Zero-energy buildings. Application to public building in Extremadura.

A. Redrado[1], F. López [2], A. Ruiz[3], F. Cuadros[4], J. García[5], M. Cobos[6], C. Segador [7].

Abstract — Social development links to the exploitation of energy resources. As a consequence of this fact, buildings, both residential and services sector play an outstanding roll on the energy consumption of our current society. Therefore, buildings have a very significant demand of heating, refrigeration system, warm sanitary water access, lighting, ventilation, etc.
In this sense, the combination of different bioclimatic strategies in existing buildings establishes the way to achieve the reduction of energy consumption and the decrease of its produced CO_2 emissions. In fact, we have worked on a five floor building in the center-west of Spain, where Central Service of SES (Mérida, Badajoz) is located. The study is based in the influence of the decrease of CO_2 emissions from the air-conditioning system by means of an absorption equipment use with biomass thermal support.
The current research identifies the different variables that determine the demand of energy in the air conditioning system of the building. It drives on an optimum parameter combination that allows adjust a correct running building and a good level of comfort to the decrease of energy use and the CO_2 emissions reduction.

Keywords — Absorption, biomass, energy efficiency, lighting.

1 Introduction

The evolution of our society is linked to the use of energy resources. The urban environment in which we deal, demands a lot of energy to adapt to the wide spectrum of human activities that are developed in it. In this sense, the buildings, both residential and services sector's play an important role since they are of great importance for the demand of heating, cooling, hot water, lighting, ventilation, etc. [1]
The promotion of new buildings with high energy efficiency and the identification of measures to improve energy efficiency in existing buildings within a context of economic and technical feasibility are contained in the 93/76/EEC CO_2 emissions reduction and 2002/91/CEE energy efficiency European Directives.
These regulations are implemented in the Spanish Technical Building Code, in particular in the CTE Basic Document about energy saving (DB-HE) **Error! Reference source not found.**, and also in the process of energy certification of new buildings **Error! Reference source not found.** and the HVAC facilities Code for Buildings (RITE) **Error! Reference source not found.**.
The efficient management of energy use of a building allows substantial savings in energy consumption and significant improvements in the adaptation to conditions of comfort. The strategies taken into account when improving the energy efficiency in the functioning of the buildings are intended to lower energy demands and cover it through renewable energies **Error! Reference source not found.**.
Energy efficiency strategies are divided in two main ways, passive and active strategies, related to energy consumption.
Passive strategies are used to maximize heat loads and minimize heat losses of the building in winter and minimize heat loads and maximize heat losses of the building in summer. Building orientation, design and distribution of space and materials selection and use of solar protections will be the key that will set the level of consumption of the building. Bioclimatic design is based on the combination of these two measures together with the use of alternative energy.
Projects such as PSE-ARFRISOL **Error! Reference source not found.**, the building PETER **Error! Reference source not found.**, the project ECOCITIES **Error! Reference source not found.** and the Spanish Pavilion for the International Exhibition Water and Sustainable Development (2006 - 2008) **Error! Reference source not found.** are pioneers in the development of bioclimatic buildings. Some of these projects have been developed as experimental buildings to evaluate the

1. *A. Redrado is with the Department of Energy Saving and Efficiency of the Extremadura Energy Agency, E-mail: aredrado.agenex@dip-badajoz.es*
2. *F. López is with the Department of Graphic Expression of the University of Extremadura, E-mail: ferlopez@unex.es*
3. *A. Ruiz is with the Department of Mechanical and Material Engineering of the University of Extremadura, E-mail: aruiz@unex.es*
4. *F. Cuadros is with the Department of Applied Physics of the University of Extremadura, E-mail: cuadros1@unex.es*
5. *J. García is with the Central Services of the Extremaduran Service of Health, E-mail: jgsanz@unex.es*
6. *M. Cobos is with the Department of Energy Saving and Efficiency of the Extremadura Energy Agency, E-mail: mcobos.agenex@dip-badajoz.es.*
7. *C. Segador is with the Department of Renewable Energies of the Extremadura Energy Agency, E-mail: csegador.agenex@dip-badajoz.es.*

