ISBN: 978-84-697-1815-5

Zero energy equipment building Lucia: a case study according to European directive

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Abstract *The University of Valladolid has constructed itself an applied research building for laboratories and spin-off related to research, called LUCIA, which shows that to reach a zero CO2 emissions building with an affordable cost is possible, using combined passive strategies (specially from design decisions), only renewable energies (geothermal, photovoltaic and biomass) and social aspects which can have strong impacts on local development. It offers a model for conducting research into areas that will shed light on other as yet unexplored methods, reducing demand to 81,82 kWh/*m2 *year (totally acclimatized) and yielding a "ZERO CO2" and "CERO ENERGY" building, according Directive 2010/31/ EU. The total cost of the building was 8.225.000 € (VAT included), covering a total built area of 7500 m2 (5920 m2 acclimatized). It has been evaluated, opting to LEED-Platinum and more than four leaves V.E.R.D.E. Funding comes from Junta de Castilla y León and the European Regional Development Fund.*

Keywords, Zero Energy, Zero CO2, Bioclimatic, Equipment, Design

INTRODUCTION

The LUCIA building will be used for laboratories and will provide areas for spin-offs related to nutrition, food, and dietetics; metabolopathies as well as the development of the Digital Knowledge Society. It will offer the chance to investigate a range of features that will shed light on other as yet unexplored areas, using only renewable energies. Strategies lay in the fields of reducing energy demands through bioclimatic design, efficient systems, use of local resources and important training and dissemination activities, which are provided to the user's implication. The integral use of local resources (bio-mass) implies researching in an area with great potential in local job creation.

The Directive 2010/31/ EU of 19 May 2010 urges member states to ensure that all new buildings are "nearly zero energy consumption" through 31 December 2020 (2018 for public administration buildings). The building LUCIA shows a spectacular example both in very low rate of energy consumption, and cero CO2 emission building. According to the E-Quest evaluation system, (DOE-2 program E-Quest 3.64), compared to ASHRAE baseline building, LUCIA shows saving demands of 90% (heating); 41% (refrigeration) and 61% electricity for light. The final energy demand of the buildings is 81,82 kWh/m2 year, the energy balance including HVAC (heating, ventilation, and air conditioning). Annual production of the building is 0 (zero CO2 emissions).

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Those results will be checked; because the building includes a sophisticate integral building management system (BMS) called DESIGO INSIGHT from Siemens, based in SCADA technology (Supervisory Control and Data Acquisition software). Control system operations and data transfer (based in LON / KNX / MODBUS technologies) conduct to analyze the real effect of energy efficiency measures implemented results isolating variations in demand not attributable to own efficiency measures installed.

2. STRATEGIES ABOUT SAVING ENERGY

2-1. Passive and compact bio-climatic design to reduce heating and cooling demand.

The building has a 0.37m-1 form factor for its 5,920 m2 of usable space, giving a ratio which is hard to improve. (Fig. 1) Compactness means the relation between surface and [i]envelope and the climate controlled area can be optimised, thereby reducing the former. Added to that, the specific design of external area, local vegetation, deciduous trees, implementation of green permeable pavement on the park area and the sedum type intensive vegetation (73.5% of the surface on the green roof), produce a microclimate to reduce the heat island effect at the site (VALBUENA, F. GONZÁLEZ, MJ, 2012).

Fig. 1- Optimized compactness- South- West façade.

Fig.2 Zig-zag façade to obtain self-shadowing effect.

2.2. Form façade design:

The characteristics of the site require long walls facing South-West and North-East. This meant that a careful re-orientation study was performed when designing the spaces combined with the eaves in the parts facing the sun. (Figure 2) Using this system, 89% of the surface openings face South and East, achieving thermal gains in winter, and a self-shadowing effect in summer, thereby reducing the cooling load, whilst at the same time ensuring natural light. On its longest sides, the resulting surface resembles a “saw-tooth”, one drawback being the increased surface envelope. This strategy of design leads to a 24% reduction in the building’s cooling loads, according to the simulations carried out.

