as it will definitively look

Figure1: Views of PETER building.

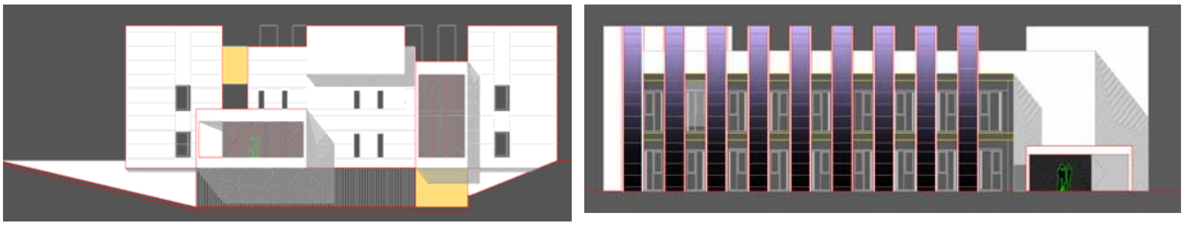

Figure 2: Views of the North and South facades of PETER building.

The concrete technologies involved are the following:

- Construction according to the local climate parameters of Badajoz.
- Monitoring of energy fluxes and of wind, as well as installation of human presence detectors, in order to achieve an automatic operation to control such fluxes.
- Application of the specific concepts concerning passive solar heating. Use of Trombe walls. Ventilation of South facade by installing photovoltaic panels. Avoid direct solar radiation into the building during the summer (and vice versa during the winter).
- Efficient thermal insulation, avoiding thermal bridging.
- Window and cover shadowing.
- Natural lighting, combined with high efficiency artificial support lighting.
- Mixed solar-biomass acclimatisation. Installation of approximately 70 m^2 high efficiency solar surface collectors using a biomass boiler (pellets), which will serve as energy supply to a cooling absorption engine.
- Full monitoring of the building.
- Real time data transfer to the internet.

3. Techniques

The most innovative techniques will be applied in order to ensure the bioclimatic behaviour of the building, the installation of efficient insulation and the use of renewable energy sources. The specific actions concerning each of the technical aspects are described in next subsections:

3.1. Use of solar radiation

The position of the sun has been simulated along the whole year in order to evaluate its influence and project actions to avoid heating during the summer and to favour solar exposure during the winter. This will be of special interest for rooms of general used, which will thus be facing South. Figure 3 shows the trajectory of the sun for all months, referred to the concrete location of the building. The aim is to avoid shadowing by surrounding buildings.

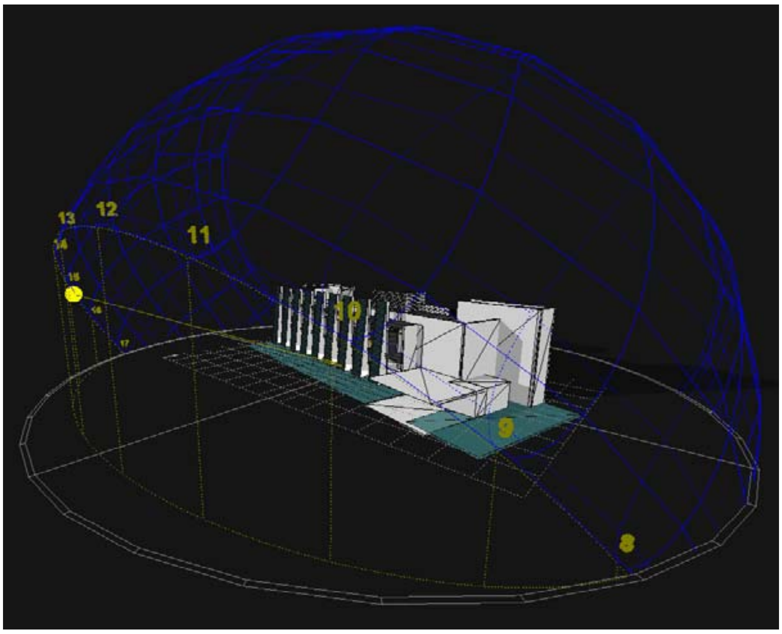

Figure 3: Position of the sun referred to the concrete location of PETER building.