use of renewable energy sources and bioclimatic techniques, and some of them have not been constructed.
For this study it has been selected the Central Services Building for Extremadura Health Service (SES) **Error! Reference source not found.** for being the first public building, not experimental, for administrative activities energy rated "A". Since it has been operational from 2010, real performing results can be compared. Several techniques in parallel with the use of renewable energies are intended to be simulated.
These energy-efficient systems will demonstrate the ability to reduce not only emissions of the building but also the energy consumptions, with the combination of renewable and non renewable fuels and high energy efficiency systems. It will test the influence of lighting and air conditioning demand in the building so the improvement of the energy intensity of it is avoided.
The study will try to identify the variables that affect on energy demand, while showing the combinations with which they get the proper functioning of the building, reduced energy consumption and reducing emissions.
Therefore the simulation of different energy systems in the building will be carried out, using conventional and renewable sources of energy, In order to evaluate the most efficient strategies from the economic, energy and environmental points of view. Likewise, the energy rating by CALENER software **Error! Reference source not found.** in each solution will be compared.

2 MATERIALS AND METHODS

2.1 Computer Software

To simulate the measures we have used the computer program CALENER. It is a software tool promoted by the Ministry of Industry, Tourism and Commerce **Error! Reference source not found.**, of Spain through the IDAE **Error! Reference source not found.**, and the Ministry of Public Works **Error! Reference source not found.**, and it determines the energy efficiency level for buildings. The software has two versions for easier use. CALENER-GT version has been developed for the energy efficiency rating of large buildings in the tertiary sector, and CALENER VYP version for housing and small tertiary buildings.
CALENER-GT uses as calculation engine DOE-2.2 program **Error! Reference source not found.**. It includes in its database performance curves of various equipment, essential for the simulation of the different systems. A flow chart of the program is shown in Fig. 1 which appears as sub-shaded boxes.
After being applied, the CALENER-GT offers as the final result the Building Rating. Additionally the rating must include a description of the energy characteristics of the building, ie, must produce an additional document, that when reflects the energy characteristics of the building, indicates that the rating has been obtained on the basis of accredited and collected merits of the building. This document is called a management tool. In it appears the Provisional assessment of building and additionally serves as an element in the award of the final grade, having intended to inform the assessor of technical contributions to the level of CO_2 emissions from energy end-uses of the building.

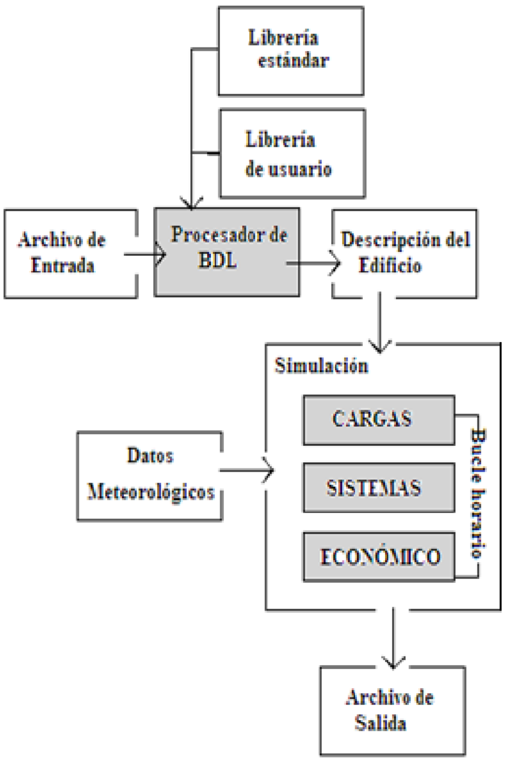

Fig. 1 Calener GT flowchart

This information allows the assessor to propose modifications to the building with the aim of reducing emissions. So an “object” building that corresponds to the building to be rated is defined and another “reference” building with the same geometry, void ratio and weather conditions than the “object” building, but with the minimum standards required in the CTE.

2.2 Characteristics of the building.

The building of the study houses the Central Services SES, being a landmark building for its particular envelope and new HVAC system. In the design, concepts of passive solar gain and thermal insulation have been applied, avoiding thermal bridges, shading roofs and windows and promoting natural lighting as long as possible.
It is located in the city of Mérida (Badajoz) Fig. 2 in the southwest of Spain, at an altitude of 220 m. The climate in the area is Continental Mediterranean

with Atlantic influence due to its proximity to the Portuguese coast (located 70 km from the Portuguese border). Winters are cold and summers are hot. Irregular rainfall is recorded mostly in the winter months. The humidity and winds are low, but there is frequent presence of mist in the months of December, January and February.