2.3. Strong Insulation:

The thermal transfer coefficients used in the building envelope compared to those stipulated by Spanish Building Regulations (CTE) and ASHRAE (ASHRAE 2007) are really important: The insulation coefficients used, a key factor (U=0.17 W/m^{2}K on facades, and U= 0.15

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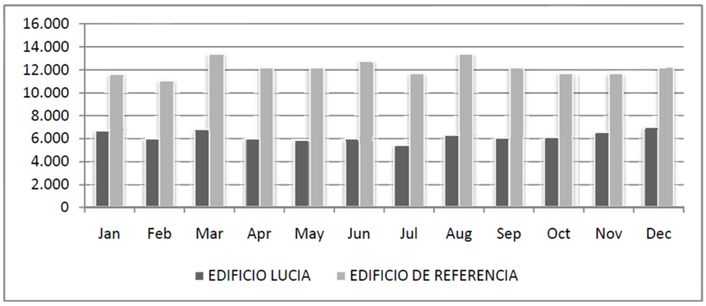
W/m^{2}K on the green roof) will restrict loss through transfer and therefore lead to a reduction in demand. One drawback is the increased energy in the materials that can be reduced or even removed through the use of natural insulation (100% natural from wood), and an extra financial cost which is offset by the reduction in energy consumption. One further aspect to be taken into account in this section is the effect of thermal inertia achieved in the structure of the building itself (reinforced concrete), particularly with the green roof, which covers 73.5% of its surface.

2.4. Improvement of Natural Lighting using solar tubes:

The decision to construct a compact building has been merged with an increase in natural lighting of indoor areas through the widespread use of tubular day lighting devices or solar-tubes (27 in all) and skylights above the staircases (Fig 3 and 4). In addition to offering beneficial effects for health and wellbeing, natural light reduces the electricity requirement for artificial light: these are static elements which simply reflect incident sunlight, as a result of which they require no power to work. (Table 2).

Fig 3 - Tubular daylighting devices (Solatubes) in green roof

Fig. 4- Internal staircases with skylight



ILUMINACIÓN	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
LUCIA (kWh)	6.640	5.990	6.810	5.960	5.800	5.980	5.420	6.330	6.040	6.070	6.480	6.980	**74.490**
REFERENCIA (kWh)	11.650	11.070	13.400	12.230	12.230	12.810	11.650	13.400	12.230	11.650	11.650	12.230	**146.190**

Tabla 2. Save energy with daylight System compared to ASHRAE reference building (DOE-2 from EQUEST 3.64).Dark grey: Lucia building. Pale grey: ASHRAE reference building

2.5. Open design of park places.

In addition to the personal benefits (an open-plan car park is far more pleasant than a closed one), taking such a decision allows for natural ventilation and lighting, allows green

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permeable pavement, and drastically reducing the need for artificial lighting, fire-fighting facilities, anti-CO2 equipment, and so on. (Fig 5)