3.2. Insulation

The process of thermal energy transmission in a building of these features takes place mainly by radiation process (75%), but also involves residual conduction and convection (25%). Therefore, any type of building insulation project should be designed mainly to impede the radiative thermal energy flux, but it should also account for residual conductive processes. This way, reflective insulation appears as the most adequate and efficient technique, provided very high output due to high reflective power and to the specific structure for the retention of air bubbles.

The results achieved by reflective insulation (versus traditional methods) are quite significant. Figure 4 shows the thermal resistance for several types of insulation (values of thickness between 1-10 cm, with 5 mm step interval).

Reflective insulation presents a flat curve from a concrete value of the air chamber thickness, and efficiency is not improved for higher values. However, thermal resistance is significantly higher than that of a conventional insulating material. In sum, this feature favours the optimisation of useful interior space.

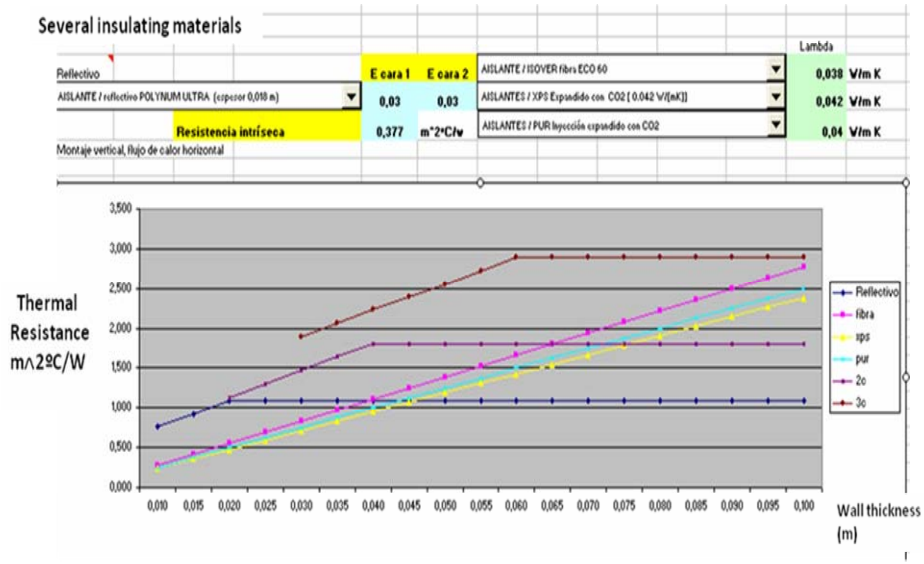

Figure 4: Comparative plot of thermal resistance of a wall as a function of thickness for several types of insulating materials.

Let us describe as an example the insulation pattern projected for both South and West facades of PETER building, following the actual order of the insulating coatings:

- Marble shield (model Frontek de Venatto), 2 cm thick.
- Low-emissive air chamber (4 cm).
- 4 mm reflective insulator, with intrinsic resistance 0.11 m^2 K W^{-1}.
- Structural panel (12 mm).
- Natural fibre insulator (25 mm).
- Low-emissive air chamber (2 cm) (ε = 0.03).
- 4 mm Superpolynum reflective insulator, with intrinsic resistance 0.11 m^2 K W^{-1}.
- Low-emissive air chamber (4 cm) (ε = 0.03).
- Laminated plaster sheet (15 mm).

The total transmission coefficient (the U-value) of this type of wall is U-value=0.31 W m^{-2} K^{-1}.