Fig. 2 Map of situation of the city of Merida.

The extreme weather that is submitted to the building (heating needs in winter and cooling in summer) can demonstrate the possibility of using renewable energy to serve in the most unfavorable conditions.

The main entrance is located on the SW front as shown in the Fig. 3. From here you enter the main lobby that controls the complex. Through this it is acceded to other buildings. It is built on four floors used as offices and a fifth one below grade as a garage. Two modules with stairs and elevator located in the NW and SE allows vertical communication in the building. The office area has natural light from the southwest and northeast facades.Fig. 4 shows the simulation NE facade of the building.

Fig. 3 Main entrance of the building.

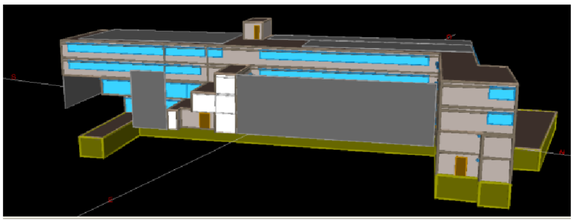

Fig. 4 Front NE. Image of the simulation of the building

The building integrates bioclimatic passive strategies such as a ventilated façade, the use of solar radiation to avoid overheating in summer and promoting warming in winter, or use of carpintería metalica with thermal bridges break.

The air-conditioning of the different areas is done by a water-water four-pipe fan coil units. These are placed in the roof and are equipped with a temperature control system with a constant flow regulator.

It has two identical "Vulcano" fire-tube boilers conducting the heat production. They use biomass as fuel (now crushed olive pits) and have a thermal power of 465 kW each. The system has a fuel storage silo of 70 m^3 and a system of three hot water storage tanks 10 000 liters each.

The cold production is performed by a Carrier chiller with 545 kW nominal cooling capacity. The chiller is simple effect absorption cycle using lithium bromide as absorbent and water as coolant. It's powered by hot water from biomass boilers. The facility has four cold water storage tanks of 5 000 liters each and a cooling tower with cooling capacity of 1 203 kW.

The ventilation of the building is resolved with a unit for the supply of outside air in the housing, with 19 000 m^3h^{-1} capacity. This system is equipped with a heat recovering unit and an indirect adiabatic humidification system that lowers the outside air temperature.

The building has a power generation system of photovoltaic solar power of 76 kWp. It consists of 380 modules of 200 Wp polycrystalline each. The system generates 95 095 kWh per year.

For the production of hot water, the building has a system consisting of a set of seven flat-plate solar collectors of 2.03 m^2 of real capture area each, optical performance of 0.7720 and loss factor of 4 Wm^{-2}. They are placed at an angle of 45 degrees and an azimuth of 0 °. As a conventional system for the support of the solar system, the building has 50 liters electrical water heaters.

2.3 Strategies

In the study, the following strategies that are the result of combining the following systems where carried out:

- Photovoltaic solar energy system.
- Lighting System.

- Air conditioning system. Heat generator.

With respect to the solar PV system, according to the Spanish Technical Building Code (CTE), being an office building over 4 000 m^2, it must incorporate a system to capture and transform solar energy by photovoltaic procedures. The building has 5 394 m^2 and is located in climate zone V of the HE Basic Document for Energy Saving of the Spanish Technical Building Code.

Therefore, the minimum photovoltaic power to be installed is 11.31 kWp.

This system does not increase the energy efficiency of the building, but it reduces emissions by using a renewable source of energy. Simultaneously improves the economic balance of the building through the sale of electricity not consumed and improve the grade to reduce global emissions of CO_2.

It is noted that the power currently installed in the building is much higher than required, thus reducing installed capacity will be proposed to monitor its behavior.

The lighting system features progressive control of artificial lighting to suit the natural lighting conditions. The relocation of the sensors to optimize the system will be studied.

It was found that the average illuminance (Em) in each zone was not adjusted to the recommendations of the European Standard UNE-EN 12464-I **Error! Reference source not found.**. Therefore, it was set by using high efficiency lamps and matching the installed power and the level of illuminance required in each area. For this parameter value is used on Energy Efficiency in Lighting (VEEI) indicated in the CTE.