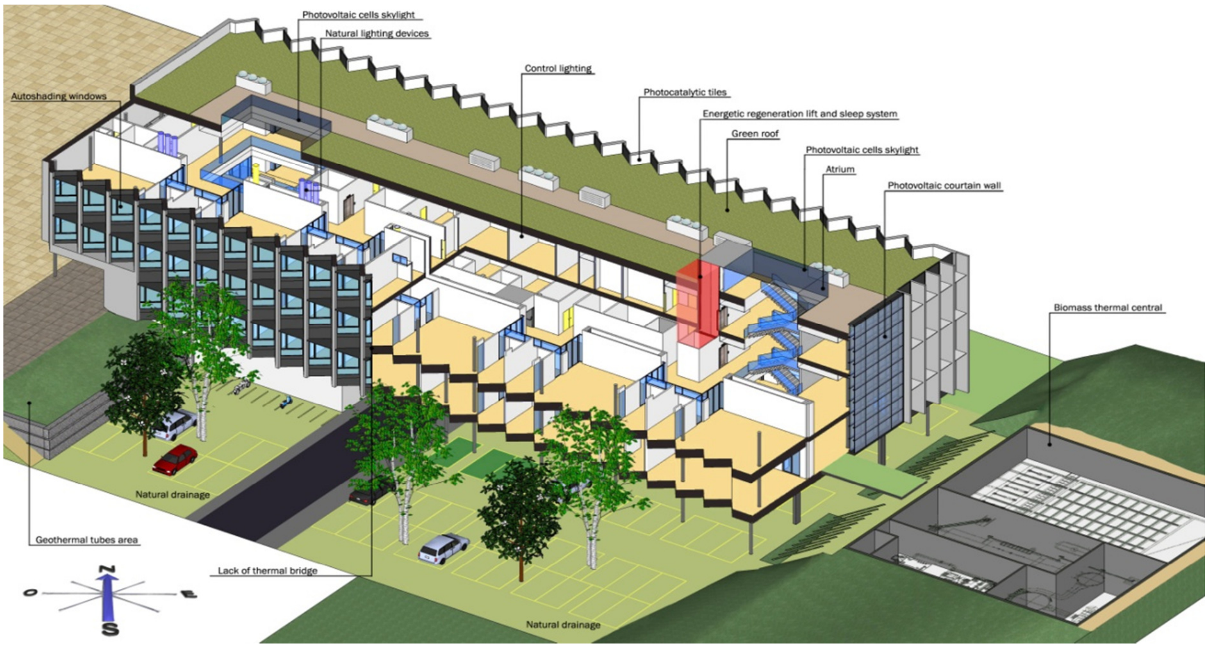

Fig. 5. Axonometric section: Green roof, Tubular day-lighting devices, open car park, and biomass place

2.6. Special control devices

Using energy efficiency equipment (saving energy lifts) and Digital Addressable Lighting Interface (DALI), a communication interface system for lighting to regulate according to natural daylight.

3. USE OF RENEWAB

3.1. Geothermal

The site covers a large
environmental conditions
ventilation systems using
conditions outdoor air n
deemed both a bioclimatic
Geothermal tubes to produ

Fig 6- Different construction phases of geothermal pipes.

3.2. Photovoltaic

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The architectural design of the building merges photovoltaic systems in two ideal areas: the double skin curtain wall (Fig. 7 and 8) in the South-East facing wall (where common rest areas are located) and two skylights above each of the staircase areas (Fig. 9). The actual photovoltaic panels themselves and the double skin allow this strong natural light to be filtered into the building’s interior. The double skin facade produces 5,000 kWh per year and the skylights 5,500 kWh, leading to an annual saving of 3,570.00 euros. They contribute to the building’s positive renewable energy balance as well as encouraging research into the topic such that, in addition to producing electrical energy, the skylights aid climate control in the building, both in winter and summer. This entails an added cost in financial terms which is offset by the constant reduction in energy consumption, further research, and emission reduction.

Fig. 7 and 8- Integration in façade of double skin curtain wall (External and internal). Fig 9- skylights above the staircase

3.3. Biomass

Use of biomass, a surplus resource in the region (Castilla y León- Spain) where the building is being constructed, has a major socio-economic impact, and will lead not only to job creation but also to enhanced self-sufficiency in energy. Especially worthy of note among the power generating systems is a cogeneration system that uses lignocellulosic biomass as fuel, and which covers most of the building’s thermal (heating, cooling, ventilation, ACS) and electricity demand. The cogeneration system based on biomass, operates as a self-sufficient system from the power point of view. In this sense, the 100 kW of electric power generated by the cogeneration system allows the annual electrical requirements to be covered, and the average value of 180 kW of thermal energy generated satisfy the thermal needs of the absorption chiller responsible for supplying the building with cooling needs. In any case, and given the special characteristics of the building’s use (biomedical laboratories), the system is connected to the grid, has a support biomass boiler and a hot water tank that allows the energy supplied to adapt to instantaneous variations in the building’s power demand throughout the year. (VALBUENA & HORRILLO 2013) Foundation for small-scale cogeneration based on the gasification of biomass because this new system fits the building’s needs, thus achieving an autonomy that can serve as an example for other buildings of the tertiary sector.