The next step is the comparison of the thermal conductivity parameters with those of the TBC, DB-HE 1, which indicates the maximum limitation of the energy demand of a building, considering maximum required transmittance according to the type of walled enclosure and to the climatic zone of the location of the building. Taking this aspect into account, a detailed analysis of the energy demand shows energy savings over 69% in winter and over 86% in summer with respect to the values stated by the TBC (see Table 1).

	Winter values			Summer values		
Walls	TBC	Project	Reduction	TBC	Project	Reduction
N	4 294.0	1 259-50	71%	4 294.00	557.30	87%
E	1 073.50	354.08	67%	1 073.50	156.67	85%
W	1 073.50	354.08	67%	1 073.50	156.67	85%
S	2 147.00	708.17	67%	2 147.00	313.35	85%
	Winter values			Summer values		
SE	0.00	0.00		0.00	0.00	
SW	0.00	0.00		0.00	0.00	
Σ =	8 588.00	2 675.84	69%	8 588.00	1 184-00	86%

Table 1. Values for the energy efficient of the envelope of PETER building, compared with those stated by the TBC.

Such a reduction of the energy demand will lead to lower power in the heating and the acclimatisation systems. Besides, if renewable energy devices were installed, then fossil fuels or conventional energy sources would not be required. The use of those devices would not only result in environmental benefits, but also in notable economic savings.

3.3. Heating system

The heating system of the building is designed as the combination of the following installations:

- Radiant floor warming.
- Solar thermal panels.
- Biomass boiler support.
- Hot air support for rooms of general use from photovoltaic panels installed in walls.

The installation of 25 solar thermal panels (50 m^2 effective surface, approximately) will provide 56% of the energy demand of the building. A biomass boiler will work as energy support equipment. Besides, the air flow along the back side of the photovoltaic panels installed as a chimney on the South facade will serve as supplementary heating system in winter. On the other hand, the thermal energy obtained from the photovoltaic panels will be transferred to the surroundings, according to the principles of Trombe walls.

Thermal energy supply to the building will be made by radiant floor warming, which is currently considered to best approach the ideal heating profile, since it provides very high efficiency and maximum thermal comfort. Figure 5 shows values for energy supply of photovoltaic panels.

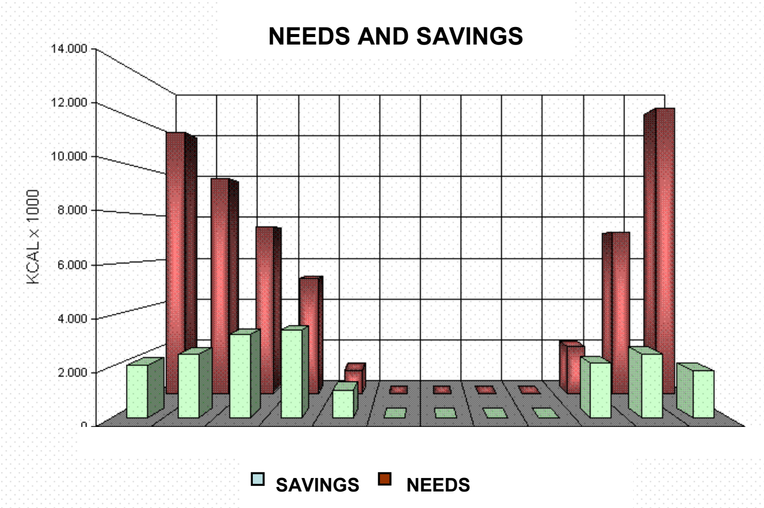

Figure 5: Energy supplied by the solar thermal panels heating system.

3.4. Cooling system

Some of the installations projected will also be used for the cooling system of the building.

- Upper air grilles.
- During night hours, use of grilles to collect cool air flow generated at an artificial lake located in front of the South facade.
- Absorption engine, supplied by solar thermal panels and a biomass boiler.
- Automatic natural ventilation support at nights.