The air conditioning system uses biomass as fuel for heat generation, with zero emission of CO_2. Thus the emissions generated by the system are those governing the operation of the chiller, fans, pumps and auxiliary equipment caused by power consumption.

The use of biomass as fuel reduces emissions of heat-generating system, but this implies more efficient use of energy. It is therefore study the use of conventional fuels such as diesel or natural gas with high efficiency boilers as low temperature or condensing boilers. To evaluate the performance of the building will break the existing building and then conduct a simulation of each of the proposed measures. Finally we combine those most successful solutions compatible. The program gives results Calener-GT CO_2 emissions, primary energy consumption and final energy consumption. These results allow an objective comparison of each of the solutions.

3 RESULTS

The results of the simulations are presented, to analyze the advantages and disadvantages of each solution proposed and make the analysis of the alternative energy sources simulated with Calener GT.

The ratios of CO_2 emissions per m^2 in HVAC, generation of ACS and lighting, as well as the total annual emissions of the building has been taken as data for the study. To compare the energy intensity between the different alternatives studied the ratios for primary energy and final energy consumption ($kWhyear^{-1}$) were used.

The first simulation corresponds to the current rating of the finished building. Therefore, this has a solar coverage of 70% for hot water generation and a photovoltaic system capable of generate 95 095 $kWh·yr^{-1}$. In addition, as described above, the building has two biomass boilers for heat generation. Table 1 shows the results of the qualification in Calener-GT.

Table 1 Measure 1, Current building's qualification in Calener-GT.

MEASURE Nº	1	
ENERGY LABEL	A	
Solar photovoltaic production	95.095 $kWh•yr^{-1}$	
Solar thermal coverage	70 %	
FUEL	Biomass	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2·m^{-2}$)	16,50	41,40
Warm sanitary water's emissions ($kg\ CO_2·m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2·m^{-2}$)	9,10	26,90
Total emissions ($kg\ CO_2·m^{-2}$)	25,80	68,50
QUALIFICATION – ENERGY LABEL		0,38
Final energy ($kWh·year^{-1}$)	863.207,40	599.606,50
Primary energy ($kWh·year^{-1}$)	1.136.569,00	1.398.581,40
Emissions ($kg\ CO_2·year^{-1}$)	132.237,20	350.567,50

Measures 2 to 7 refer to isolated measures. This will assess the direct effect of every measure in the operation of the building as is detailed below:

Table 2 Result of the simulation of the measure 2 in Calener GT.

MEASURE Nº	2	
ENERGY LABEL	B	
Solar photovoltaic production	15 400 $kWh•yr^{-1}$	
Solar thermal coverage	70 %	
FUEL	Biomass	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2·m^{-2}$)	20,10	41,40

Warm sanitary water's emissions ($kg\ CO_2 \cdot m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2 \cdot m^{-2}$)	11,10	26,90
Total emissions ($kg\ CO_2 \cdot m^{-2}$)	31,40	68,50
QUALIFICATION – ENERGY LABEL		0,46
Final energy ($kWh \cdot year^{-1}$)	863.207,40	599.606,50
Primary energy ($kWh \cdot year^{-1}$)	1.252.749,40	1.398.581,40
Emissions ($kg\ CO_2 \cdot year^{-1}$)	161.204,10	350.567,50

- Measure 2: Reduction of solar photovoltaic power generation to the minimum required by the CTE. The building will generate 95 095 $kWh \cdot yr^{-1}$ to generate only 15 400 $kWh \cdot yr^{-1}$. The results are shown in Table 2.

- Measure 3: Improving lighting efficiency by selecting more efficient lighting and adjusting the luminance value of the work assigned in each room according to the European Standard UNE-EN 12464-I . The result of simulation in Calener-GT of this measure is shown in **Error! Not a valid bookmark self-reference.**.

Table 3 Result of the simulation of the measure 3 in Calener GT.