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4. OTHER STRATEGIES ABOUT SUSTAINABILITY

4.1. Reduced water consumption has been achieved by; collecting and reusing rainwater (73%) and all grey water (100%), with networks which separate those from the laboratory water to be processed before discharge; bathroom facilities equipped with electronic taps that incorporate flow reduction; the use of autochthonous vegetation that does not require mechanical watering, etc.

4.2. Strong selection of constructions materials: low-environmental impact ; low embodied energy; no-VOC; recycled end renewal; methods which reduce as much as possible the waste generated during the building process (prefabricated, dry wall partition, etc); provide for easy disassembly. Even recycled materials as well as reused building materials are employed, in addition to photocatalytic building materials based in applications of TiO_2.

4.3. A further aspect taken into consideration is waste management during the construction phase as well as during the building's use. The project includes a plan for studying all the waste generated during the building's life-cycle, and the creation of compost from vegetable waste is also envisaged. Finally, the waste generated during future demolition of the building has also been studied with a view to securing the maximum possible recovery of the materials used.

4.4. Improvement of devices and facilities for people with disabilities;

4.5 Educational plan about maintenance for technicians; information to staff, users and personal form the University and general people to improve the general knowledge of environmental items related to buildings. (JANDA K, B. 2011), (WARD et all, 2012)

5 . RESULTS

According to VERDE environmental assessment method (TORRE DE COMARES ARQUITECTOS 2014), the provisional ratios reach by LUCIA building as built is shown in the Fig 10 (last column: reached impact over 5) in different environmental impacts

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Resultados de la evaluación Absoluta									
•	*Los datos estan basados sobre las puntuaciones obtenida en la Auto-evaluacion*	*Indicador/ m2 año*	Peso	Edificio de Referencia	Edificio objeto	Impacto Evitado	% de Redución de Impacto	% de Impacto	Impacto Evitado Reltivo
1	Cambio Climatico	kg CO2eq	27%	90,64	12,67	77,97	90,5%	9,5%	4,5
2	Aumento de las radiacione UV a nivel del suelo	kg CFC11eq	0%	0,00	0,00	0,00	0,0%	100,0%	0,0
3	Perdida de fertilidad	Kg SO2eq	5%	0,0111	0,0002	0,01	98,5%	1,5%	4,9
4	Perdida de vida acuática	kg PO4eq	6%	0,01	0,00	0,01	100,0%	0,0%	5,0
5	Emision de productos foto-oxidantes	kg C2H4eq	8%	0,01	0,00	0,01	99,9%	0,1%	5,0
6	Cambios en la biodiversidad	%	4%	100%	-4%	1,04	100,0%	0,0%	5,0
7	Agotamiento de energía no renovable, energía primaria	MJ	8%	1117,02	689,47	427,55	39,7%	60,3%	2,0
8	Agotamiento de recursos no renovable diferente de la energía primaria	kg de Sb	9%	74,67	58,46	16,21	100,0%	0,0%	5,0
9	Agotamiento de aguas potables	m3	10%	0,34	-0,02	0,36	100,0%	0,0%	5,0
11	Generación de residuos no peligrosos	kg	6%	35,86	1,79	34,07	100,0%	0,0%	5,0
16	Salud, bienestar y productividad para los usuarios	%	12%	100%	12%	0,88	87,7%	12,3%	4,4
19	Riesgo financiero o beneficios para los inversores-Coste del Ciclo de Vida	€ (EUR)	5%	38,96	15,03	23,94	100,0%	0,0%	5,0
	Impacto Evitado		100%						4,55

Fig 10: Impacts of LUCIA building -Provisional VERDE tool (Column 2: 1-Climate change; 2-UV radiations; 3- Infertility; 4- Water habitat destruction; 5- Photo-oxidants emissions; 6- Biodiversity changes; 7- Primary non renewable energy; 8- Other energy no renewable neither primary; 9- Depletion potable water; 11- No hazardous waste generation; 16- Health and wellbeing of users; 19- Economical risk and LCA cost.)