Figure 6 describes the cooling circuit of the building. The analysis of data from the 30 solar thermal panels shows that the absorption cooling engine supplies 88% of the acclimatisation needs of the building. The remaining 12% will be supplied by the supplementary biomass boiler.

The absorption cooling system, together with the solar thermal panels, provides a high efficiency since the greater the energy demand for cooling is, the higher will also solar radiation be. This will make the photovoltaic panels work at maximum capacity.

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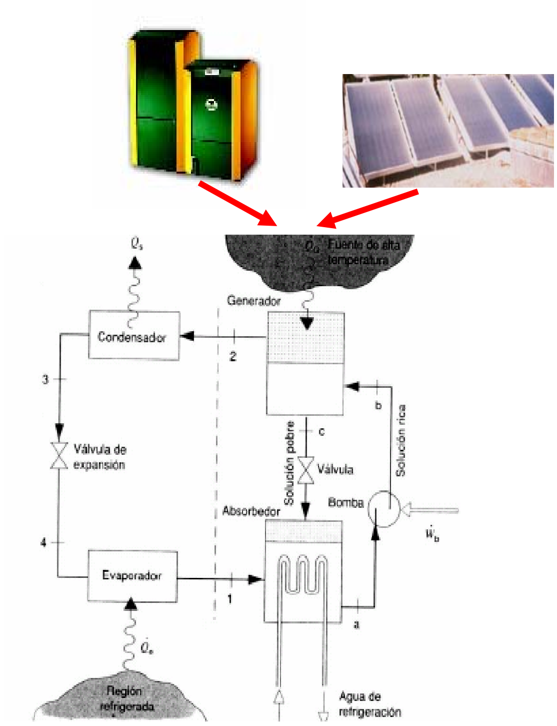

Figure 6: Working scheme of the absorption cooling engine.

3.5. Electric system

A set of photovoltaic solar modules are projected to be installed on the South facade of the building in order to work as electric energy supply. Part of this energy will be used to design a high output installation for lighting. The remaining energy will be transferred to the electricity grid, which will allow the perception of the bonus for photovoltaic solar energy production, according to the Spanish legislation.

The photovoltaic panels are designed to be installed at an angle of 85º with the horizontal. Despite such value is not optimum (i.e. it does not maximise the production of electricity), this configuration favours the integration of the panels to the design of the building, which in the end should also be a priority goal.

3.6. Rest of installations

An installation for the management of water is also projected. For this purpose, the following actions are considered:

- Collection of rainwater and storage in an artificial lake.
- Use of water for cooling of air and radiating floor.
- Recycling of wastewater for WC and for garden irrigation.

Moreover, all the systems are designed to be fully integrated and monitored by a control unit, so that a global quantification of systems and resources can be carried out at any moment. The main actions regarding this are:

- Lighting control.
- Temperature control for the solar collection system, the photovoltaic installation, the biomass boiler and the adsorption engine.
- Control of the photovoltaic installation connection to the electricity grid.
- Control of blinds at night.
- Control of blind slats according to solar radiation.
- Control of the natural cooling system at night.
- Control of the heating of common use rooms with the air from the chambers between the photovoltaic panels and the facade of the building.

4. Conclusion

The aim of the construction of a building with these particular features is to put in practice the most innovative technologies in order to minimise the energy demand. The basic line of work is the detailed analysis of all equipment, as well as the focusing on the thermal insulation of the building so that energy supply –always from renewable sources- is reduced as much as possible.

Following the principles of *sustainable construction*, the project described in the present communication is intended to show that renewable energy technologies can be satisfactorily integrated in construction, with similar efficiency to conventional ones. It is also relevant to note that important economic savings and high profitability will be achieved during the life of the building.

The PETER building is projected to work as a laboratory that will allow the comparison of results obtained in real situations with simulation data generated in the present study. In sum, our efforts are focused towards the *industrialisation of construction*, and we believe this project to provide an important "know how" reference in such direction.

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