MEASURE Nº	3	
ENERGY LABEL	A	
Solar photovoltaic production	95.095 kWh•yr[-1]	
Solar thermal coverage	70 %	
FUEL	Biomass	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2 \cdot m^{-2}$)	15,90	42,90
Warm sanitary water's emissions ($kg\ CO_2 \cdot m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2 \cdot m^{-2}$)	3,90	29,10
Total emissions ($kg\ CO_2 \cdot m^{-2}$)	20,00	72,20
QUALIFICATION – ENERGY LABEL		0,28
Final energy ($kWh \cdot year^{-1}$)	797.759,60	627.180,20
Primary energy ($kWh \cdot year^{-1}$)	1.002.431,20	1.473.633,30
Emissions ($kg\ CO_2 \cdot year^{-1}$)	102.289,30	369.242,40

Table 4 Result of the simulation of the measure 4 in Calener GT

MEASURE Nº	4	
ENERGY LABEL	C	
Solar photovoltaic production	95.095 kWh•yr[-1]	
Solar thermal coverage	70 %	
FUEL	Diesel	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2 \cdot m^{-2}$)	47,80	41,40
Warm sanitary water's emissions ($kg\ CO_2 \cdot m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2 \cdot m^{-2}$)	9,10	26,90
Total emissions ($kg\ CO_2 \cdot m^{-2}$)	57,10	68,50
QUALIFICATION – ENERGY LABEL		0,83
Final energy ($kWh \cdot year^{-1}$)	814.364,10	599.606,50
Primary energy ($kWh \cdot year^{-1}$)	1.132.871,00	1.398.581,40
Emissions ($kg\ CO_2 \cdot year^{-1}$)	292.196,80	350.567,50

- Measure 4: Replacing the biomass boilers by equivalent conventional diesel boilers. After the performance of these measures in Calener GT you get the results in Table 4.

- Measure 5: Replacement of biomass boilers for conventional boilers fired by natural gas. The results obtained after applying this measure to the current building are shown in **Error! Not a valid bookmark self-reference.**.

MEASURE Nº	5	
ENERGY LABEL	C	
Solar photovoltaic production	95.095 kWh•yr[-1]	
Solar thermal coverage	70 %	
FUEL	Natural Gas	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2 \cdot m^{-2}$)	38,70	41,40
Warm sanitary water's emissions ($kg\ CO_2 \cdot m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2 \cdot m^{-2}$)	9,10	26,90
Total emissions ($kg\ CO_2 \cdot m^{-2}$)	48,10	68,50
QUALIFICATION – ENERGY LABEL		0,70
Final energy ($kWh \cdot year^{-1}$)	814.364,10	599.606,50
Primary energy ($kWh \cdot year^{-1}$)	1.093.856,50	1.398.581,40
Emissions ($kg\ CO_2 \cdot year^{-1}$)	245.936,70	350.567,50

Comparing the different measures with the current situation (as number 1) can extract the following results:
Measure 2: the reduction of photovoltaic production increases the emissions in the object building in HVAC and lighting, and the whole CO_2 emissions of the building. This measure does not affect the final energy consumption, but increases the primary energy consumed in the building.
Measure 3: Improving the lighting system not only

reduces emissions but as the installed capacity in each area is reduced it also reduces the heat load and hence emissions in HVAC.
In line with the needs of illuminance and minimum energy efficiency rating according to the uses of each area, increases the reference building emissions and thereby improves the calification.
The replacement of existing TL-D fluorescent lamps by compact fluorescent lamps together with the necessary illuminance adjustment for the use in each zone allows installing less power with the consequent consumption savings in air conditioning and lighting in the object building. All of this, results in a lower primary energy and final energy consumed compared with the reference building.
Table 5 Result of the simulation of the measure 5 in Calener GT.

Emissions ($kg\ CO_2 \cdot year^{-1}$)	212.940,50	369.242,40

Measures 4 and 5 compared with the current situation (as measure 1) have the following common effects:

• Increased emissions of CO_2 in HVAC. Because we change a renewable fuel with zero emissions to a conventional fuel. This increase is reflected in the same way in the global CO_2 emissions of the building.

• Sensible reduction of final and primary energy consumed. That is, the amount of fuel consumed decreases with conventional systems.

Table 6. Simulation of the measure 6 in combination with boilers of natural gas (measure 5) and improvement of the lighting system (measure 3).