In the field of energy results and its economical maintenance costs, the E-Quest model (VEGA INGENIERÍA 2013) shows the comparison versus baseline building, the building excluded the generation system (LUCIA v/o CHP) and the final building with the generation power system. (Table 3)

ENERGY DEMAND	BASELINE BUILDING		LUCIA W/O CHP		LUCIA BUILDING	
COOLING	54.32	kWh/m2	31.97	kWh/m2	31.97	kWh/m2
HEATING	58.72	kWh/m2	6.02	kWh/m2	6.02	kWh/m2
ELECTRICITY	68.77	kWh/m2	31.33	kWh/m2	38.59	kWh/m2
SANITARY HOT WATER	5.24	kWh/m2	5.24	kWh/m2	5.24	kWh/m2
TOTAL W/O EQUIPMENT	187.05	kWh/m2	74.56	kWh/m2	81.82	kWh/m2
EQUIPMENT (PROCESS)	73.73	kWh/m2	73.73	kWh/m2	73.73	kWh/m2
TOTAL	260.78	kWh/m2	148.29	kWh/m2	155.55	kWh/m2
FINAL ENERGY USE	**BASELINE BUILDING**		**LUCIA W/O CHP**		**LUCIA BUILDING**	
TOTAL W/O EQUIPMENT	196.85	kWh/m2	116.29	kWh/m2	258.25	kWh/m2
PRIMARY ENERGY USE	**BASELINE BUILDING**		**LUCIA W/O CHP**		**LUCIA BUILDING**	
TOTAL W/O EQUIPMENT	339.98	kWh/m2	166.52	kWh/m2	258.25	kWh/m2
CO2 EMISSIONS	**BASELINE BUILDING**		**LUCIA W/O CHP**		**LUCIA BUILDING**	
TOTAL W/O EQUIPMENT	150.84	kg CO2/m2	52.93	kg CO2/m2	0.00	kg CO2/m2
ECONOMIC COST	**BASELINE BUILDING**		**LUCIA W/O CHP**		**LUCIA BUILDING**	
TOTAL W/O EQUIPMENT	16.68	€ / m2	6.64	€ / m2	4.30	€ / m2

Table 3- final results about energy and co2 of LUCIA building according E-QUEST

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6. CONCLUSIONS

The building proves that achieving energy independence is possible, and shows how to improve the use of surplus material in the region, such as forest wood, which can also lead to the creation of new jobs. The building will be "zero emission", and will provide the springboard for research into social aspects of building sustainability. It will constitute a prototype on which to test hypotheses that will provide the bases for environmental methods and assessment for buildings. It could be an example for NZEB ratios, specially the demand reached of 81,82 kWh per m2 year for tertiary sector buildings. The maintenance cost of 4.30 €/m2 (including no equipment) is highly reduced compared to a baseline building. We believe that the systems and strategies used can be replicated when constructing tertiary-sector buildings aiming to be energetically self-sufficient, and also for NZEB. The bio-climate design and passive strategies are replicable in any type of building, even in those subject to rehabilitation. Something similar occurs with integrated photovoltaic systems or Geothermics. The results of this example will be spread to other new University buildings and the use of bio-energy in central-heating systems in existing ones in the Campus. More information: http://lucia-building.blogspot.com.es/ Funding comes from Junta de Castilla y León (Program of Infrastructure of Research and Technological Development), and the European Regional Development Fund.

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