MEASURE Nº	6	
ENERGY LABEL	B	
Solar photovoltaic production	95.095 $kWh \cdot yr^{-1}$	
Solar thermal coverage	70 %	
FUEL	Natural Gas	
RATIOS:	Object	Referece
Air conditioning ´s emissions ($kg\ CO_2 \cdot m^{-2}$)	37,60	42,90
Warm sanitary water's emissions ($kg\ CO_2 \cdot m^{-2}$)	0,20	0,20
Light's emissions ($kg\ CO_2 \cdot m^{-2}$)	3,90	29,10
Total emissions ($kg\ CO_2 \cdot m^{-2}$)	41,70	72,20
QUALIFICATION – ENERGY LABEL		0,58
Final energy ($kWh \cdot year^{-1}$)	747.996,40	627.180,20
Primary energy ($kWh \cdot year^{-1}$)	958.634,60	1.473.633,30

With regard to the latter two solutions, in view of the results, it can be said that the measure 5 (use of natural gas) is the one that presents the biggest reductions in CO_2 emissions and the lower primary and final energy consumption.
Finally we study the joint solution to improve the efficiency of the lighting system along with the replacement of biomass boilers with equivalent natural gas boilers (measure 6). The results of this measure are depicted in Table 6.
While energy analysis was performed, an economic study of the energy consumed in each of the measures was done; taking into account the fuel used. This is shown in Table 7. The price used for biomass is 0.03983 €$\cdot kWh^{-1}$ to be the annual average price for olive pits used as fuel during operation of the building in 2010. For diesel 0.06266 €$\cdot kWh^{-1}$ **Error! Reference source not found.** and natural gas 0,05229 €$\cdot kWh^{-1}$**Error! Reference source not found.**.

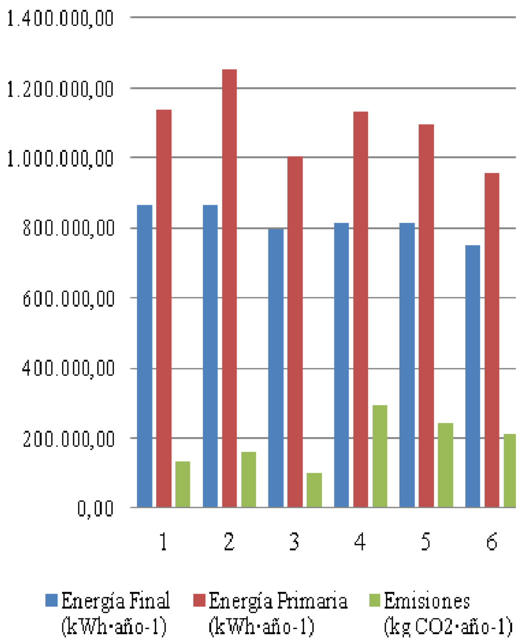

Fig. 5 Final energy, primary energy and CO_2 emissions for each studied situations.

Table 7 Economic study of each one of the studied measures.

MEASURE Nº	1	2	3	4	5	6
ENERGY	A	B	A	C	C	C

LABEL												
	Cost	Final Energy	Cost	Final Energy	Cost	Final Energy	Cost	Final Energy	Cost	Final Energy	Cost	Final Energy
Consumptions:	€·yr^{-1}	kWh·yr^{-1}	€·yr^{-1}	kWh·yr^{-1}	€·yr^{-1}	kWh·yr^{-1}	€·yr^{-1}	kWh·yr^{-1}	€·yr^{-1}	kWh·yr^{-1}	€·yr^{-1}	kWh·yr^{-1}
Biomass	26.272,00	659.452,08	26.272,00	659.452,08	24.280,07	609.452,87						
Diesel							46.039,90	610.608,78				
Natural gas									31.934,23	610.608,78	29.271,21	559.689,67
Electricity	12.768,00	203.755,32	12.768,00	203.755,32	11.799,94	188.306,73	12.768,00	203.755,32	12.768,00	203.755,32	11.799,94	188.306,73
Total	39.040,00		39.040,00		36.080,01		58.807,90		44.702,23		41.071,15	

4 CONCLUSIONS

The analysis of simulation results in GT Calener of the solutions described above allows us to distinguish three types of solutions:

- The most energy efficient solution.
- The most environmentally friendly solution.
- The most profitable solution.

The first corresponds to the measure 6, where the decrease in consumption of primary and final energy is much lower than in the other solutions. Thanks to the use of natural gas, the use of efficient lighting and the adjustment to the needs, the energy intensity of the building can be reduced.

It is important to note that although energy intensity is lower than in the current situation, the energy rating is lower as they respond to the level of CO_2 emissions. As in this case we are using a fossil fuel, it cannot be achieved the same reduction of greenhouse emissions in the current situation, with existing technology.

More environmentally friendly solution corresponds to the best energy rating. Measure 3 is the most successful in this regard for it uses a renewable fuel without emissions impact of heat generation and high-efficiency lighting.

Far more profitable proposal coincides with the measure 3. In this case the photovoltaic generation is a maximum and power consumption is reduced (although it is not the lowest) and uses less expensive fuel.

About measure 2, which has reduced the PV system is not logical the increase of the emissions in air conditioning and lighting, as these systems are not modified. In any case it should impact on aggregate emissions, since less energy is been injected into the electrical network. So, maybe this is a bug in the program, because it can be considering that PV produced is used for consumption of the building and not to be injected into the network that is more profitable.

Finally the study shows that measure 6 seems to be the best because the fuel cost is similar to the measure 1 and the final energy consumption is much lower, but the score is lower because the software rewards more the use of biomass fuel.

REFERENCES

[1] Instituto para la Diversificación y Ahorro de la Energía (IDAE), "Guía Práctica de la Energía. Consumo Eficiente y Responsable", 2010.

[2] Real Decreto 314/2006 Código Técnico de la Edificación CTE y en particular el Documento Básico de Ahorro de energía (DB-HE), 2006.

[3] Real Decreto 47/2007 sobre certificación energética de edificios nuevos, 2007.

[4] Real Decreto 1027/2007 Reglamento de Instalaciones Térmicas de Edificios (RITE), 2007.

[5] J. García Sanz-Calcedo, F. Cuadros, and F. López Rodriguez, "Edificio Administrativo de alta calificación energética en Mérida. Un modelo de construcción bioclimática y de integración de energías renovables". Submitted for publication.

[6] PSE-ARFRISOL Con referencia PS-120000-2005-1, Fuente: http://www.arfrisol.es/ARFRISOLportal/. 2005.

[7] Instituto para la Diversificación y Ahorro de la Energía (IDAE), Junta de Extremadura (Consejería de Fomento), Agencia Extremeña de la Energía (AGENEX), Universidad de Extremadura, Diputación de Badajoz, Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Universidade de Évora, INETI y Agência de Desenvolvimento Regional do Alentejo (ADRAL), "As energias renováveis em ambos os lados da frontera", http://www.lasenergiasrenovables.com/downloads/lasenergiasrenovablesaambasorillasdelafrontera.pdf, 2008.

[8] CENER, Proyecto ECOCITIES http://www.cener.com/es/arquitectura-bioclimatica/ecocities-tudela.asp. 2006

[9] CENER, and F. Mangado, "Pabellón de España para la Exposición Internacional Agua y desarrollo sostenible (2006 – 2008)", 2008.

[10] Junta de Extremadura, Extremadura Health Service. Central Services located in Avda. de las. Américas, 2 en la localidad de Mérida (Badajoz, España).

[11] Computer program Calener. Recognized document and tool promoted by the Ministry of Industry, Tourism and Commerce through the IDAE, and the Ministry of Public Works, which determines the level of energy efficiency for buildings. http://www.mityc.es/energia/desarrollo/EficienciaEnergetica/CertificacionEnergetica/ProgramaCalener/Paginas/DocumentosReconocidos.aspx

[12] Ministry of Industry, Tourism and Commerce. http://www.mityc.es/es-ES/Paginas/index.aspx

[13] The Instituto para la Diversificación y Ahorro de la Energía (Institute for Diversification and Saving of Energy, or IDAE). http://www.idae.es/

[14] Ministry of Public Works. http://www.fomento.es/mfom/lang_castellano/

[15] DOE-2.2 conducted by the U.S. Department of Energy Berkeley Laboratory and the U.S.

[16] Norma Europea UNE-EN 12464-I, Iluminación de los lugares de trabajo.

[17] IDAE, "Informe de precios energéticos: carburantes y combustibles", 2011

[18] Corporación de Reservas Estratégicas de Productos Petrolíferos (CORES), "Informe Resumen Anual del Boletín Estadístico de Hidrocarburos", http://www.cores.es/pdf/Resumen_BEH_Cores_2009.pdf 2009.